No. 142, Original

In The
Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

GEORGIA'S OPPOSITION TO FLORIDA'S MOTION *IN LIMINE* REGARDING EXPERT TESTIMONY OF DR. SUAT IRMAK

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September 30, 2016

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INTRODUCTION

Florida's motion *in limine* has little to do with *Daubert* or its ostensible critiques of Dr. Irmak's expert opinions. Dr. Irmak is eminently qualified to offer all the opinions in his report and formed his opinions using reliable and well accepted methodologies. Rather than attack those opinions and methodologies, Florida spends most of its motion *in limine* summarizing the evidence it expects to present at trial, including by attaching exhibits that have little to do with Dr. Irmak's report or his opinions. Relying on cherry-picked quotes and facts devoid of context, Florida tries to argue that Georgia's management of agricultural irrigation in the ACF Basin has led directly to lower streamflows into Florida. But the facts simply do not bear that story out, no matter how many times—or in how many inappropriate ways—Florida tries to tell it.

Discovery has shown that Georgia has responsibly and proactively managed its agricultural water resources. Since the 1990s, Georgia has extensively studied agricultural water use in the ACF Basin and enacted a suite of effective statutory and regulatory measures designed to promote conservation and efficient water use. Those measures have required great financial investment from the State and the cooperation of hundreds of state policymakers, experts, farmers, and independent contractors. Those efforts have also paid significant dividends: a more rigorous system of permitting is now in place in the ACF Basin; a comprehensive program to meter agricultural withdrawals was approved and funded by the Georgia General Assembly; regional planning initiatives have produced actionable management practices specific to agricultural water use; irrigation from surface water sources in ACF Georgia has gone down since 2004; over 90% of center-pivot irrigation systems in the Lower Flint River Basin now use highly efficient, low pressure equipment; and average streamflow reductions attributed to agricultural withdrawals has remained relatively stable since 1999 while crop yields have increased.

More fundamentally, Florida's critique of Georgia's agricultural water use has no relevant connection to the injuries Florida alleges in this case. Analysis conducted by experts from both Georgia and Florida shows that Georgia's agricultural water use does not materially impact streamflows into Florida. Instead, state-line flows are predominantly determined by the operations of the U.S. Army Corps of Engineers ("Corps") in the ACF Basin. For example, even in July 2012—the middle of the worst drought in Georgia history—Corps operations still guaranteed Florida 5,000 cubic feet per second ("cfs") at the state line, which is more than ***four times*** the amount of water that Georgia consumed for agricultural purposes during that month. That is more than Florida's equitable share of ACF water, and even Florida itself argues that 5,000 cfs is "enough water both to supply approximately 19 million people ***and*** irrigate approximately four million acres of farmland[.]"[1] Moreover, even if Georgia's agricultural water use had been significantly reduced during that month, the evidence, including analysis by Florida's own experts, shows that the Corps still would have maintained a streamflow of 5,000 cfs at the state line, and would not have increased flows into the Apalachicola River as Florida contends. Florida's complaints about Georgia's agricultural water use, therefore, have no direct connection to state-line flows, especially during the seasonal low-flow times when Florida claims it needs water the most.

Setting aside those factual issues (which Florida inappropriately injected into this case during pretrial motions practice), there is no basis for excluding any of Dr. Irmak's testimony. *First*, Dr. Irmak applied his extensive experience and knowledge to find that, in his opinion, "Georgia has instituted significant regulatory and policy initiatives to promote soil and water

[1] State of Florida's Motion *In Limine* to Preclude Expert Testimony by Dr. Philip Bedient and Dr. Sorab Panday on "Lost Water" and Memorandum in Support Thereof, at 3 (emphasis in original) ("Bedient-Panday MIL"); *see also* Panday Dep. 706:21 - 709:20.

conservation and has taken a proactive, responsible, and conscientious approach to agricultural water use challenges."[2] In reaching that opinion, he reviewed hundreds of documents and scholarly articles, visited the ACF Basin, analyzed state statutory and regulatory requirements, and interviewed numerous state officials. That is precisely the kind of process in which respected experts engage all of the time. Florida's disagreement with Dr. Irmak's ultimate conclusion is no basis to exclude his testimony.

Second, Dr. Irmak found that agricultural soils in ACF Georgia have a very limited ability to retain water for crop uptake. That is not a controversial finding: numerous other witnesses in this case testified that soils in the ACF can retain water for only a few days during dry periods, and that frequent irrigation is required to ensure the viability of crops. Dr. Irmak also testified that he relied on data from the very same source on which Florida's own experts relied, undermining any suggestion that his methodology was somehow unreliable.

Third, Dr. Irmak conducted extensive analysis relevant to Florida's proposal to "limit" Georgia's agricultural water use, the precise meaning of which Florida only clarified for the first time during Dr. Irmak's deposition. Among other things, Dr. Irmak analyzed the yield difference between irrigated and non-irrigated fields, explained why the nature of the soils in the ACF make crops highly sensitive to water stress, and calculated the seasonal irrigation requirement for different crops. Dr. Irmak found that deficit irrigation "would not be practically possible or feasible in Georgia, and . . . would be very detrimental to Georgia agriculture and the broader economy of Georgia."[3] He also found that rainfed agriculture, or "dryland farming," was not

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[2] Attachment 1, Expert Report of Suat Irmak, Ph.D., at 8 (May 20, 2016) ("Irmak Report") (emphasis omitted).

[3] *Id.* at 19.

feasible and could lead to significantly reduced yields and even total crop failure in the region—something to which other witnesses in this case have also testified.[4]

In short, there is no basis to exclude Dr. Irmak's testimony. Florida has no real complaint with Dr. Irmak's underlying methodologies or the way in which he applied those methodologies to the facts before him. Rather, Florida appears to have used its disagreements with Dr. Irmak's conclusions to preview for the Court other arguments it intends to make. That is not a proper use of *Daubert*. And the evidentiary story Florida tries to tell does not hold up to scrutiny.

I. BACKGROUND

A. Georgia's Regulation Of Agricultural Water Use

ACF Georgia is home to a substantial and important agricultural economy. In 2013 alone, agricultural revenues in ACF Georgia from three key row crops (corn, cotton, and peanuts) were over $1 billion, and total agricultural revenues for the region exceeded $4 billion. ACF Georgia accounts for over 25% of all peanut acreage nationwide, and grows nearly half of all cotton in the State, which is the nation's second largest cotton producer. Within the ACF Basin, substantial economic activity also depends on output from the agricultural sector, contributing an additional $687 million per year to gross regional product.[5]

Irrigation is a critical requirement for agricultural production in ACF Georgia. Soils in ACF Georgia can retain water for only a few days before more water is needed.[6] During dry conditions, frequent irrigation is required to ensure the viability of crops and avoid water stress, which can cause crop damage or even total crop failure. Large-scale rainfed agriculture, or

[4] *See id.* at 14-16, Bottcher Dep. 81:8-18.

[5] Attachment 2, Expert Report of Robert Stavins at 30 (May 20, 2016) ("Stavins Report").

[6] Attachment 3, James Hook, Kerry Harrison, Gerrit Hoogenboom, and Daniel Thomas, *Ag Water Pumping Project Report 52, Final Report, Statewide Irrigation Monitoring* (2005) at UGA_00134039 ("Ag Pumping Study") ("With sandy loam or sandy clay loam soils that have relatively low water holding capacities, most of Georgia's crop production regions require frequent replenishment by rainfall to maintain economical crop production.").

dryland farming, is not viable in the ACF Basin, particularly in drought years which are difficult (if not impossible) to predict.[7]

The Floridan Aquifer is the primary source of water for agricultural irrigation in ACF Georgia. The aquifer is both large and quickly rechargeable. Unlike aquifers in other parts of the country that can take years or decades to recharge, the Floridan Aquifer can be replenished rapidly with heavy rainfall during the winter or even throughout the summer growing season. The quickly rechargeable nature of the Floridan Aquifer makes it a reliable source for farmers to irrigate their crops while also maintaining the sustainability of the resource.[8]

In the late 1990s, signs emerged that, during times of extreme drought, agricultural pumping in ACF Georgia could have an impact on water levels in the Flint River. At the time, the evidence was uncertain. Very few scientists had studied the issue and those who had conducted inconclusive analyses; the hydrologic models available were rudimentary; there were no precise studies of the amount of irrigated acreage in the ACF Basin; agricultural water uses were unmetered and estimates of total agricultural water use were often overstated; and the interaction and impacts of groundwater pumping to surface water flows was not fully understood.[9] Nonetheless, Georgia quickly implemented a process to comprehensively and scientifically study agricultural water use in the ACF Basin, while also taking steps to better conserve and manage water resources.

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[7] Attachment 1, Irmak Report at 14-16; Attachment 2, Stavins Report at 59-60; Bottcher Dep. 81:8-10, 81:13-16, 81:18.

[8] Attachment 4, Flint River Basin Regional Water Conservation and Development Plan (2006) ("Flint River Basin Plan") at GA00141782-1784.

[9] Attachment 5, *See* Lynn J. Torak, *Water Availability and Competing Water Demands*, USGS (2005) at USGS-0020249, 20260-20265 (explaining that the Torak and McDowell (1996) model was outdated but USGS working to fill data gaps and develop model to improve understanding of groundwater and surface-water interaction).

In 1999, Georgia placed a ***six-year*** moratorium on new irrigation permits in the ACF Basin. While the moratorium was in place, Georgia initiated a "Sound Science Study" to better understand the impact of agricultural irrigation on surface water flows.[10] The Sound Science Study brought together technical experts, policymakers, farmers, third-party consultants, environmental groups, local government representatives, and other stakeholders in a collaborative and iterative process that lasted several years. Georgia hired contractors to map irrigated acreage in the ACF Basin; collected data on irrigation application amounts for different crops and climatic conditions; measured annual and monthly distributions of agricultural water use; worked with the United States Geologic Survey ("USGS") to study the hydrology of the region; commissioned the development of an advanced hydrologic model to study the impact of groundwater pumping on streamflows; and evaluated numerous conservation practices and irrigation efficiency measures.[11]

While the moratorium was in place and the Sound Science Study was underway, Georgia took other steps to improve conservation and management in the ACF Basin. In 2000, Georgia passed the Flint River Drought Protection Act ("FRDPA"), which allowed the State to administer an auction to take acreage out of irrigation. In 2003, Georgia passed legislation requiring the installation of flow meters on irrigation withdrawals, and to date has installed more than 12,000 meters.[12] Georgia also enacted legislation requiring comprehensive regional water planning in the ACF Basin (as well as in other areas of the state).[13] Those plans, which are funded by the State and created by the Regional Water Councils with the support of expert technical

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[10] Cowie Dep. 473:1-21; Masters Dep. 159:20 - 160:8.

[11] Attachment 4, Flint River Basin Plan at GA00141736-1737, GA00141766-1775.

[12] Attachment 1, Irmak Expert Report at 60-61.

[13] *See* O.C.G.A. § 12-5-522

consultants and policymakers, estimate the amount of water needed for agricultural and other uses and propose management and conservation practices.

In 2006, after years of careful study and development, Georgia's Sound Science Study culminated with the Flint River Basin Regional Water Development and Conservation Plan (the "FRB Plan"). The FRB Plan divided the Flint River Basin into different "zones" based on hydrologic sensitivity to groundwater withdrawals. Applications for new agricultural withdrawal permits were banned entirely in the most sensitive zones, termed "Capacity Use Areas," and remain banned to date. New or modified permits in the remaining zones were required to implement a suite of advanced conservation protections, including end-gun shut-off switches, which turn off portions of center pivot irrigation systems to prevent irrigation of non-cropped areas; leak prevention and repair plans; pump-safety shutdown switches; rain-gage shut-off switches; and low-flow protection plans that mandated cessation of irrigation during extreme drought conditions.[14]

Since 2006, Georgia has gone even further to conserve water used for agricultural irrigation. Georgia promotes irrigation efficiency measures through its Mobile Irrigation Laboratory[15] and works with the USDA's National Resources Conservation Service ("NRCS") to encourage farmers to switch from high-pressure to more efficient low pressure systems.[16] Those efforts have proved successful: currently over 90% of the irrigated acres in the Lower Flint River Basin use efficient low pressure systems.[17] Georgia also funds institutions that provide resources to farmers regarding irrigation efficiency and technology, including the

[14] *See* Attachment 4, Flint River Basin Plan at GA00141751.

[15] *See* Attachment 1, Irmak Report at 64.

[16] *See id.* at 72-73.

[17] *See id.* at 73-74.

University of Georgia Extension Service, the Georgia Water Planning and Policy Center, and the Flint River Soil and Water Conservation District. And Georgia continues to improve its knowledge of agricultural water use through annual investments in detailed mapping of irrigated acreage in the ACF Basin, support for the Agricultural Metering Program, and other work related to agricultural water use.

In 2011 and 2012, a severe drought occurred in southwest Georgia. Florida tries to attribute the consequences of this drought to Georgia's management of agricultural water resources.[18] But the record shows that the 2011-2012 drought was one of the worst on record. According to NOAA, the 24-month period from December 2010 to November 2012 was the driest 24-month period ***ever recorded*** for the State of Georgia.[19] Georgia took appropriate action in response to this historic drought in ACF Georgia. In 2012, Georgia placed another moratorium on all new irrigation permits in most of the ACF. That moratorium is still in effect today. In 2014, Georgia amended the FRDPA to, among other things, (1) give the State greater flexibility with respect to conducting irrigation-reduction auctions; (2) create new and more-stringent efficiency requirements for all surface water and groundwater withdrawal permits, including so-called "grandfathered" permits; and (3) give EPD the authority to protect stream flows generated from state-sponsored augmentation projects.

Florida makes much of Georgia's decision not to implement the FRDPA in 2011 and 2012. But the record shows that drought-prediction indicators used by the USGS did not predict a severe drought in 2011 at the time a drought declaration had to be made under the statute.[20] By

[18] *See* Irmak MIL at 7-9.

[19] *See* Attachment 6, National Oceanic and Atmospheric Administration ("NOAA"), *State of the Climate: Drought - Annual 2012*, accessed Sept. 29, 2016, available at https://www.ncdc.noaa.gov/sotc/drought/201213

[20] *See* Attachment 7, Wei Zeng & Inchul Kim, *Memo to Allen Barnes re Year 2011 Flint River Drought Protection Act* (Feb. 17, 2011) (GA00080569).

March 2012, moreover, Georgia's Environmental Protection Division determined that hydrologic conditions were so poor that implementing the Act—which would have cost tens of millions of dollars—would not have had a material impact on stream flows.[21] Unsurprisingly, policymakers in Georgia made the decision not to waste tens of millions of dollars of taxpayer money on an auction that would have no corresponding benefit. In addition, although the initial FRDPA was well intentioned and demonstrated a commitment to conservation, in practice, based on experiences in 2001 and 2002, the State knew that the "auction process was very inefficient," resulted in "a significant number of participants [being] paid for very marginal or long-fallow land, or for land that is not typically irrigated," and "failed to remove the highest water use cropland from irrigation."[22] As discussed above, in response to these issues Georgia amended the FRDPA in 2014 to require heightened efficiency requirements and to give the State more flexibility and authority to protect flows during times of drought.

Florida also mischaracterizes the findings of the Lower Flint-Ochlockonee Regional Water Plan when it argues that groundwater pumping in the Upper Floridan Aquifer is greater than "sustainable yield." The Plan did not purport to assess the "sustainable yield" of the Floridan Aquifer as a whole or of the Flint River in its entirety. Instead, the Plan focused on localized impacts. The "sustainable yield" threshold that Georgia utilized was triggered if surface water flows decrease by 40% in ***any*** location in the Basin, and because some of the creeks in the ACF are ***extremely*** small, that threshold could be triggered by minor reductions—including ***less than 1 cfs in one creek and less than 0.1 cfs in a second.***[23] Such a small flow

[21] *See, e.g.*, Cowie Dep. 319:5-24; Turner Dep. 220:18-25; Zeng Dep. 28:3-9.

[22] Attachment 4, Flint River Basin Plan at GA00141764-1765.

[23] *See* Attachment 8, Expert Report of Sorab Panday, Ph.D. at F-5 (May 20, 2016) ("Panday Report") (explaining that the "sustainable yield" range was derived from a reduction in streamflow of 0.07 cfs in Mosquito Creek and 0.7 cfs in Muckalee Creek).

reduction may be of local significance in a small creek, but it has no bearing on the state line flow into Florida.

Today, the extensive time and resources that Georgia has invested in agricultural water management since the late 1990s have paid benefits. Combined acreage irrigated from surface water and Floridan Aquifer sources in ACF Georgia has declined since 2004; irrigation efficiency has improved; and the streamflow impact of agricultural water use has remained relatively constant. A moratorium also remains in place on new irrigation permits in the most-important areas of the ACF Basin, thereby constraining future growth. Florida appears to be making the worst predictions of policymakers in the late 1990s the cornerstone of its case, but those estimates were always known to be based on rudimentary models, overstated estimates of agricultural water use, and other limited data. Not surprisingly, those predictions did not pan out. The Flint River has not "run dry" as Florida alarmingly claims, and indeed Flint River flows have remained at healthy levels.

Florida's motion *in limine* also argues that Georgia's agricultural irrigation practices "have substantially reduced the amount of water flowing to Florida's Apalachicola River."[24] That topic is clearly beyond the proper scope of the *Daubert* motion that Florida has filed. It is also directly contrary to what the evidence has shown after nearly two years of discovery. Georgia's expert, Florida's expert (in modeling buried in his backup material), and Florida's chief modeler from the ACF Compact negotiations in the 1990s, all agree that reductions in agricultural water use will not increase flows into Florida during times of drought, and instead will contribute to storage in the federal reservoirs in the ACF Basin. Georgia will present that evidence at trial.

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[24] Irmak MIL at 1.

II. ARGUMENT

Dr. Irmak is eminently qualified to testify as an expert witness in this case on Georgia's water-management policies, the nature of the soils in ACF Georgia, and the impact that Florida's "deficit irrigation" proposals would have on crop yield. Dr. Irmak has 28 years of experience in the fields of "soil and water resources[,] irrigation engineering, agricultural water management, and soil and water conservation."[25] Since 2003, he has been a professor at the University of Nebraska-Lincoln's Institute of Agriculture and Natural Resources, where he has taught graduate courses in Soil and Water Resources, Irrigation Engineering, Water Management, and Crop Water Use Efficiency. He has also conducted extensive research on soil physical properties, crop physiology, crop productivity, and crop responses to water use and climatic conditions, including "how different irrigation practices and agricultural water management approaches affect crop water use and crop productivity."[26] Dr. Irmak founded the South Central Agricultural Laboratory Engineering and Water Management Research Facilities, a well-regarded environmental research facility at the University of Nebraska-Lincoln. He has specifically "studied the soil and water resource characteristics . . . of the [ACF] River Basin" and "participated in numerous field research projects in Georgia and Florida," "develop[ing a] familiarity with the agricultural industry in both states."[27] Florida has not retained an expert with Dr. Irmak's credentials or specific focus of study.

Dr. Irmak also has experience working directly with farmers and other stakeholders. He "founde[d] and lead[s] the Nebraska Agricultural Water Management Network" which is "the

[25] Attachment 1, Irmak Report at 1

[26] *Id.*

[27] *Id.* at 2.

largest and most comprehensive agricultural water management network in the USA."[28] He has worked directly with farmers through Extension programs, and has "chaired national committees on irrigation management, ET, and consumptive water use."[29] He has received the Gold Medal award from the American Society of Agricultural and Biological Engineers, the youngest person to ever do so, for his "significant contributions to the soil and water resources engineering profession" and his "exemplary accomplishments in the application of science- and research-based information to educate farmers, crop consultants, and state and federal personnel."[30] His research and work have also been "adopted and implemented nationally by the United States Department of Agriculture's Natural Resources Conservation Service[,]"[31] and he was selected by the Association of Public and Land Grant Universities to serve on the National Water Resources Working Group, which submitted a report on water resource issues and policies to the USDA.[32]

A. Dr. Irmak Can Offer Expert Testimony About Georgia's Policies And Programs Governing Agricultural Irrigation

Over the past year, Dr. Irmak has analyzed the numerous programs and policies that Georgia has implemented for managing agricultural water resources. That is not a new task for him: Dr. Irmak has been heavily involved in reviewing and formulating water management programs outside of Georgia.[33] The programs and policies he reviewed in this case included

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[28] *Id.* at 1-2.

[29] *Id.* at 2.

[30] *Id.* at 2-3.

[31] *Id.* at 1.

[32] *See id.* at A-13.

[33] *See id.* at A-5 (citing Suat Irmak, et al., *Connecting Soil to the Cloud: A Wireless Underground Sensor Network Testbed*, 2012 9th Annual IEEE Communications Soc. Conf. on Sensor, Mesh and Ad Hoc Communications and Networks (2012)), A-13 (citing Suat Irmak, et al., *National Initiative on the Improvement of U.S. Water Security: Recommendations of the Water Working Group Representing the Nation's Land Grant Institutions*, National Water Working Group, Association of Public and Land-Grant Universities (2014)).

Georgia's permitting processes; its multiple moratoria on new permits; its six-year Sound Science Study; the requirements of the Flint River Plan; Georgia's various efficiency and conservation requirements; its resource planning efforts; and its numerous legislative enactments. After reviewing those programs, Dr. Irmak concluded that "Georgia has instituted significant regulatory and policy initiatives to promote soil and water conservation in the ACF Basin, and has taken a proactive, responsible, and conscientious approach to agricultural water use challenges."[34]

This is not an unusual analysis or opinion for an expert witness. Courts routinely allow experts to evaluate the reasonableness of actions or procedures.[35] Nonetheless, Florida seeks to exclude Dr. Irmak's opinion that Georgia has adopted reasonable and proactive regulatory practices. The very first sentence of Florida's argument, however, betrays that Florida's real concern is with the ***conclusion*** that Dr. Irmak reached, not the well-accepted process in which he engaged.[36] It is well established that the *Daubert* inquiry "must be solely on principles and methodology, not on the conclusions that they generate." *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 594 (1993). But time and again Florida takes issues with Dr. Irmak's ***conclusions***, citing facts or evidence Florida would have considered or weighed differently to reach its own conclusions. That is not the proper basis for a *Daubert* motion.

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[34] *Id.*at 8. (emphasis omitted).

[35] *See, e.g., Lees v. Carthage College*, 714 F.3d 516, 525 (7th Cir. 2013) (finding that district court abused its discretion in excluding expert's testimony on reasonableness of campus security measures where criticisms "[went] to the weight of the expert's testimony, not its admissibility"); *First Tennessee Bank Nat'l Ass'n v. Barreto*, 268 F.3d 319, 325, 332 (6th Cir. 2001) (sustaining expert's evaluation of the reasonableness of a bank's lending procedures against *Daubert* challenge); *McKenzie v. Benton*, 388 F.3d 1342, 1351 (10th Cir. 2004) (affirming admissibility of expert's testimony on reasonableness of police departments hiring decision); *Ferragamo v. Chubb Life Ins. Co. of America*, 94 F.3d 26, 28 (1st Cir. 1996) (per curiam) (Expert "testified regarding the reasonableness of [the insurance company's] actions as to the period of time that lapsed from the time the investigative reports were received to the suspension of the benefits.").

[36] *See* Irmak MIL at 11 ("[I]t is difficult to understand how Georgia could take the position that its policies are 'reasonable,' 'proactive,' 'responsible,' and 'progressive.'").

Florida says that Dr. Irmak conducted "no analysis" to support his opinion. That is demonstrably false—Dr. Irmak conducted extensive analysis. Florida just does not agree with the result that analysis produced. Among other things, Dr. Irmak reviewed Georgia's statutory and regulatory requirements; reviewed literature and scholarly papers concerning Georgia's water management; reviewed hundreds of internal documents produced in discovery; spent several days visiting the ACF Basin; and spoke to numerous policymakers, stakeholders, and researchers. That is precisely the kind of thorough and complete "analysis" in which experts engage all of the time. Nor was it somehow improper for Dr. Irmak to "list" Georgia's responsible water management practices, as he did in his report.[37] It is hard to see how Dr. Irmak could evaluate the reasonableness of Georgia's regulatory system without listing the aspects of the very system he is evaluating. And Florida cites no case law for the odd and counterintuitive proposition that an expert's opinion can somehow be excluded for including a detailed description of the bases for his opinion.

Florida also faults Dr. Irmak for not "compar[ing] Georgia's policies against the policies of other states."[38] But such cross-state comparisons, as Dr. Irmak explained, are often misleading and inappropriate.[39] States differ significantly in physical and climactic conditions, hydrologic factors, precipitation patterns, agricultural practices, the size of state economies, the extent of established uses, and the availability of stored water.[40] States often tailor their agricultural management to state-specific conditions and needs. The programs and policies that are appropriate in one state are not necessarily appropriate in another state. As Dr. Irmak

[37] Irmak MIL at 11.

[38] Irmak MIL at 12.

[39] *See* Dr. Irmak Dep. 583:20-21, 585:21-24.

[40] *See* Attachment 1, Irmak Report at 87 (noting that different recharge rates between the Floridan Aquifer in Georgia and the Ogallala Aquifer in Great Plains States makes interstate comparisons of agricultural management practices inappropriate).

explained in his deposition, that is why he generally declined to draw cross-state comparisons.[41] Indeed, such fundamental differences between states are the primary reasons undermining Florida's suggestion that Georgia should adopt practices implemented in Nebraska or California: those states are very differently situated from Georgia, making it unreasonable and implausible for Georgia to embrace those states' practices wholesale.[42]

Florida is also wrong when it argues that reasonableness "by definition requires a comparison to something else."[43] Reasonableness is an objective, multi-factored analysis of the totality of the circumstances that considers a number of concepts.[44] Courts routinely allow experts to testify about whether actions or policies are "reasonable" based on that experts' extensive experience in the field—even without direct comparative analysis.[45] Dr. Irmak evaluated the reasonableness of Georgia's agricultural water management based on their suitability for the climatic, soil, and crop conditions in Georgia, their scientific validity, and in light of real world management conditions. The cases cited by Florida fail to establish that an expert opinion about "reasonableness" requires a subjective comparison. *Calhoun v. Yamaha Motor Corp., U.S.A.*, 350 F.3d 316 (3d Cir. 2003) involved an expert whose opinion was that the

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[41] *See* Dr. Irmak Dep. 583:20-21, 585:21-24.

[42] Florida also suggests that Dr. Irmak should have "analyze[d] Georgia's irrigation water use policies by reference to an environmental goal." Irmak MIL at 12. It is unclear what Florida means by that, or even how one would go about doing that. In any event, Florida cites no case standing for the proposition that experts evaluating the reasonableness of regulatory programs must evaluate those programs against an "environmental goal"—or any other specific goal—before they will be deemed admissible.

[43] Irmak MIL at 11.

[44] *See, e.g., Missouri v. McNeely*, 133 S. Ct. 1552, 1559 (2013) ("[T]he fact-specific nature of the reasonableness inquiry demands that we evaluate each case . . . based on its own facts and circumstances." (citation and quotation marks omitted).

[45] *See, e.g., Camacho v. Nationwide Mut. Ins. Co.*, 13 F. Supp. 3d 1343, 1369 (N.D. Ga. 2014) (court allowed testimony on whether insurance company had a reasonable basis for rejecting settlement agreement based on expert's "knowledge, experience, and reliance on . . . industry standards" even though expert cited no specific industry standard or reference manual.)

defendant's design was not as safe as other alternative designs.[46] Given that the opinion was based on alternative designs, it is unremarkable that the expert should have actually compared and evaluated alternative designs. *Cruz v. Beto*, 405 U.S. 319 (1972), moreover, did not concern expert testimony at all, but instead involved an analysis into whether a state had infringed a prisoner's right to free exercise of religion. The case bears no obvious connection to the issues in dispute here.

Florida also tries to exclude Dr. Irmak's testimony because he purportedly failed to consider a number of facts that Florida believes are relevant.[47] That is wrong on two scores. *First*, Dr. Irmak ***did*** consider many of the facts Florida identifies; Florida just disagrees with the conclusions he draws from those facts.[48] *Second*, the facts to which Florida points in its motion *in limine* are the types of things that can be raised on cross examination—these facts do not undermine or even relate to the reliability of Dr. Irmak's underlying methodology or processes. As a long line of case law has recognized, such cross-examination points do not justify exclusion under *Daubert*.[49]

Finally, Florida seeks to exclude Dr. Irmak's testimony because he refused to agree with Florida's theory of the case. Throughout his deposition, counsel for Florida repeatedly pressed Dr. Irmak to opine on the reasonableness of ***other*** regulatory policies that Florida believed

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[46] *See Calhoun*, 350 F.3d at 323.

[47] *See* Irmak MIL at 13-14.

[48] *See* Attachment 1, Irmak Report at 29-31 (specifically reporting "impacts to streamflow" from irrigation); *id.* at 55-60 (discussing state-water planning process); *id.* at 62-63 (discussing FRDPA).

[49] *See, e.g.*, *Quilez-Velar v. Ox Bodies, Inc.*, 823 F.3d 712, 720 (1st Cir. 2016) (expert's failure to use equations opposing party claims are necessary does not justify exclusion under *Daubert* because opposing party "had ample opportunity to cross examine [the expert] and to use its own expert witness"); (citation and quotation marks omitted) *Walker v. Gordon*, 46 F. App'x. 691, 695-96 (3d Cir. 2002) ("An expert is, nonetheless, permitted to base his opinion on a particular version of disputed facts and the weight to be accorded to that opinion is for the jury. It is also . . . a proper subject for cross-examination.").

Georgia should adopt to manage agricultural water resources.[50] Dr. Irmak consistently responded by explaining that he believed the current policies that Georgia had adopted were reasonable and were appropriate to have in place going forward.[51] Unsatisfied with that response (because it did not fit Florida's theory of the case), counsel for Florida continued to press Dr. Irmak to evaluate its hypothetical policy recommendations for Georgia. Dr. Irmak explained that such evaluations were outside the scope of his expert testimony, in which he evaluated the reasonableness of Georgia's existing measures, which he found reasonable.[52] Nothing in that exchange justifies exclusion. Dr. Irmak appropriately limited his testimony to the issues on which he is providing expert testimony, and Florida's counsel cannot exclude Dr. Irmak's testimony merely because Dr. Irmak would not give additional opinions that Florida sought.

B. Dr. Irmak's Opinion On The Available Water In Georgia's Soil Is Sound

Dr. Irmak found—consistent with testimony from other witnesses throughout this case—that agricultural soils in ACF Georgia have a very limited ability to retain water for crops. Florida faults Dr. Irmak for purportedly providing no "information" or "basis" to support his conclusion. But as Dr. Irmak explained, he arrived at his opinion after reviewing the USDA Natural Resource Conservation Service's Web Soil Survey, a well-accepted and reliable source for such information.[53] Indeed, Florida's own experts rely exclusively on the same source to

[50] *See, e.g.*, Dr. Irmak Dep. 291:4-8, 293:14-17, 309:6-9; 309:18-20.

[51] *Id.* at 292:25-293:13.

[52] Dr. Irmak also evaluated the reasonableness of specific proposals offered by Florida's experts from an agricultural management perspective and concluded they were unreasonable. *See* Attachment 1, Irmak Report at 14-19, 45, 87, 90-91. Dr. Stavins similarly concluded that Florida's proposed policies were unreasonable from an economic perspective. *See generally*, Attachment 2, Stavins Report.

[53] *See* Dr. Irmak Dep. 171:20 - 173:2.

determine the predominant soil types in the basin.[54] Dr. Irmak also physically visited sites in the Flint River Basin and evaluated the texture of the soil in person, a method that "many people use . . . to estimate soil moisture."[55]

Dr. Irmak's opinion is also not controversial. As other testimony and documents in this case make clear, it is well-accepted that agricultural soils in ACF Georgia have a very limited ability to retain water for crops, thus requiring frequent irrigation during dry times. For example, Dr. James Hook from University of Georgia, who has worked in this area for almost forty years, described the soils in southwest Georgia as "sandy" which means that "it's hard to get the water to stay up and buffer the growth of the plant[.]" Such soil types require irrigation "frequent enough to completely replace crop use every three to four days."[56] Moreover, a study by Dr. Gerrit Hoogenboom (Florida's own agricultural irrigation and crop yield expert) explained that the soils in ACF Georgia are "sandy loam or sandy clay loam soils that have relatively low water holding capacities" and that most crop production in the region therefore require frequent replenishment by rainfall or irrigation to maintain crop viability.[57]

Florida claims that its own experts disagree with Dr. Irmak's calculation of specific soil-water holding capacities in ACF Georgia.[58] But, as explained, disagreement with an expert's conclusions is not a proper basis to exclude under *Daubert*.[59] Dr. Irmak's methodology was reliable—indeed, he relied on the same sources on which Florida's own experts relied. There is no basis for exclusion under *Daubert*.

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[54] *See* Attachment 9, Expert Report of Dr. David L. Sunding at 28-29 (Feb. 29, 2016) ("Sunding Report") (relying on USDA NRCS Soil Survey and related database for all soil-related analysis).

[55] Dr. Irmak Dep. 180:12 - 181:12.

[56] Hook Dep. 169:14-170:16

[57] *See, supra* note 5, Attachment 3, Ag Pumping Study at UGA_00134039.

[58] Irmak MIL at 17.

[59] *Daubert*, 509 U.S. at 594.

C. Dr. Irmak's Report Provides The Bases For His Opinion That Florida's Proposed Irrigation Cuts Are Not Feasible In Georgia

Florida finally asks this Court to preclude Dr. Irmak from providing any opinion on the feasibility of implementing Florida's proposed remedies. Florida bases this on the thin reed that Dr. Irmak only opined on the feasibility of "deficit irrigation" and not on Florida's proposed solution of "limited irrigation." But as Florida admits, Dr. Irmak's choice of language in his expert report was in direct response to ***Florida's own error*** in using the same term in ***its own*** expert reports. Specifically, Florida's economic expert described his proposed remedy as "deficit irrigation," which has a specific meaning in the fields of agricultural water use and agricultural engineering.[60] Florida cannot fault Dr. Irmak for using the same term that Florida's own experts used.

Setting aside any disagreements about whether Florida has proposed "deficit irrigation" (as Florida's economic expert explicitly proposed in his report) or "limited irrigation" (as Florida now claims), the simple fact is that Dr. Irmak conducted extensive analysis to address either scenario, both of which involve stressing crops by applying less water than necessary. Dr. Irmak analyzed the yield difference between irrigated and non-irrigated fields, which showed that irrigated fields consistently generate higher yields.[61] He also explained that the low amount of water that Georgia soils can hold for plant uptake makes crops highly sensitive to water stress, particularly given ACF Georgia's climate and precipitation patterns.[62] Dr. Irmak also calculated the seasonal irrigation requirement for different crops, and showed how it varied across counties and across different years. Finally, Dr. Irmak also evaluated how many Georgia farmers already irrigate at or below the crop irrigation requirements. As a result, Dr. Irmak found that deficit

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[60] *See* Dr. Irmak Dep. 647:5 - 648:19 (explaining specialized definition of deficit irrigation); Irmak MIL at 17.

[61] *See* Attachment 1, Irmak Report at 16-17.

[62] *See id.* at 14-15, 17-19.

irrigation "would not be practically possible or feasible in Georgia, and . . . would be very detrimental to the Georgia agriculture and the broader economy of Georgia."[63] The factors that Dr. Irmak analyzed, in other words, relate to *any* conservation strategy that involves less than full irrigation of crops, including Dr. Sunding's limited irrigation scenarios.

Dr. Irmak's opinions about limited irrigation are also consistent with those of Florida's own experts. Dr. Hoogenboom, who provided expert opinions for Florida on the relationship between crop yield and irrigation, found that irrigated crops consistently generate higher yields than non-irrigated for every crop type that he analyzed.[64] He also testified that crop yield "is extremely responsive to supplemental irrigation"[65] and that total crop failure is possible without irrigation.[66] Dr. Hook also agrees. As he testified, row crops in ACF Georgia "[c]learly ... cannot be grown dryland," and that farmers "cannot produce an economically viable crop of corn" without irrigation.[67] Dr. Stavins, one of Georgia's experts in this case, also found that crop yields would drop dramatically (even as high as 93% for corn) if irrigation were not permitted in dry years.[68]

III. CONCLUSION

For the foregoing reasons, Dr. Irmak's opinions are reliable under Rule 702 of the Federal Rules of Evidence and the *Daubert* standards. Florida's motion *in limine* to exclude them should be denied.

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[63] *Id.* at 19.

[64] *See,e.g.*, Attachment 10, Expert Report of Dr. Gerrit Hoogenboom at 9-10 (peanut), 18-19 (corn), 27-28 (cotton), 36-37 (soybean), (February 29, 2016) ("Hoogenboom Report")

[65] Hoogenboom Dep. 89:20-23.

[66] Hoogenboom Dep. 117:20-118:1.

[67] Hook Dep. 66-67.

[68] *See* Attachment 2, Stavins Report at 34.

Date: September 30, 2016

Respectfully submitted,

/s/ *Craig S. Primis*

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No. 142, Original

In The
Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

ATTACHMENTS TO GEORGIA'S OPPOSITION TO FLORIDA'S MOTION *IN LIMINE* REGARDING EXPERT TESTIMONY OF DR. SUAT IRMAK

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September 30, 2016

ATTACHMENTS

Georgia has attached the documents below to its opposition to Florida's motion *in limine* regarding the expert testimony of Dr. Suat Irmak. Pursuant to Case Management Rule 3.2, Georgia has not attached copies of the depositions cited in its opposition brief, but can provide them upon request.

Attachment 1	Excerpts from Report of Suat Irmak, Ph.D. (May 20, 2016)
Attachment 2	Excerpts from Report of Robert N. Stavins, Ph.D. (May 20, 2016)
Attachment 3	Excerpts from James Hook, Kerry Harrison, Gerrit Hoogenboom, and Daniel Thomas, *Ag Water Pumping Project Report 52, Final Report, Statewide Irrigation Monitoring* (2005) (UGA_00133960)
Attachment 4	Excerpts from Flint River Basin Regional Water Conservation and Development Plan (2006) (GA00141718)
Attachment 5	Excerpts from Lynn J. Torak, *Water Availability and Competing Water Demands*, USGS (2005) (USGS-0020235)
Attachment 6	National Oceanic and Atmospheric Administration ("NOAA"), *State of the Climate: Drought - Annual 2012*, accessed Sept. 29, 2016, available at https://www.ncdc.noaa.gov/sotc/drought/201213
Attachment 7	Wei Zeng & Inchul Kim, *Memo to Allen Barnes re Year 2011 Flint River Drought Protection Act* (Feb. 17, 2011) (GA00080569)
Attachment 8	Excerpts from Expert Report of Sorab Panday, Ph.D. (May 20, 2016)
Attachment 9	Excerpts from Expert Report of Dr. David L. Sunding (Feb. 29, 2016)
Attachment 10	Excerpts from Expert Report of Dr. Gerrit Hoogenboom (Feb. 29, 2016)

ATTACHMENT 1

***State of Florida v. State of Georgia*, No. 142, Original**

Expert Report of SUAT IRMAK, PH.D.

Prepared for:
The State of Georgia

Suat Irmak, Ph.D.
Harold W. Eberhard Distinguished Professor
Soil & Water Resources and Irrigation Engineering;
Water Management; Crop Water Productivity;
Energy Balance and Evapotranspiration;
Land Surface-Microclimate Interactions.

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I. QUALIFICATIONS & CREDENTIALS

I am an agricultural and soil and water resources engineer and one of the nation's leading researchers in the fields of irrigation engineering and efficiency, agricultural water management, and crop water use. Since 2003, I have served as Harold W. Eberhard Distinguished Professor of Biological Systems Engineering at the University of Nebraska-Lincoln's (UNL) Institute of Agriculture and Natural Resources.

I have a Ph.D. (2002) in Agricultural and Biological Engineering, with an emphasis on Land, Soil, and Water Resources, from the University of Florida. I have an M.S. (1996) in Soil and Water Resources and Irrigation Engineering from Mediterranean University in Antalya, Turkey. I have a B.Sc. (1993) in Agricultural Structures and Irrigation Engineering from Çukurova University in Adana, Turkey, which is one of the top agricultural and irrigation engineering universities in Europe.

I have 28 years of experience in the fields of soil and water resources and irrigation engineering, agricultural water management, and soil and water conservation. I have 25 years of experience in measuring and modeling water use efficiency (crop water productivity) of agro-systems, including evapotranspiration (ET), or the loss of water from vegetation communities and soil surface to the atmosphere, and other aspects of soil-moisture dynamics and soil physical properties. As an irrigation engineer, I have extensive experience on installation and maintenance of irrigation systems, including center pivots, surface and subsurface drip irrigation systems, and low-pressure irrigation systems. I have significant experience implementing technologies to enhance crop water use efficiency.

My research also focuses on soil physical properties, crop physiology, crop productivity, and crop responses to water use and climatic conditions. I have significant experience quantifying crop water use and crop ET for a large number of crops. My expertise also includes understanding how different irrigation practices and agricultural water management approaches affect crop water use and crop productivity.

I have been involved in research, education, and hands-on application of irrigation technologies and practices for my entire life. I teach graduate (M.S. and Ph.D.) courses on Soil & Water Resources and Irrigation Engineering, Water Management, Crop Water Use Efficiency, Energy Balance and Evapotranspiration, and Land Surface-Microclimate Interactions. I conduct research and educational programs focused on the application of engineering and scientific principles in soil and water resources engineering, irrigation engineering, and crop water use to water resources management and agro-ecosystem productivity. I am highly active in university Extension programs, which apply scientific research to agricultural practices. My research and education activities in soil and water resources engineering have been adopted and implemented nationally by the U.S. Department of Agriculture's Natural Resource Conservation Service (USDA-NRCS).

I am the founder and leader of the Nebraska Agricultural Water Management Network (NAWMN). The Network, which is composed of over 1,400 farmer cooperators, is the largest and most comprehensive agricultural water management network in the USA, and focuses on enhancing agricultural water use efficiency. Since the beginning of the NAWMN, over 10,000 producers, crop consultants, and agricultural industry personnel have been reached and educated, and since 2005, over $80 million in associated energy savings have been achieved due to reduction in irrigation water withdrawals.

I am one of the founders of UNL's South Central Agricultural Laboratory Irrigation Engineering and Water Management Research Facilities, which is widely regarded as one of the state-of-the art environmental research facilities in the USA.

My experience not only covers irrigation management, irrigation efficiency, and soil and water conservation, but also the impact of policies, rules, and regulations on the agricultural industry and irrigation practices. I have developed expertise and understanding of how governmental policies can influence on-farm irrigation practices and other aspects of day-to-day agricultural water use and management. I have chaired national committees on irrigation management, ET, and consumptive water use. I have also chaired a task committee on crop coefficients.

During my 8 years of research at the University of Florida for my Ph.D. program, I studied the soil and water resource characteristics of the humid/sub-humid climatic conditions of the Apalachicola-Chattahoochee-Flint (ACF) River Basin. I participated in numerous field research projects in Georgia and Florida (from south Florida to the Panhandle), and developed familiarity with the agricultural industry in both states. I also conducted analyses of soil physical properties and evaluated soil moisture sensors from soil samples in the ACF Basin in Alabama. Throughout this work, I developed familiarity with sandy-loam and sandy soils, which are typical soils found in southwest Georgia and northwest Florida.

I have published over 125 refereed journal articles in prestigious journals, 2 book chapters, 30 professional society conference technical papers, and 23 peer-reviewed extension and outreach articles. I am currently serving as a technical reviewer for numerous national and international refereed journals on agricultural water management, evapotranspiration and surface energy balance, irrigation engineering, hydrology, water resources research, agronomy, and soil science.

I have received 60 national, international, and regional awards for my research and education programs. I was honored to be named the youngest Gold Medal award winner in the history of the American Society of Agricultural and Biological Engineers (ASABE), which is one of the highest honors bestowed by the Society and is granted to at most one person each year "for exceptional, meritorious engineering achievement in agriculture." I am also the youngest recipient of the ASABE's Heermann Sprinkler Irrigation Award, which I received in 2014 for my "significant contributions to the improvement of efficient and effective sprinkler irrigation." In granting the Gold Medal award, the ASABE wrote of me:

> Irmak is an internationally recognized servant leader, researcher, and educator who has made significant contributions to the soil and water resources engineering profession. He is well recognized for his exemplary

> accomplishments in the application of science- and research-based information to educate farmers, crop consultants, and state and federal personnel in enhancing the efficiency of sprinkler irrigation practices to improve crop water productivity, minimize losses, and reduce water and energy use in agriculture.[1]

I have also received the New Holland Outstanding Young Researcher and Outstanding Extension Professional Awards from the ASABE, and I hold the honor, to date, of being the first and only scientist and researcher who received both awards in the history of the ASABE, which was founded in 1907.

Additional details about my background and accomplishments are provided in my CV in Appendix A.

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1 ASABE, "Gold Medal Winners Honored," July 21, 2014, http://www.asabe.org/news-public-affairs/july-2014/gold-medal-winners-honored.aspx.

responsible stewardship and conservation of agricultural water resources in the ACF Basin, and there is substantial evidence that Georgia is putting its water resources to reasonable, good, and efficient use.

- **Contrary to Florida's claims, Georgia has instituted significant regulatory and policy initiatives to promote soil and water conservation in the ACF Basin, and has taken a proactive, responsible, and conscientious approach to agricultural water use challenges.** There is significant evidence of wide-ranging, large-scale, and proactive efforts by the State of Georgia to study, enhance, and implement scientific and technical advancements for reducing consumptive agricultural water use, improve irrigation efficiency, and enhance conservation of surface and groundwater resources in the ACF Basin. These regulatory and policy efforts include, but are not limited to, (i) the institution of permitting moratoriums on agricultural withdrawals in key watersheds in the ACF Basin; (ii) significant investments in "sound science" and statewide and regional water planning for responsibly managing surface and groundwater resources; (iii) significant investments in agricultural withdrawal data collection, including the statewide Agricultural Water Metering Program and detailed mapping of irrigated acreage. These policy initiatives, in my judgment, are evidence of progressive and responsible management of water resources that should serve as examples to other states.

- **Dr. Sunding overlooks numerous state-led programs, initiatives, research, and outreach relating to soil and water conservation that have resulted in better on-farm stewardship of agricultural water resources.** Dr. Sunding's recommended "conservation scenarios" ignore the substantial investments to date by Georgia to enhance agricultural water use efficiency and promote soil and water conservation in the ACF Basin. These large-scale water conservation efforts include high-efficiency center pivot retrofits, irrigation system uniformity improvements, end-gun shutoffs, variable rate irrigation, subsurface drip irrigation, and soil moisture monitoring. In addition to improving agricultural water use efficiency, these efforts have also been successful in transferring knowledge and technology to Georgia farmers in the ACF Basin, thereby enhancing farm-level management and stewardship of water resources. Furthermore, since 1999, Georgia has limited permitting of new agricultural withdrawals in areas that the best available science indicates have the most significant impact to surface streamflow. Over the same time period, irrigated acreage in the Florida portion of the ACF has increased dramatically. For example, Jackson County, Florida has seen a 142% increase in irrigated acreage since 2002 (FSAID Final Report).[2]

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2 Irrigated acres in Jackson County, Florida (2002): 13,374; 2015: 32,378. Florida Statewide Agricultural Irrigation Demand (FSAID) – Final Report. Table A-4. Pg 54.

withdrawals of water from the aquifer system, particularly in Subarea 4 of the Flint River Basin, do not cause long-term declines or depletions in aquifer storage.[11]

Not only does the Upper Floridan Aquifer recharge quickly, it is also an abundant water source for irrigation and public supply due to the the natural geology of the karst system and the deep sandy soils of the coastal plain. The Upper Floridan Aquifer stores and transmits large quantities of water, mainly in a zone of high permeability in the lower part of the aquifer. The transmissivity of the aquifer, or measure of volume of groundwater that will flow through it, can be as high as 1 million ft^2/d (FL USGS/DNR, 1990) in the karstic areas of central and northern Florida. In comparison, the average transmissivity of the High Plains Aquifer in eastern Colorado and eastern New Mexico is only about 4,500 ft^2/day.[12] As a result of the aquifer's thickness and transmissivity, irrigation wells in the Upper Floridan Aquifer can have substantial capacity. Well yields can range from several hundred to more than 10,000 gal/min (gallons per minute), depending on the well construction features, depths, and the location of wells.[13] Wells that yield several thousand gal/min are very uncommon and considered extremely high productivity wells in the USA. Thus, the Upper Floridan Aquifer has proven to be a viable and sustainable water source for irrigation.

D. Florida's Assertions that Irrigation Is "Largely Discretionary" and that Georgia Can Switch to Dryland Farming Are Unfounded; Irrigation Plays a Critical Role for Agricultural Productivity in Georgia's ACF Basin

Dr. Sunding states that "agricultural water use remains largely discretionary and is not a necessity for crop production." Similarly, Dr. Bottcher recommends "[c]onversion to alternative, less water-demanding crops or dryland farming" as a method to achieve water savings. Those claims are unfounded and are not practicable options for farmers in the Georgia portion of the ACF Basin. In fact, irrigation plays a critical role in crop production in the ACF Basin.

At the outset, in Georgia, there is no "dryland farming." Dryland farming is defined as farming under conditions of moderate to severe moisture stress during a substantial part of the year, and is generally understood to apply to regions that receive less than 500-750 mm of precipitation annually.[14] Georgia has a humid climate and, during a normal year, receives substantially more precipitation than dryland regions; therefore, "rainfed agriculture" is the correct scientific term.

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11 FL USGS/DNR, 1990.

12 USGS Publication HA 730-C; 2009. GROUND WATER ATLAS of the UNITED STATES: Arizona, Colorado, New Mexico, Utah.

13 FL USGS/DNR, 1990.

14 United Nation Food and Agriculture Organization, "Definitions of Drylands and Dryland Farming," available at http://www.fao.org/docrep/012/i0372e/i0372e08.pdf.

Rainfed agriculture is a highly risky practice and not a realistic option for many farmers in southwest Georgia, given the significant variability in precipitation and extremely sandy soils with very limited water-holding capacity. Lack of precipitation for even a short period of time can impose extreme water stress on the crops and can cause irreversible damage, either significantly reducing yield quantity and quality or resulting in complete crop failure.

Due to the climatic characteristics and very low water-holding capacity for the sandy soil conditions in southwest Georgia, irrigation is necessary to sustain agricultural productivity and the regional economy. In the summer growing season, irrigation must be used frequently to ensure crop health, promote crop growth, and sustain profitability given the extremely sandy soils. Irrigation is not a discretionary practice, but a requirement. Without irrigation, Georgia's agricultural productivity would suffer substantially, resulting in harm to the well-being of agricultural producers and for the broader economy of the state.

Dr. Bottcher relies on USDA census data to opine on the extent of rainfed agriculture in Georgia, but, as even Dr. Sunding acknowledges, USDA understates irrigated acreage compared to other sources. This inflates the number for acreage not under irrigation in the USDA census.[15]

More importantly, both Dr. Bottcher and Dr. Sunding fail to analyze the extent to which row crop production occurs on irrigated acreage vs. non-irrigated acreage. As Dr. Stavins explains, in a typical dry year, USDA data indicates that irrigated acreage produces 94% of corn, 77% of cotton, and 63% of peanuts grown in the ACF Basin.[16]

Finally, rainfed agriculture is not an economically viable option for many farmers in Georgia because on a per-acre basis, rainfed farms have a much lower crop yield than irrigated farms.

To demonstrate the critical importance of irrigation for crop yields, I present statewide average irrigated and non-irrigated yields for 1988, 1998, 2002, 2008, and 2012 for four major crops (corn, peanuts, cotton, and soybean) in Figure 3. In Figure 4, I present the temporal data in terms of the difference between irrigated and non-irrigated yields for the same crops. Without exception, irrigated yields exceeded non-irrigated yields substantially in all years. Irrigated yields for corn were 75, 76, 44, 115 and 59 bu/acre greater than the non-irrigated grain yields in 1988, 1998, 2002, 2008 and 2012, respectively (Figure 4). Irrigated peanut yields were 867, 1245, 664, 1074, and 740 lbs/acre greater than the non-irrigated nuts yields in 1988, 1998, 2002, 2008, and 2012, respectively. Irrigated cotton lint yields were 400, 326, 157, 398, and 215 lbs/acre greater than the non-irrigated cotton lint yields in 1988, 1998, 2002, 2008, and 2012, respectively. Similarly, irrigated soybean grain yields were 14, 22, 12, 19, and 9 bu/acre

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15 Sunding Report at 31 (Table 4).

16 Expert Report of Robert N. Stavins, Ph.D. (May 20, 2016).

greater than the non-irrigated soybean grain yields in 1988, 1998, 2002, 2008, and 2012, respectively.

It is important to note that these are statewide average yields, and thus include crop production from regions with heavy deep fine-textured soils that require far less irrigation than those soils found in the Flint River Basin. Therefore, the irrigated and non-irrigated yield differences in the Flint River Basin for these four major crops would be expected to be much greater than those reported in Figure 3 and Figure 4.

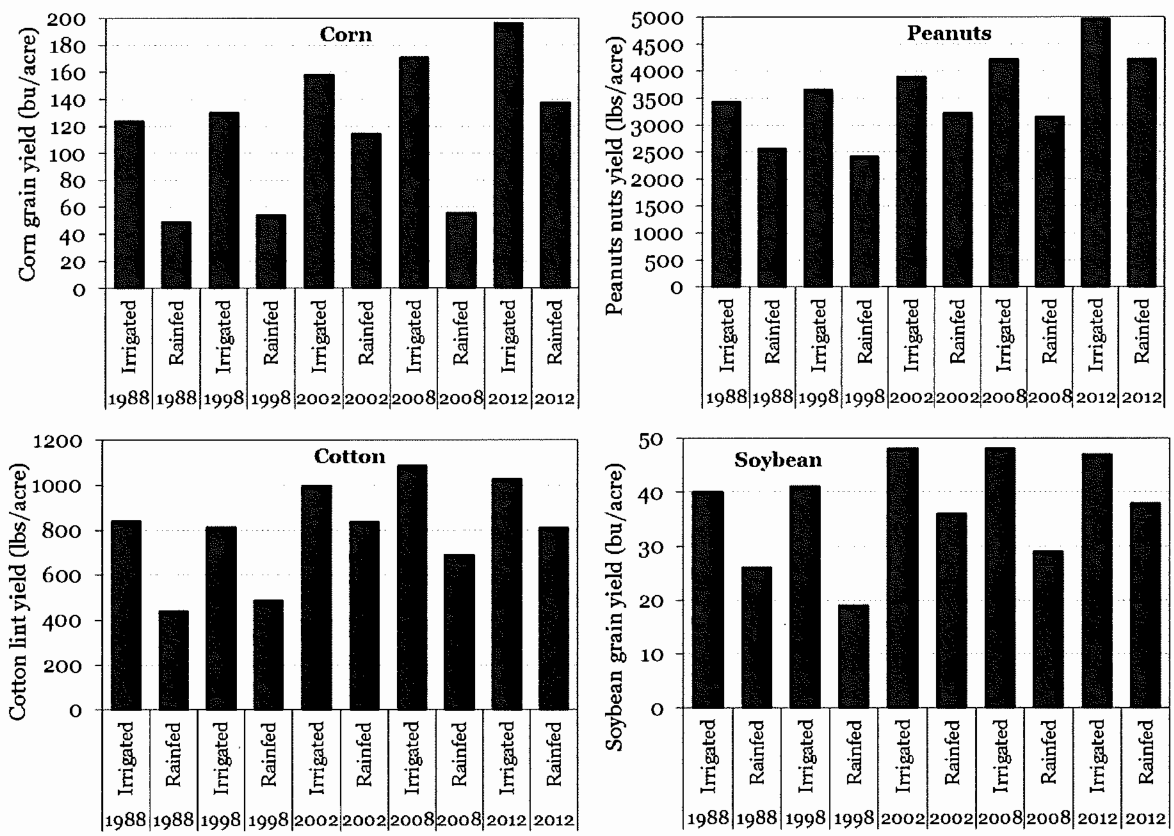

Figure 3. Statewide average irrigated and rainfed yield for corn, peanuts, cotton and soybean in 1988, 1998, 2002, 2008 and 2012 in Georgia (Source: USDA-NASS) (Source: Figure 3_IRR vs Rainfed Yields.xlsx).

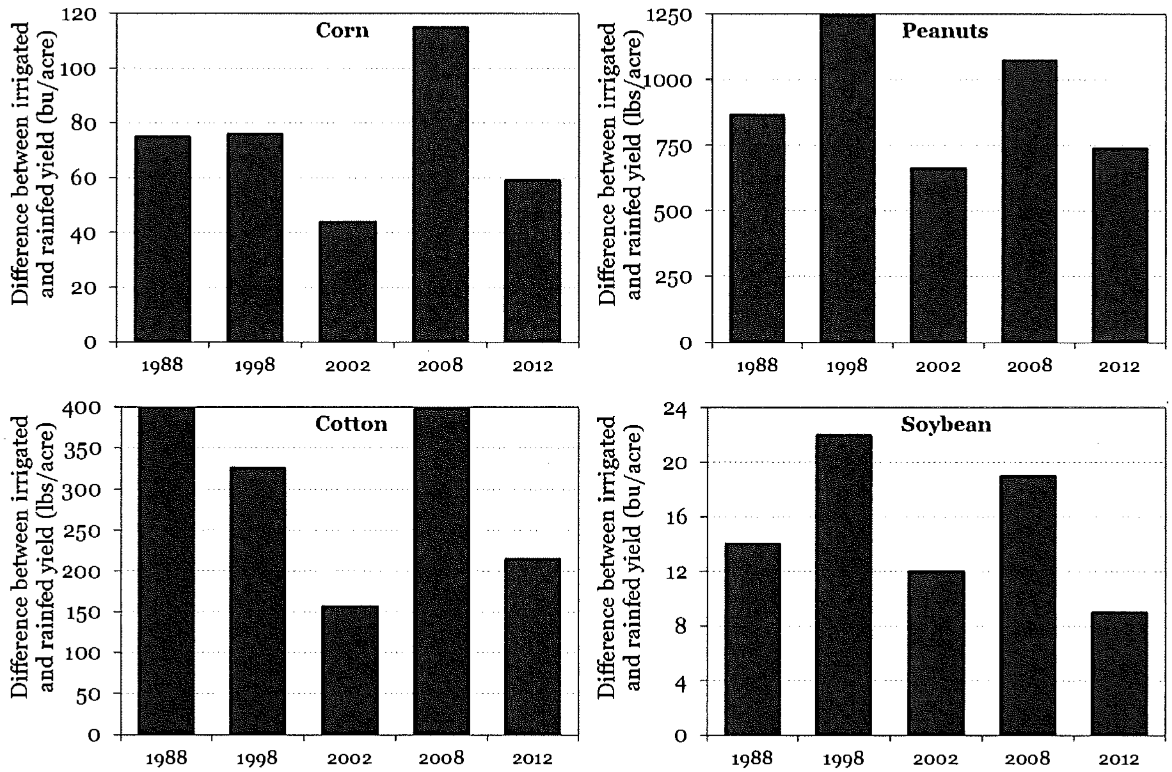

Figure 4. Statewide average difference between irrigated and rainfed yields for corn, peanuts, cotton and soybean in 1988, 1998, 2002, 2008 and 2012 in Georgia (Source: USDA-NASS, Figure 4_Average difference between irrigated and rainfed yields.xlsx).

E. Contrary to Dr. Sunding's Suggestion, "Deficit Irrigation" Cannot Be Reasonably or Profitably Adopted for Corn, Cotton, Peanuts, and Soybean in the ACF Basin

Dr. Sunding's report states that "Georgia can adopt deficit irrigation on corn, cotton, peanuts, and soybean" and (without pointing to any specific examples) refers to deficit irrigation as a "common conservation measure employed by states during times of drought." In fact, Dr Sunding's deficit irrigation proposal would be substantially detrimental to Georgia's agriculture industry and would severely reduce Georgia's ability to produce agricultural commodities. Dr. Sunding's proposal also indicates a lack of knowledge regarding some of the fundamentals and basic operational principles of deficit irrigation.

Deficit irrigation is a specialized practice that can only be applied in limited cases. Deficit irrigation management practices have generally only been applied in states with fine-textured soils that have very high water-holding capacities. Plants grown on fine-textured soils may have adequate time to adjust to low soil water status until the next irrigation and/or rainfall. In sandy soils, however, plants experience water stress very fast under deficit irrigation. Thus, the success of deficit irrigation is usually greater in fine-textured soils than in coarse-textured soils under the same climatic conditions.

To quantitatively demonstrate the impact of deficit irrigation strategies in fine- and coarse-textured soils, I created Figure 5. Figure 5 shows two soil types: sandy soil (typical of soils found in southwest Georgia) and fine-textured soil (typical of soils found in the Midwest). The sandy soil has about 0.6 inch/ft soil-water holding capacity, whereas silt-loam soil has 2.2 inch/ft. Thus, early in the growing season, considering root-zone depth for typical corn production of 4 ft, the silt-loam soil will have 8.8 inch/4 ft of soil-water, whereas the sandy soil will have 2.4 inch/4 ft of total soil-water in the soil profile. In general, 50% of the total water is available for crop uptake, known as "plant-available water." Thus, silt-loam and sandy soils have 4.4 inch/4ft and 1.2 inch/4ft plant-available water. Assuming that in mid-summer, the crop water use is about 0.25 inch/day in southwest Georgia, the soil-water will be depleted at a rate of 0.25 inch/day. Corn, for instance, could survive for as long as 18 days with 4.4 inch of water in silt-loam soil before the next irrigation is applied (in the absence of precipitation), whereas corn grown in sandy soil can last for a maximum of only 5 days before the crop needs to be irrigated again (in the absence of precipitation). If, for some reason, corn is not irrigated within 5 days in the sandy soil, crops will be exposed to severe water stress and irreversible damage will occur to plant physiological functions.

As this data shows, the irrigation timing in deficit irrigation must be determined with exceptional accuracy in sandy soils, whereas there is more flexibility for potential error in determining the irrigation timing in silt-loam soils. Therefore, practicing deficit irrigation strategy in very sandy soils (as those found in the Georgia portion of the ACF basin) is extremely difficult and, in most cases, would not be feasible or profitable.

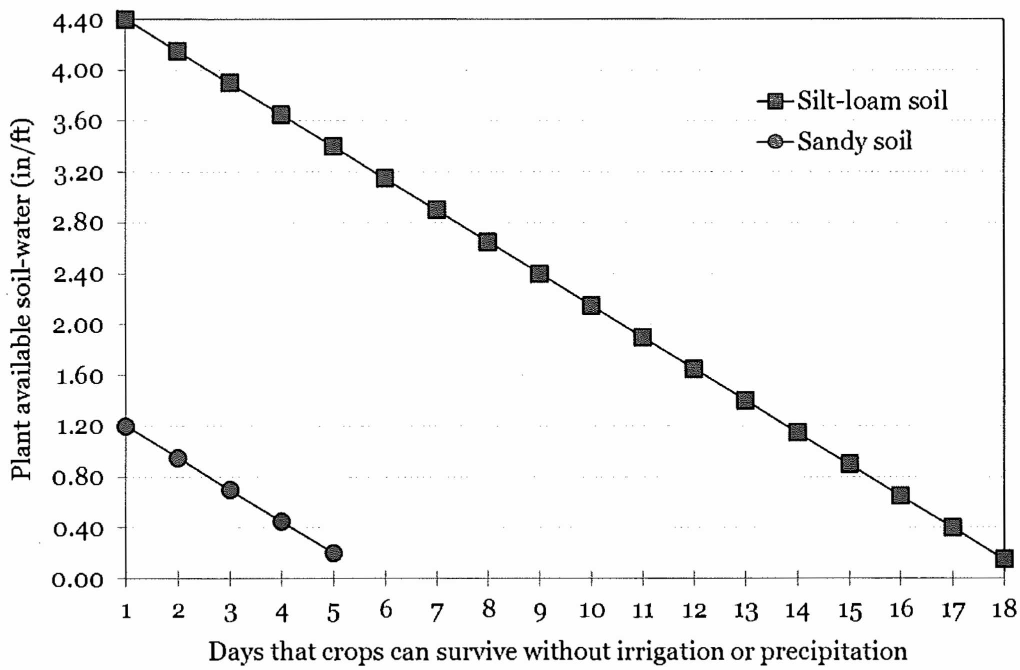

Figure 5. Demonstration of practicability of application of deficit irrigation practices in and silt-loam soils (fine-textured) and unfeasibility of extremely sandy soils (coarse-textured).

It has been reported that even a single water stress event during the critical growth stages of various crops can result in a 30 to 40% yield reduction in a dry year in silt-loam soils and the yield reduction can be up to 100% in sandy soils. For example, if water stress occurs during the critical time period for corn, the following may result: delay in silk growth or elongation, drying of silks, and delay in tassel emergence, which can all lead to reduced pollination and substantially reduced or no yield, depending on the severity of the water stress. In addition, water stress can lead to kernel abortion; which is most susceptible within two weeks following pollination. This time period also usually coincides with rapid nutrient (e.g., nitrogen) uptake. With the exception of fertigation through sub-surface drip irrigation systems, nitrogen (N) fertilizer is applied at the surface, which typically dries up first during periods of water stress, which can result in combined water and N stress if water and N are unavailable lower in the soil profile.

Dr. Sunding's opinions regarding deficit irrigation do not account for any of the real-world implications and difficulties of implementing this highly specialized practice in southwest Georgia. Given the reasons outlined above, implementation of deficit irrigation strategies would not be practically possible or feasible in Georgia, and such strategies would be very detrimental to the Georgia agriculture and the broader economy of Georgia.

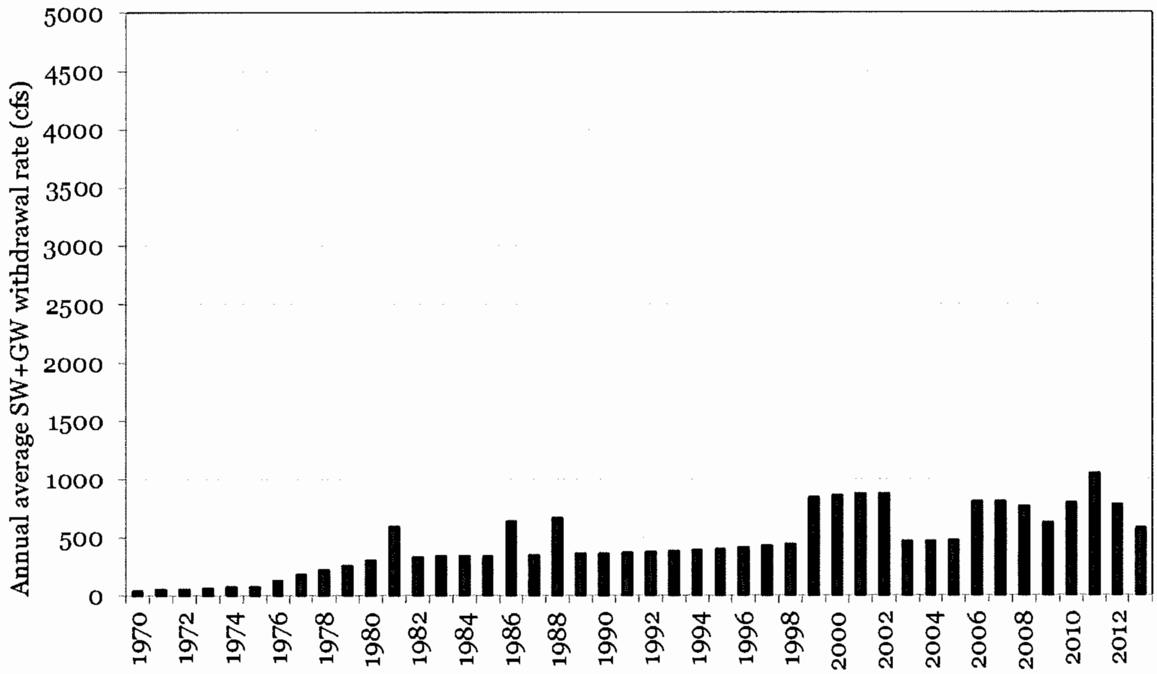

Figure 12. Annual average total (SW + GW) agricultural withdrawals from 1970 to 2013 in the Georgia portion of the ACF Basin.

- ***Annual average SW and GW withdrawals*** **(Figure 10, Figure 11, and Figure 12)** Long-term, annual average SW and GW withdrawals were 118 and 335 cfs, respectively. Long-term, annual SW+GW withdrawals ranged from 42 cfs in 1970 to 1,401 cfs in 2011 with an average of 453 cfs.

As these figures show, water withdrawals for irrigation and other agricultural uses fluctuate on both a monthly and annual basis, primarily as a function of precipitation trends and in conjunction with the changing requirement of commodity crops during a given growing season.

2. Long-Term Streamflow Reduction Resulting from Agricultural Consumptive Water Use

As noted, total consumptive use in terms of net withdrawals does not accurately reflect the impact of Georgia's consumptive use on streamflow. Groundwater withdrawals do not result in one-to-one reductions in streamflow, but instead indirectly influence streamflow through aquifer-stream interactions. Thus, groundwater withdrawals (the majority of agricultural use) must be translated to surface water reductions in order to fully understand the true impact of Georgia's consumptive use on streamflow in the ACF Basin. Dr. Panday and Georgia EPD have performed hydrogeologic modeling using the

Jones-Torak USGS model to translate groundwater withdrawals to streamflow reductions. The basis for those calculations is presented in detail in Dr. Panday's expert report.[25] Figure 13 and Figure 14 show total streamflow reductions resulting from Georgia's agricultural consumptive use in the ACF Basin on a monthly and annual average basis, respectively.

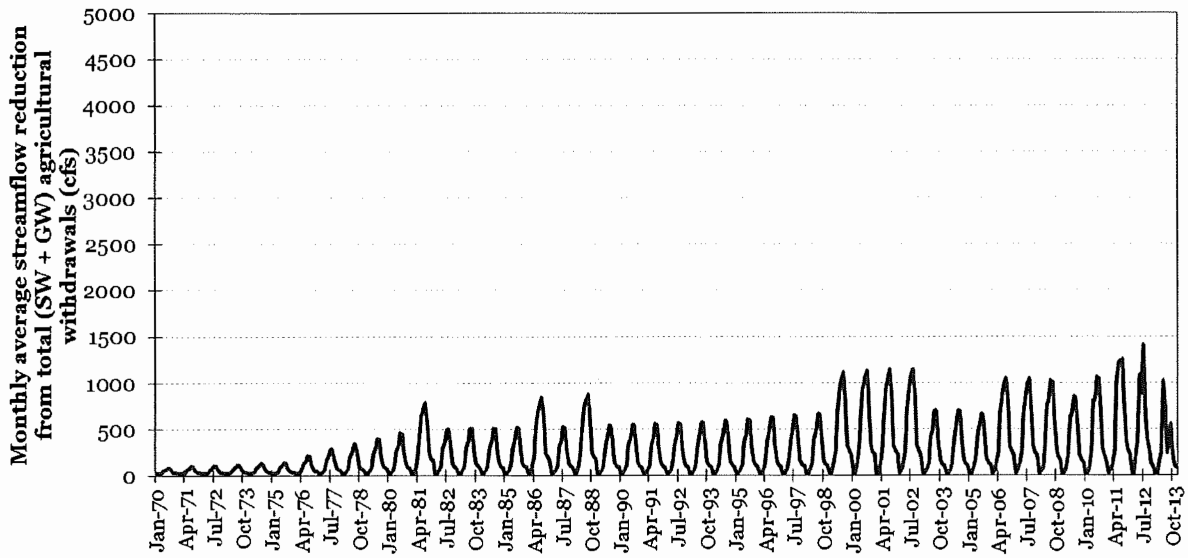

Figure 13. Monthly average streamflow reduction due to surface and groundwater (Upper Floridan Aquifer) agricultural withdrawals in Georgia's ACF Basin from 1970 to 2013.

25 See Expert Report of Sorab Panday, Ph.D. (May 20, 2016).

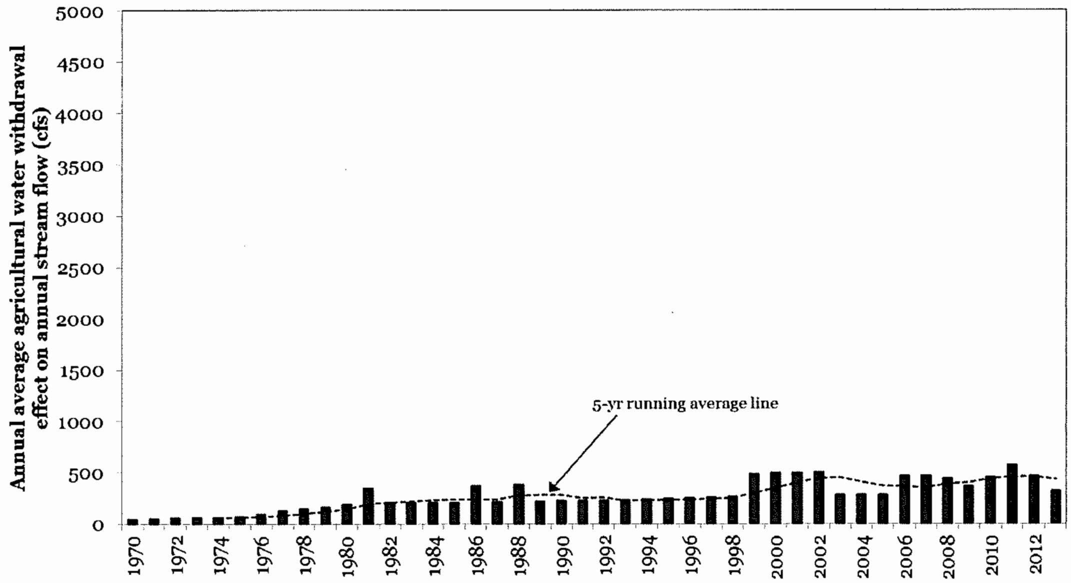

Figure 14. Annual average streamflow reduction due to surface and groundwater agricultural withdrawals in Georgia's ACF Basin from 1970 to 2013.

- ***Monthly average streamflow reduction*** **(Figure 13)** due to agricultural irrigation ranged from 22 cfs in winter months in 1970 to 1,407 cfs in July 2012 with a long-term average of 270 cfs. While streamflow reductions show an increasing trend over time, from 1999 to 2013, the reduction in streamflow remained relatively stable or even exhibited a slight decrease (y = -0.0002x + 431.91; where y = reduction in streamflow (cfs) and x = year).

- ***Annual average streamflow reduction*** **(Figure 14)** due to irrigation in the ACF Basin from 1970 to 2013 ranged from 45 cfs in 1970 to 572 cfs in 2011 with a long-term average of 270 cfs and standard deviation of 145 cfs. While the reduction in streamflow due to irrigation withdrawal did not seem to change significantly in the last two decades, further investigation of the trend line post-irrigation development indicates that the reduction in streamflow due to irrigation has actually declined since 1999 [y = -1.3758x + 433.31; where y = reduction in streamflow (cfs) and x = year].

3. Long-Term (1970–2013) Temporal Distribution of Monthly Total Water Withdrawals and Standard Deviations

To gauge the long-term temporal distribution of monthly total (SW + GW) withdrawals during the growing season, I present monthly data from March through November in Figure 15. While the growing season in Georgia is generally considered to be from March through November, data in Figure 15 shows peak agricultural irrigation withdrawals in May, June, July, and August and some in September. Withdrawals in March, April, October, and November are relatively small.

- USGS finds total agricultural irrigation from the entire basin in 2005 to be 365 mgd (564 cfs), including 265 mgd from groundwater and 100 mgd from surface water (Page 12; Table 2).
- USGS finds total Georgia agricultural irrigation from the ACF Basin in 2005 to be 327 mgd (506 cfs), including 243 mgd from groundwater and 84 mgd from surface water (Page 15; Table 4).

This USGS report is consistent with my own water use calculations and investigations.

I. Dr. Flewelling's Suggestion of Limiting Georgia's Water Use to 1992 Levels Is Impracticable Given Changing Climatic Conditions over the Past Quarter Century

Dr. Flewelling suggests limiting water use in Georgia's ACF Basin to 1992 levels. Given changing climatic conditions since 1992, this suggestion is not practicable and would significantly harm the ability of irrigators in Georgia to sustain their businesses and livelihoods. Georgia counties today receive several inches less precipitation than they did in 1992. Thus, changes in precipitation amounts, as well as patterns, must be taken into account. To demonstrate this, I presented the growing season total precipitation temporal trends for Mitchell County from 1955 to 2013 and from 1990 to 2013 in Figure 20a and b. For both time periods, the regression lines and the 5-year moving average trend lines indicate that Mitchell County received less precipitation. Figure 20b shows that it received 6.9 inches less precipitation in 2013 than it did in 1990, which is a substantial decrease that impacts the water balance analyses.

of potential impacts	vary greatly depending on location, condition of the receiving aquifer and water quality considerations. • ASR is probably best suited to provide water supply storage; its capability to provide for in-stream flow augmentation has not been directly evaluated. • The Council recognizes the need for further evaluation of specific proposals for ASR in the region on a case-by-case basis. • The Council recommends that any ASR proposal be thoroughly evaluated for its environmental and other impacts.	Basin

The work of the RWPCs did not end upon adoption of the 2011 Plans. Funding provided by the State of Georgia allowed Georgia EPD to continue to support the Councils to develop reports on Plan implementation and prioritize items for discussion as part of the 5-year Review and Revision process now underway. Georgia EPD is now leading the effort to compile updated information on water use, including a revised assessment of current and forecast agricultural water demand, update the resource assessments based on surface and groundwater modeling and provide technical assistance to the RWPCs to revise their Plans as needed. This effort is scheduled to be complete in 2017.

D. Investments in Data and Information

Prior sections of this report have briefly mentioned occasions where the State acknowledged a need for additional data and information and responded with an appropriate commitment of funding and coordinated effort. The following section offers additional detail on two important data collection projects that have improved the State's ability to measure, and manage, its water resources.

1. Agricultural Metering

In 2003, the Georgia General Assembly passed legislation to establish the Agricultural Water Use Measurement Program (Agricultural Metering Program), an effort designed to measure use of permitted agricultural water withdrawals statewide. While metering of agricultural withdrawals exists in other states, I am not aware of any state making a commitment to capturing agricultural water use comparable to that of Georgia. Since

2004, the State has invested more than $22 million in deploying, maintaining and managing data collection on over 12,000 meters statewide.[30] Initial flowmeter installations during 2004–2007 were concentrated on agricultural irrigation in southwest Georgia. By the end of 2009, the Commission monitored agricultural withdrawals from a network of 6,985 meters.

Table 3. Water Meter Installations in the Middle and Lower Chattahoochee and Flint River Basins in Georgia (Source: USGS)

Source	**Meter Type**	
	Annually Reported	**Telemetry**
Middle and Lower Chattahoochee and Flint River Basins		
Groundwater	3,609	46
Surfacewater	748	35
Subtotal	4,357	81
Coastal Region		
Groundwater	679	20
Surfacewater	378	16
Subtotal	1,507	36
Central south Georgia		
Groundwater	912	15
Surfacewater	659	16
Subtotal	1,571	31
Grand total	6,985	148

Administered by the Georgia Soil and Water Conservation Commission (GSWCC), the Metering Program captures annual data on permitted withdrawals throughout the State. Meters are read each year between October 1 and December 31 which, when compared to the previous year's reading, provides a use generally corresponding to the growing season for most crops. At the time of reading, GSWCC personnel or their contracted support staff also record the crop grown during the previous year and perform a visual inspection of the meter. All meters receive a comprehensive inspection on a three-year rotating basis. Further, approximately 1% of meters are read on a monthly basis as a sample to provide additional information on timing and use patterns during the growing season.

2. Irrigated Acreage

Along with capturing data on agricultural withdrawals through the Metering Program, the State has invested heavily in compiling a database of irrigated acreage. These ongoing efforts, funded primarily through Georgia EPD and GSWCC, are completed under contract to the Georgia Water Planning and Policy Center (GWPPC) at Albany

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30 Interview with David Eigenberg, GSWCC, Dawson, GA (September 22, 2015).

State University. While also statewide in scope, detailed assessments of irrigated acreage began and have largely focused on the Flint River Basin. Since 2013, GWPPC personnel have visited and performed a detailed, on-farm assessment of over 88% of the irrigated acreage in the lower Flint River region.[31] An evaluation of all irrigated acreage in selected HUC 12 watersheds has been completed as well as an evaluation all surface water withdrawals in the remaining portions of three sub-basins. These assessments involve capturing exact withdrawal locations and source information, precise acreage irrigated by a particular source, acreage associated with each flowmeter, irrigation system type, installed conservation measures, and a series of other useful, site-specific information. The data collected as part of this mapping program was used to develop a statewide database of irrigated acreage.

E. Additional Policies

In 2000, the Georgia Legislature passed the Flint River Drought Protection Act (FRDPA). The purpose of the FRDPA was to provide the State of Georgia a mechanism for reducing irrigated acreage in the Flint River Basin during periods of severe drought, should the best available information indicate existing use could result in unreasonable impacts to surface water flows in the Basin. It is worth noting that adoption of the FRDPA followed closely Georgia EPD's implementation of the 1999 agricultural permit moratorium. Under the original statutory provisions of the FRDPA, a "severe drought" declaration by the Director of Georgia EPD would trigger a series of steps including an auction to voluntarily remove land from irrigated production, in exchange for a per acre payment, for the balance of the calendar year.

Following severe drought declarations by the Georgia EPD Director, an auction process consistent with provisions in the FRDPA resulted in retiring a total of 33,101 acres of irrigated land from production in 2001 and 40,894 acres in 2002. The State invested a total of approximately $10 million in the 2001 and 2002 auctions. The auctions were not without certain inefficiencies. In the 2001 auction, a number of participants were paid for very marginal land, or for land that was permitted but not typically irrigated. This "loophole" was closed for the 2002 auction such that only those permit holders who had irrigated in the previous three years could participate.

Following adoption of the 2006 Flint Plan and, significantly, action by the Georgia General Assembly in 2014, a set of amendments to the FRDPA established additional conservation mandates and enhanced Georgia's ability to manage water use within the Flint Basin. A summary of the amendments is as follows:

- ***Inclusion of groundwater*** – The original FRDPA applied only to irrigated acreage sourced by surface water. Amendments to the FRDPA Rules following

31 Defined as the Lower Flint (HUC 03130008), Ichawaynochaway (HUC 03130009) and Spring Creek (HUC 03130010) Sub-basins.

the 2006 Flint Plan expanded the acreage that could participate under the FRDPA to include groundwater within certain regions based on proximity to streams.

- ***Targeting of watersheds*** – Refinements to the FRDPA now allow Georgia EPD to target certain HUC 8 watersheds with FRDPA implementation rather than the entire Flint River Basin.

- ***Demonstration of use (meters)*** – In order to be eligible for the auction, a permittee must demonstrate that the land in question is actively irrigated and metered.

- ***Flexibility of auction*** – Clarification of the original FRDPA language provided GAEPD additional flexibility regarding auction implementation following a severe drought declaration.

- ***Protection of augmented flows*** – Language was included to protect flows that may be augmented by the State of Georgia (e.g. prohibits pumping water for irrigation use that comes from a state-sponsored stream augmentation project).

- ***Conservation mandates*** – Building on the framework established in the 2006 Flint Plan, a set of conservation efficiency mandates for *all* permitted withdrawals in the Flint Basin was adopted including:

    - A minimum 80% efficiency for center pivots (60% for mobile and solid set sprinklers) was required for permits issued after January 1, 2006 as of January 1, 2016;

    - For agricultural permits issued between 1991 and 2005, the efficiency requirements must be met by January 1, 2018;

    - For agricultural permits issued prior to 1991, the efficiency requirements must be met by January 1, 2020.

F. Conclusion

Based on my analysis of Georgia's policy and regulatory initiatives, I conclude that the State has been responsible, proactive, and progressive in its management of agricultural water resources and responsive to water resource challenges in the ACF Basin, especially the Lower Flint River Basin. These programs, policies, and initiatives by the State demonstrate good and responsible stewardship of agricultural water resources, and indicate that the State has taken a proactive and approach to agricultural water resource challenges.

II. SOIL AND WATER CONSERVATION PROGRAMS AND EFFORTS

There is substantial evidence of Georgia's investment in irrigation conservation technology, education, and outreach programs to help farmers and agricultural producers conserve water resources. Most of these outreach, education and training efforts have been planned, organized, and conducted by state agencies. Georgia EPD, in partnership and collaboration with the Georgia Soil and Water Conservation Commission (GSWCC), the Georgia Soil and Water Conservation Districts (GSWCDs), and other entities, has been a vital part of all these activities. The state has also invested greatly in various units of the university system of Georgia that have helped develop and implement new technologies for conserving agricultural water resources in the ACF Basin. These include the University of Georgia's Stripling Irrigation Research Park in Camilla, Georgia, and the Georgia Water Planning and Policy Center (GWPPC) at Albany State University.

A. Georgia Mobile Irrigation Laboratory

One of GSWCC's programs is the Mobile Irrigation Laboratory (MIL). The MIL is a service that GSWCC provides to farmers at no cost. The MIL increases irrigation efficiency by improving the uniformity of a farmer's irrigation system. Irrigation uniformity refers to the uniform distribution of water from a center pivot onto a field. For any given irrigation system to have a high irrigation efficiency, it must first have a high uniformity coefficient.

Upon request from an irrigator, a MIL technician visits the grower's field to collect data on the application uniformity of the farmer's irrigation system, including data about system pressure, flow rate, and sprinkler application rate. Once this data is collected and charted, the farmers have knowledge of the flow, application rate, and a scoring of the uniformity of their system. In conducting their analyses, the MIL technicians provide services and recommendations to improve the uniformity of the farmers' irrigation system (i.e., end-gun shut-offs and sprinkler uniformity), which can result in reducing water waste and increasing the efficiency of the system.

Over 450 center pivot systems have been serviced and/or retrofitted by the MIL, including many center pivot irrigation systems in the Lower Flint River Basin, to address and improve uniformity. Figure 23 shows the location of complete MIL projects in the State of Georgia, including a large number of projects in the LFRB.

B. Conversion from High-Pressure Impact Sprinklers to Low-Pressure Drop Nozzle Sprinklers

Many of the center pivot irrigation systems adopted during the 1970s-1980s operated at high pressure with sprinklers spraying water from the top of the pivot mainline. These high pressure systems tend to spray water higher in the air with smaller droplets. In contrast, low pressure sprinklers on drop hoses apply water more closely to the crop canopy, in larger droplets, thereby reducing water losses from wind drift and evaporation. Low pressure spray-type sprinklers operate between 10 to 30 psi allowing them to have a lower energy requirement. Accordingly, converting high pressure systems to low pressure sprinklers on drop hoses can generate water and energy savings.

1. USDA Data Show that Georgia Has Undertaken Extensive Efforts to Convert Farmers to Low Pressure Systems in Recent Years

Georgia has undertaken extensive efforts to convert farmers from high pressure systems to low pressures systems with drop nozzles. To measure the extent of those efforts in recent years, I examined data on USDA-NRCS contracts in Flint River Soil and Water Conservation District counties from 2005-2014. That data reflects center pivots that have been retrofitted with financial assistance from USDA-NRCS.

As shown in Figure 26, USDA-NRCS data indicates that 1,065 center pivot irrigation systems in the region have been converted from high pressure impact sprinklers to low pressure drop nozzles from 2005 to 2014. The number of pivots retrofitted with low pressure nozzles ranged from 26 in Dougherty County to as high as 216 pivots in the Miller County.

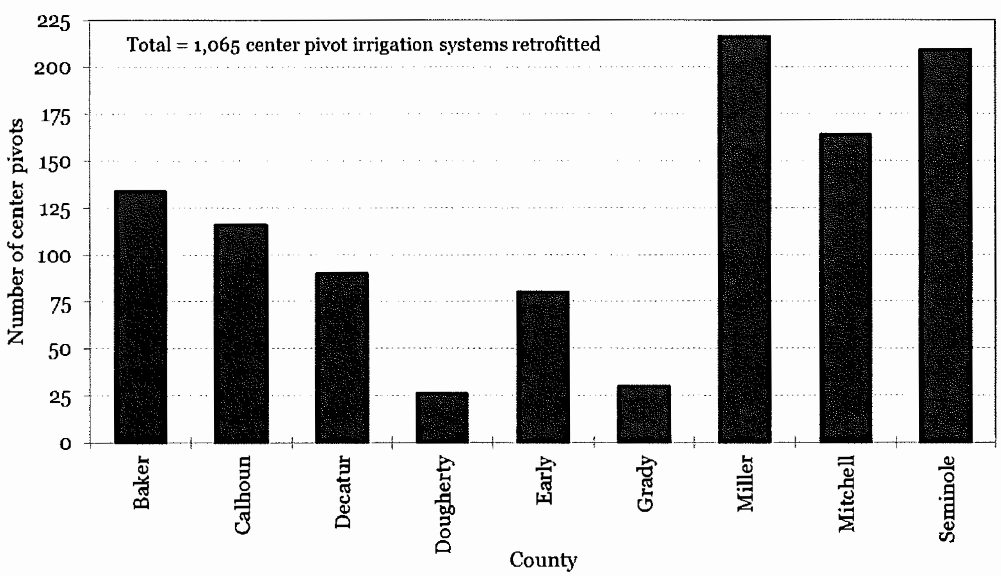

Figure 26. Center pivot irrigation systems that have been converted from high pressure impact sprinklers to low pressure drop nozzles from 2005 to 2014 in

various counties in the Lower Flint River Basin in Georgia (Source: USDA NRCS EQIP[32]).

As shown in Figure 27, 106,519 acres of irrigated land area have been converted to low pressure center pivot systems through USDA-NRCS contracts. The irrigated land area ranged from 2,901 acres in Dougherty County to 20,640 acres in Baker County.

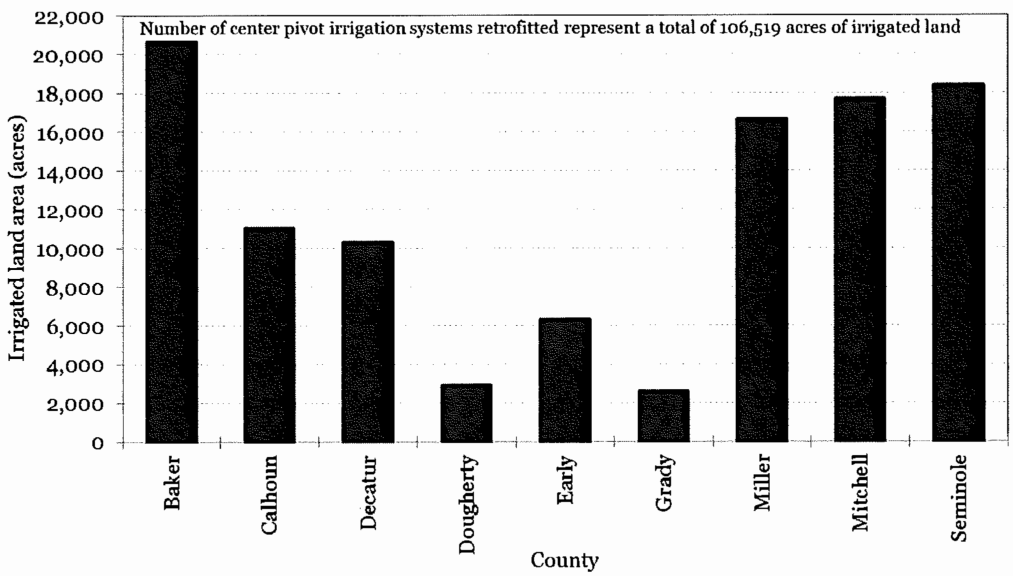

Figure 27. Total irrigated land areas represented by the retrofitted center pivot irrigation systems from 2005 to 2014 in various counties in the Lower Flint River Basin in Georgia (Source: USDA NRCS EQIP).

As mentioned earlier, the data in Figure 26 and Figure 27 only represents the number of center pivots that have been retrofitted with financial assistance from USDA-NRCS. It does not reflect farmers in the area that have retrofitted systems without any financial assistance, and therefore understates the number of pivots and total irrigated land area that have been converted to low pressure drop nozzles from 2005-2014.

2. GWPPC Data Demonstrate that the Majority of Center Pivots in the Lower Flint Basin Use Low Pressure Systems.

Data collected by the GWPPC demonstrates that Georgia's efforts to covert farmers to low pressures systems have been very successful. From 2013 through 2015, GWPPC conducted detailed field mapping in large portions of the Lower Flint River Basin, including field mapping covering 100% of the Capacity and Restricted HUC 12 watersheds. As shown in Table 4 below, this data demonstrates that approximately 90% of the center pivots in Capacity and Restricted Use watersheds employ low pressure

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32 Flint River Soil and Water Conservation District, USDA Natural Resources Conservation Service Environmental Quality Incentives Program (EQIP), 2005-2014.

sprinklers or low pressure drop nozzle technology. Table 4 also shows that low pressure systems irrigate approximately 93% of the acreage in those areas. To illustrate the efficiency improvements resulting from conversion to low pressure sprinklers, Table 4 includes my best estimate of the range of potential irrigation system application efficiency values for each type of center pivot system.

Table 4. Center Pivot Efficiency Data Collected Through Detailed Acreage Assessments (Source: GWPPC Field Mapping)

Type of Center Pivot	Percentage of Irrigation Systems	Percentage of Acreage	Efficiency Estimate[33]
Low Pressure/Sprinkers	30.6%	27.9%	75-85%
Lower Pressure/Drop Nozzles	58.9%	64.9%	80-85%
Total Low Pressure	**89.5%**	**92.8%**	-
High Pressure Impact Sprinklers	10.5%	7.2%	70-75%

Dr. Bottcher suggests that "irrigation efficiency can increase from 70% to 80% by upgrading to low pressure drop sprinkler systems at a cost of $115 to $150 per acre with a water savings of 45,000 gallons per year" and that "irrigation efficiency can increase from 80% to 90% by upgrading to even lower pressure drop nozzle in-canopy type systems for the additional cost of $17 to $70 per acre with an additional water savings of about 45,000 gallons per year."

Dr. Bottcher, however, does not cite to or rely on the above data regarding high-efficiency retrofits, and thus fails to account for the fact that a substantial percentage of irrigated acreage in the ACF Basin is already irrigated by the very irrigation systems he proposes. Again, in Capacity and Restricted Use Areas, nearly 90% of the center pivots employ low pressure sprinklers or low pressure drop nozzle technology, covering approximately 93% of the irrigated acreage in those areas.

Moreover, contrary to Dr. Bottcher's assumptions, some farmers cannot use low pressure or drip systems on their farms due to topographical conditions, water source issues, or other factors. Additionally, to the extent that there are any potential savings available from efficiency improving upgrades, farmers in Georgia are naturally incentivized to make those upgrades. Reducing waste in agricultural operations reduces costs and provides financial benefits for farmers. Finally, Georgia law already requires that all center pivots be 80% efficient as of January 1, 2016 for permits issued after 2005, as of January 1, 2018 for permits issued after 1991, and as of January 1, 2020 for

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33 These efficiency values represent a potential range of values; actual values are impacted by various factors, including how the irrigation system is managed by the irrigators, field characteristics, and weather conditions.

- Conserving Water in the Vegetable Garden (Extension Circular 964)
- Alfalfa Management in Georgia (including irrigation management) (Extension Bulletin 1350)
- Protecting Georgia's Surface Water Resources (Extension Bulletin 1217)
- Water Recycling and Water Reuse Assessment (Extension Bulletin 1278)
- Conservation and Best Management Practices in Georgia: Implementing, Funding and Assistance (Extension Bulletin 1335)
- Water Management Assessment (B 1276)
- Water Use Regulation, Legislative Awareness and Company Water Policy Assessment (B 1279)

L. Dr. Sunding's and Dr. Bottcher's Proposed Additional Conservation Measures

In their reports, Drs. Sunding and Bottcher state that Georgia should implement a number of conservation practices. For the most part, those proposed conservation practices ignore key distinctions between Georgia and other regions, have already been successfully adopted by Georgia, or would be ineffective for various reasons.

1. Dr. Sunding Does Not Address Key Distinctions Between Georgia and Other Regions—and the Fact that Georgia Has Already Successfully Adopted Many Suggested Practices from Other Regions

Dr. Sunding suggests that Georgia adopt management programs practiced in the Platte and Republican River Basins in Colorado, Kansas, and Nebraska. However, there are significant differences between Georgia and the western states discussed by Dr. Sunding. In general, Midwestern/Great Plains states have substantially different climates, surface and groundwater resources, and recharge rates. For example, the Ogallala aquifer underlying the Great Plains has a very slow recharge rate, whereas the Floridan aquifer underlying the southeastern USA has a very fast recharge rate. One of the other key differences between Midwestern/Great Plains states and Georgia in terms of agricultural production systems is the soil type. The Midwestern/Great Plains region has deep silt loam soils that have some of the highest soil-water holding capacity, whereas Georgia soils are mostly sandy soils and have some of the lowest soil-water holding capacities. Those differences require different irrigation and water management implementation strategies between the two regions.

would be often reached in loamy sand soils, which will require frequent irrigations of pecan trees.

Finally, Dr. Wells and Dr. Sunding did not acknowledge that early season stress did reduce the pecan yield substantially by 8 kg/tree in 2012 and by 4 kg/tree in 2014 . The non-irrigated treatments reduced the yield significantly by 15 and 13 kg/tree in 2012 and 2014, respectively, demonstrating the importance of irrigation for sustaining the yield and economic/viable productivity of pecans in the region.

4. Dr. Bottcher's Suggestion to "Avoid Irrigation" During Daylight Hours Is Not Practical and Would Likely Lead to Total Crop Failure

Dr. Bottcher suggests that "avoiding irrigation between 10am and 4pm can significantly reduce consumptive use of water." This is not practical and is a potentially harmful practice for many irrigators. Most irrigation systems in Georgia are center pivots. For a typical 130 acre field, it can take 3-4 days for a center pivot to make a complete revolution to apply 1 inch of water to the entire field, although the exact time may vary slightly depending on numerous factors, including irrigation system capacity, well/pump capacity, operating conditions, system malfunction, field size, etc. During these 3-4 days, irrigators must operate their systems both during the daytime and the nighttime. If farmers were to limit their irrigation practices to nighttime only, it would take commensurately longer for them to irrigate the entire field. Crop failure would be unavoidable because there would simply not be enough time to apply sufficient water to meet the crop water requirements, especially during the summer months and with the sandy soil conditions of the ACF Basin in Georgia.

5. Contrary to Dr. Bottcher's Recommendation, Fallow Fields Actually Increase Crop ET

Dr. Bottcher states that "leaving fields fallow for as long as possible will keep the crop ET coefficients low and will, in turn, increase the replenishment of local water resources[.]" I have conducted extensive research to measure crop coefficients for various surfaces, including a fallow field. The data I present in Figure 32 show that leaving a field fallow would not reduce the crop ET coefficients (K_{co}) but in fact would increase them substantially. In a fallow field, the primary water loss comes from surface evaporation due to absence of any vegetation cover. These losses exceed ET losses from a field with vegetation because leaving the field fallow would not take advantage of the substantial benefits of having vegetation cover on the soil surface. Vegetation cover reduces the amount of incoming shortwave radiation that reaches the soil surface, which in turn reduces soil evaporation losses. Figure 32 shows that the crop ET coefficients of a fallow field can be as high as 2.4, which is a high value. Thus, research data show that fallow fields do not have reduced crop ET coefficients.

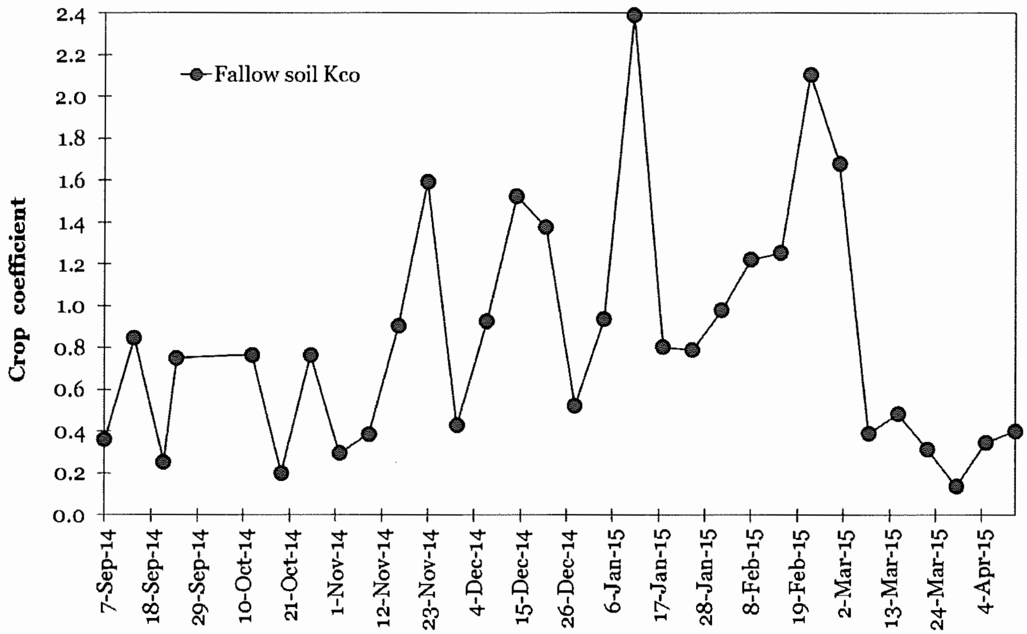

Figure 32. Distribution of crop ET coefficients for a fallow field (Source: S. Irmak research data).

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ATTACHMENT 2

CONFIDENTIAL – S. Ct. 142

ANALYSIS GROUP
ECONOMIC, FINANCIAL and STRATEGY CONSULTANTS

Expert Report of

ROBERT N. STAVINS, PH.D.

Submitted in the matter of
Florida v. Georgia
Supreme Court of the United States, No. 142, Original

May 20, 2016

2. Agriculture in the ACF Basin

Irrigation water is a critical input to a substantial portion of the total agricultural acreage in ACF Georgia, resulting in higher yields during both average and dry years. In this section, I first provide an overview of the agricultural sector, and then describe the role of water as a key input to production.

a) Overview of the Agricultural Sector

The ACF Basin supports a substantial agricultural sector, with the vast majority of this activity occurring in the State of Georgia. Exhibit 7 shows the commercial value of all agriculture products that are produced in ACF Georgia.[44] In 2013 (the most recent year with reported data), total agriculture revenues were $4.7 billion, with $1.3 billion coming from row and forage crops, the majority of which came from three crops: cotton, peanuts, and corn. Most of this agricultural activity takes place within the Lower Flint watershed.[45]

ACF Georgia is also one of the largest and most productive agricultural regions in the United States. Georgia farmers planted almost 50 percent of all peanut acreage nationwide,[46] with ACF Georgia accounting for approximately 54 percent ($478 million) of total peanut sales in 2012.[47] Georgia is also the nation's second largest producer of cotton, producing more than $1.3 billion in sales in 2012, with ACF Georgia contributing roughly 47 percent ($618 million) of this production.

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44 Agricultural statistics are reported at the county level. In this calculation, I define ACF Georgia as all counties overlapping the Local Drainage Areas (LDAs) identified by Dr. Sunding to be in the ACF River Basin. I use National Environmentally Sound Production Agriculture Laboratory ("NESPAL") dataset that has irrigated acreage to determine county-LDA overlaps.

45 As described in the Flint River Basin Regional Water Development and Conservation Plan, the highest concentration of irrigation in the Flint River Basin is in the lower Flint River and Spring Creek sub-basins. *See* Couch, Carol A., and R. J. McDowell, "Flint River Basin Regional Water Development and Conservation Plan," Georgia DNR-EPD (2006) ("Flint River Plan").

46 National commodity production by state was provided by the United States Department of Agriculture (USDA) National Agriculture Statistics Survey. Data available through the USDA quick stats tool.

47 Crop commercial values were provided by the University of Georgia Farm Gate data (UGA_00130458); According to the Georgia Cotton Production Guide, Georgia was the second largest producer of cotton in 2014 ("2015 Georgia Cotton Production Guide," The University of Georgia Cooperative Extension, January 2015.).

Exhibit 9: Georgia Crop Yields per Acre
2001-2015

	Crop Budget	USDA ARS NPRL	
	Average Year	Average Year	Dry Year
Cotton (lb)			
Irrigated Yield	1,200	1,308	1,518
Non-Irrigated Yield	750	606	329
Difference	450	702	1,189
Non-Irrigated % Difference	(-38%)	(-54%)	(-78%)
Peanuts (lb)			
Irrigated Yield	4,700	4,675	5,050
Non-Irrigated Yield	3,400	3,323	2,471
Difference	1,300	1,352	2,579
Non-Irrigated % Difference	(-28%)	(-29%)	(-51%)
Corn (bu)			
Irrigated Yield	200	191	183
Non-Irrigated Yield	85	62	13
Difference	115	129	170
Non-Irrigated % Difference	(-58%)	(-68%)	(-93%)
Soybeans (bu)			
Irrigated Yield	60	-	-
Non-Irrigated Yield	30	-	-
Difference	30	-	-
Non-Irrigated % Difference	(-50%)	-	-

Notes & Sources: Average Year yields were calculated as the average of the Crop Budget yields and the average USDA-ARS NPRL yield over all available data years (2001-2014). Dry Year yields were calculated as the average yields from the USDA-ARS NPRL in 2007 and 2011. *See* USDA-ARS-NPRL, (2015) ("Shellman Farm Data") and Smith et al. (2015) ("UGA Crop Budgets"). UGA Crop Budget yields were predicted for the entire state in 2015, USDA-ARS NPRL yields were based on data collected from 1-acre research plots on Shellman Farm located in the Lower Flint from 2001 to 2014.

The impacts described in Exhibits 15 to 18 consider the direct consequences to the agricultural sectors and the "upstream" sectors relied on by them for operations (for example, seed, fertilizer, and farm equipment). Other economic consequences can arise from the types of changes in economic activity contemplated by the proposed reductions in water use. Along with changes in upstream sectors, changes could also occur in "downstream" sectors that use the outputs from the agricultural sector as inputs to their own production processes. As described in Section III.A, ACF Georgia has processing industries that use commodities produced locally as key inputs to production. For example, in 2013, these industries in ACF Georgia accounted for $687 million in gross regional product, purchased more than $155 million in regional farm products to serve their businesses, and employed more than 4,500 individuals.[96] In both regions, inputs may be sourced locally or from producers at greater distances. To the extent that these industries would reduce activity due to the reduction in agricultural output in ACF Georgia, impacts would be larger than those reflected in Exhibits 15 to 18.

Irrigation restrictions could also have implications for the ability of farmers in the ACF Basin to secure loans on favorable terms (if at all). Farmers typically seek loans both for long-term investments (for example, for purchase of land or equipment, including irrigation systems) and short-term operating needs (for example, to purchase seed).[97] From the lender's perspective, the farmer's ability to repay loans in a timely manner depends on successful harvests.[98] In the event that a borrower is unable to repay, the lender may seize the collateral, which is often the farmland itself.[99]

As proposed by Dr. Sunding, many – *if not all* – irrigated row crop farms in ACF Georgia will essentially become dryland farms during "dry" years (approximately once every three years). In these years, deprived of the insurance provided by irrigation, these farms will be at increased risk of poor yields. Knowing this ahead of time, potential lenders would likely consider these farms at increased risk of default. Moreover, the same lenders would likely revise their estimates of the value of the farm land as

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[96] ACF Florida also has processing sectors that rely on output from the fishery sector. As shown in Exhibit 12, the "seafood product preparation and packing" sector in ACF Florida contributes approximately $6.5 million to GRP – a small fraction of agricultural processing activity in ACF Georgia. For more on seafood processing in ACF Florida, *see* Deposition of Thomas Lee Ward, January 14, 2016, 47:2- 48:3, 161:20- 1625.

[97] *See*, for example, "Comptroller's Handbook Safety and Soundness Agricultural Lending," Office of the Comptroller of Currency, May 2014, pp. 1, 11.

[98] "Comptroller's Handbook Safety and Soundness Agricultural Lending," Office of the Comptroller of Currency, May 2014, p. 2.

[99] "Comptroller's Handbook Safety and Soundness Agricultural Lending," Office of the Comptroller of Currency, May 2014, p. 17.

collateral.[100] Both of these developments would likely make it more difficult for farmers to obtain short- and long-term loans on the same terms as before.

Evidence I have reviewed suggests that these are not merely theoretical concerns. For example, in a study of risk management in farming, Crane et al. interviewed 38 farmers in southern Georgia, including some from the ACF Basin.[101] One farmer interviewed stated that "one needs to have at least 50% of landholdings under irrigation to make a profit or *even to secure a loan from the bank*."[102] In addition, in a letter dated April 7, 2016, Richard S. Monson, the CEO of the largest agricultural lender in the region, Southwest Georgia Farm Credit, stated:

> "Loss of a readily available and consistent source of water would likewise have the compounding effect of not only decreasing loan repayment capacity; it would also translate into deteriorating farm real estate values. … From a financing proposition this becomes somewhat of an untenable situation. Aside from problematic cash flows, row crop farmers would have weakening collateral and equity positions, making it all the more difficult to obtain constructive financing."[103]

2. Dr. Sunding fails to accurately characterize the potential impacts of his proposed reductions to the affected industries and local economies

While Dr. Phaneuf describes the Florida economy's reliance on the region's natural resources, Dr. Sunding downplays the reliance of ACF Georgia on water, particularly agriculture in the Flint River Basin. In summarizing his findings, he compares the economic costs of one water reduction scenario ($35 million for his Scenario 2) to the state's overall economic activity, finding that the cost is *"one-hundredth of a percent"* of Georgia's annual state product.[104] As an initial matter, Dr. Sunding fails to apply his own approach to Florida. For example, in Section V, I estimate the annual economic benefits of

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[100] For example, *see* "Comptroller's Handbook Safety and Soundness Agricultural Lending," Office of the Comptroller of Currency, May 2014, p. 18 ("Real estate, machinery, and equipment should be reevaluated whenever market conditions or other information leads the lender to believe that the collateral's original assigned value may have significantly decreased.").

[101] Crane, T.A. et al., "Seasonal Climate Forecasts and Risk Management Among Georgia Farmers," *Southeast Climate Consortium Technical Report Series*, 2008 (hereafter "Crane et al. (2008)"), p. 38.

[102] Crane et al. (2008), pp. 39-40. Emphasis added.

[103] Letter from Richard S. Monson, dated April 7, 2016.

[104] Sunding Report, p. 7.

ATTACHMENT 3

Ag WATER PUMPING

Project Report 52

Final Report

Statewide Irrigation Monitoring

EPD Cooperative Agreement Number: 764-890147
UGA ID 25-21-RF327-107

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County	GW	SW	W2P	GW	SW	W2P	All	County-wide Irr Depth
	----------- in./yr -----------			-------------------- Mgal/yr --------------------				in./y
Dodge	8.9	6.9	6.5	520	2,300	480	3300	0.38
Echols	10.5*	7.2	7.0*	1,300	81	0	1380	0.19
Glascock	18.5	11.7	7.0*	0	73	0	73	0.029
Grady	13.9	8.2	12.9	1,980	1,940	1,080	5000	0.63
Houston	7.0	10.5	4.1	1,580	590	350	2500	0.37
Irwin	10.0	6.4	6.0	3,380	1,740	760	5900	0.97
Jeff Davis	3.9	4.9	6.7	600	520	214	1330	0.23
Jefferson	15.9	7.8	7.0*	3,600	2,700	530	6800	0.75
Johnson	16.1	9.1	7.0*	770	158	73	1000	0.19
Lanier	7.7	6.4	7.0*	380	94	129	600	0.18
Laurens	9.0	5.2	7.8	1,730	460	280	2500	0.18
Lowndes	7.0	5.8	7.0*	1,740	590	93	2400	0.27
Montgomery	2.5	6.4	9.1	159	188	48	400	0.092
Peach	8.2	7.2*	7.0*	1,480	125	87	1690	0.65
Pulaski	7.0	7.2	6.5	3,600	940	1,150	5700	1.30
Telfair	6.0	5.8	6.2	1,110	50	164	1320	0.24
Thomas	13.0	7.9	5.3	3,400	740	430	4600	0.48
Tift	10.0	6.7	6.7	3,400	2,600	1,070	7100	1.52
Treutlen	9.0	5.5	9.1	177	71	0	250	0.071
Turner	9.9	5.9	7.1	2,300	2,200	430	4900	1.00
Twiggs	6.0	7.2*	7.0*	220	103	45	370	0.060
Washington	18.5	11.7	7.0*	2,400	420	33	2900	0.24
Wheeler	7.6	5.8	7.5	174	710	430	1310	0.26
Wilcox	7.7	7.0	6.5	4,900	1,210	1,320	7400	1.12
Wilkinson	12.7	5.5	7.0*	20	9	0	29	0.004
Central CP	10.5	7.2	7.0	57,000	35,000	14,300	107,000	

3.4 Monthly Distribution of Irrigation Depths

Mean annual application depths and withdrawal amounts are useful in planning for long-term water supplies. However, in Georgia, as elsewhere, irrigation applications vary over the year as affected by periods of crop growth and water needs and shortages in soil moisture. With sandy loam or sandy clay loam soils that have relatively low water holding capacities, most of Georgia's crop production regions require frequent replenishment by rainfall to maintain economical crop production. Producers in this region have traditionally viewed irrigation as a means of filling gaps or deficits in rainfall giving their water applications a strong positive relationship with these deficits in effective rainfall.

While AWP sites were sampled monthly during the long growing season of February through November, dates of sampling varied over a three week period of each month. Rather than compute monthly irrigation as though the amount accumulated since the last reading occurred during the month of observation, we prorated the amount over all of the

ATTACHMENT 4

Flint River Basin Regional Water Development and Conservation Plan

March 20, 2006

Georgia Dept. of Natural Resources
Environmental Protection Division

Carol A. Couch
Director

Robin John McDowell
Plan Coordinator

Acknowledgements

The Flint River Regional Water Development and Conservation was developed through the close cooperation of many different people and organizations. Specifically, the members of the Stakeholder Advisory Committee (SAC) and their associates in southwest Georgia have been instrumental in developing and maintaining an excellent working relationship among themselves and with the Georgia EPD. The hard work and dedication of the SAC were essential to completion of this Plan. The Stakeholder Advisory Committee consisted of the following southwest Georgia residents:

Mr. James Lee Adams, Mitchell County
Mr. Lucius Adkins, Farmer, Baker County
Mr. Dan Bollinger, Director, Southwest Georgia RDC
Mr. John Bridges, Farmer, Decatur County
Mr. Charles (Chop) Evans, Farmer, Macon County
Mr. Thomas C. Chatmon, Jr., CEO Albany Tomorrow, Inc.
Mr. Vince Falcione, Proctor and Gamble, Albany
Mr. Tommy Gregors, Georgia Wildlife Federation, Albany
Mr. Hal Haddock, Chairman, Flint River Water Council and Farmer, Early County
Mr. Chris Hobby, City Manager, Bainbridge
Mr. Bubba Johnson, Farmer, Mitchell County
Mr. John Leach III, Developer, Lee County
Ms. Janet Sheldon, Southwest Georgia Water Task Force, and Georgia Conservancy
Mr. Mike Newberry, Farmer, Early County
Mr. Kim Rentz, Farmer, Decatur County
Mr. Steve Singletary, GSWCC Commissioner and Farmer, Early County
Mr. Marcus Waters, Crisp County Power, Cordele
Mr. Jimmy Webb, Farmer, Calhoun County
Mr. Joe Williams, Farm owner, Crisp County

Technical Advisory Committee (TAC) meetings were held mostly at the J.W. Jones Ecological Research Center at Ichauway as a result of the generosity of Dr. Lindsay Boring and the Robert W. Woodruff Foundation. The TAC provided the scientific foundation of the Plan through extreme diligence and hard work. The TAC consisted of the following scientists and technical experts:

Dr. Steve Golladay. J.W. Jones Ecological Research Center, Baker County
Mr. Mike Harris, DNR Wildlife Resources Division, Non-Game Section, Social Circle
Mr. Kerry Harrison, Cooperative Extension Service, Tifton
Mr. Woody Hicks, J.W. Jones Ecological Research Center, Baker County
Dr. James Hook,, University of Georgia/NESPAL, Tifton
Dr. Mark Masters, Director, Flint River Water Policy and Planning Center
Mr. Rob Weller, DNR Wildlife Resources Division, Fisheries Section, Albany
Mr. Joe Williams, Farm owner, Crisp County
Mr. Rad Yeager, Superintendent, Stripling Irrigation Research Park, Camilla

SAC meetings were very ably facilitated by staff from the Fanning Institute of the University of Georgia under contract with EPD. The facilitators kept the meetings, and thus the entire process, on track for more than a year. The facilitators were:

Mr. Dennis Epps, University of Georgia Fanning Institute
Ms. Courtney Tobin, University of Georgia Fanning Institute
Ms. Louise Hill, University of Georgia Fanning Institute

This document was written by a variety of people; specifically, Sections 5.3 and 5.4 on municipal and industrial permitting in Georgia were written by Bill Frechette and Kevin Farrell of the Georgia EPD; Sections 6.2 and 6.3 on surface water models and scenario impact evaluation, and Appendix I were written by David Hawkins of the Georgia EPD; Section 8 (Economic Status of the Flint River Basin) was written by Dr. Mark Masters, Director of the Flint River Planning and Policy center; Section 9 (Water Conservation in the Flint River Basin) was written by Alice Miller-Keyes of the Georgia EPD); the remainder of the document was written and assembled by Rob McDowell of the Georgia EPD.

(a) In those watersheds termed Capacity Use Areas, all permits issued or modified after March 1, 2006 for irrigation systems supplied by wells withdrawing from the Floridan aquifer or any surface water will be required to: 1) have end-gun shut off switches installed to prevent irrigation of non-cropped areas by center pivot systems, 2) be maintained to prevent and repair leaks, 3) have pump-safety shutdown systems installed on center-pivot systems that will stop water delivery in the event of an irrigation system malfunction; 4) have rain-gage shut-off switches for traveler, solid set, or drip irrigation systems.

(b) In those watersheds termed Restricted Use Areas, all permits issued or modified after March 1, 2006 for irrigation systems supplied by wells withdrawing from the Floridan aquifer or any surface water will be required to: 1) have end-gun shut off switches installed to prevent irrigation of non-cropped areas by center pivot systems, 2) be maintained to prevent and repair leaks; 3) have pump-safety shutdown systems installed on center-pivot systems that will stop water delivery in the event of an irrigation system malfunction; 4) have rain-gage shut-off switches for traveler, solid set, or drip irrigation systems.

(c) In those watersheds termed Conservation Use Areas, all irrigation systems supplied by newly permitted wells drawing from the Floridan aquifer or any surface water will require end-gun shut off switches to prevent irrigation of non-cropped areas, and maintenance to prevent and repair leaks.

(d) Those sub-basins for which no detailed hydrologic modeling has yet been completed; specifically, Middle Flint and Kinchafoonee-Muckalee Creek Sub-basins, are termed Conservation Use Areas. All newly permitted wells drawing from the Floridan aquifer or any surface water will require, as a condition of the permit, end-gun shut off switches such that non-cropped areas are not watered, and maintenance to prevent and repair leaks. All proposed Floridan wells will be evaluated for their impact on existing nearby wells, streams, and springs.

If ground-water and surface-water levels are below a critical threshold and climate predictions indicate an impending drought, then the Director makes a severe drought declaration. An auction must be completed before March 22 of that year.

To participate in the drought protection auction, eligible permittees must have an auction certificate that verifies the permit number and the acres irrigated by that permitted withdrawal. EPD must verify both the permit and its associated acreage. EPD must also determine the amount of irrigated acreage to be removed from irrigation, based on an acceptable flow to be maintained in the Flint River or targeted stream basin during the drought year. The Director of EPD shall determine the auction process by which irrigators offer to voluntarily retire their irrigated acreage in return for payment. (391-2-28).

To date, there have been two drought protection auctions: in 2001 and 2002. The first auction in 2001 proceeded by an iterative and interactive process by which participants submitted blind bids for a per acre price that they wanted in order to suspend irrigation. A linked computer network installed at auction stations throughout the lower FRB accomplished this. Auction participants submitted sealed bids, which were entered into the computer network and tabulated on a central computer in Atlanta. The Director of EPD was able to monitor the incoming bids, and either accepted or rejected bids based on the total cost of all bids presented. Participants whose bids were rejected could re-submit bids during subsequent rounds until the Director had accepted enough bids to remove the targeted amount of acreage from irrigation.

This auction process was very inefficient. Bids submitted over five auction rounds ranged from $75/-800/acre, but the highest bids were rejected. The average accepted bid was $135/acre. More than 33,000 acres were taken out of irrigation for a total cost of approximately $4.5 million.

In 2002, a second auction was held due to continuation of the drought. To maximize efficiency and still remove enough acres from irrigation, the Director announced that

EPD would not accept bids above $150/acre, but that all bids below that would be accepted up to the point where sufficient acreage was taken out of irrigation. In the sole auction round, bids ranged from $74-145/acre. The average bid was $128/acre. In this auction, more than 41,000 acres were removed from irrigation at a cost of $5.3 million.

Both auctions had problems and inconsistencies. Eligibility requirements for the first auction stipulated only that a participant have a surface-water permit with no requirement of recent use. Consequently, a significant number of participants were paid for very marginal or long-fallow land, or for land that is not typically irrigated (e.g. trees). This loophole was closed for the second auction such that only those permit holders who had irrigated in the previous three years could participate. However, both auctions failed to remove the highest water use cropland from irrigation. This probably reflects the low cost per acre of accepted bids, and their inability to compensate for loss of a high-value crop. Regardless of the auctions shortcomings, other states such as Washington, Kansas, and Nebraska are either considering or enacting drought auctions similar to Georgia's.

SECTION 2: RECOMMENDED WATER RESOURCE MANAGEMENT AND PERMITTING STRATEGIES FOR THE FLINT RIVER BASIN

2.1 General Plan goals

As defined in Georgia statutes, water development and conservation plans shall:

- promote the development, conservation, reuse, and sustainable use of water within the state;
- guard against a shortage of water within the state;
- promote the efficient use of the water resource;
- be consistent with the public welfare of the state;
- be based on detailed scientific analysis of the aquifer, the projected future condition of the aquifer, and current demand and estimated future demands on the aquifer.

Upon adoption of a regional plan, all permits issued by the division shall be consistent with such plan.

2.2 Stakeholder Advisory Committee

The Flint River Basin Regional Water Development and Conservation Plan was developed in two parts: the legal and technical background upon which policy recommendations could be made, and a set of policy recommendations consensually developed by a stakeholder advisory committee (SAC). The Flint River SAC was developed by EPD in the fall of 2004 with the goal of having qualified representatives of the following major groups:

•Farmers and agribusiness representatives
•Southwest Georgia Water Task Force
•Flint River Regional Water Council
•Local elected officials
•Utilities, municipal authorities
•Sportsmen, anglers, boaters
•Georgia Conservancy, League of Conservation Voters, etc.

To this end, EPD was successful in developing a broadly based Committee representing most of these major constituencies. The FRB Stakeholder Advisory Committee SAC held their first meeting in Albany, GA on September 12, 2004. The Committee is comprised of the following southwest Georgia stakeholders:

Mr. James Lee Adams, farmer and developer, Mitchell County
Mr. Lucius Adkins, farmer, Baker County
Mr. Dan Bollinger, Director, Southwest Georgia RDC
Mr. John Bridges, farmer, Decatur County
Mr. Charles (Chop) Evans, farmer, Macon County
Mr. Thomas C. Chatmon, Jr., CEO Albany Tomorrow, Inc.
Mr. Vince Falcione, Proctor and Gamble, Albany
Mr. Tommy Gregors, Georgia Wildlife Federation, Albany
Mr. Hal Haddock, Farmer, Miller County
Mr. Chris Hobby, City Manager, Bainbridge
Mr. Bubba Johnson, Farmer, Mitchell County
Mr. John Leach III, Developer, Lee County
Ms. Janet Sheldon, Georgia Conservancy
Mr. Mike Newberry, Farmer, Calhoun County

Mr. Kim Rentz, Farmer, Decatur County
Mr. Steve Singletary, Farmer and GSWCC Commissioner
Mr. Marcus Waters, Crisp County Power, Cordele
Mr. Jimmy Webb, Sunbelt Expo 2005 Farmer of the Year
Mr. Joe Williams, Farm owner, Crisp County

The roles of the SAC were to: 1) help craft a Plan for water withdrawal in the FRB that takes conservation and economic development into consideration; 2) deliver concrete recommendations, reached by consensus, that would best manage the water resources of the FRB under *existing* statutes and regulations; 3) deliver recommendations, also reached by consensus, for regulatory and statutory reforms that would fulfill the broader goals of a regional development and conservation plan.

A central aspect of the Plan is the current moratorium on farm-use permits in the FRB. The immediate goal of the Plan is to develop water management strategies that would allow the Director of EPD to lift the moratorium while protecting the resource during droughts. However, the FRB Plan will necessarily be a significant part of the developing Statewide Water Plan, and in many ways will be a model for it. Specifically, the FRB Plan illustrates the importance of long-term stakeholder development, the need for a transparent stakeholder involvement process, and the importance of comprehensive scientific studies upon which to base water management strategies.

Agricultural production is the biggest category of water use in the FRB. Agriculture is the economic engine of southwest Georgia, and water is the basis of successful agriculture. For this reason approximately half of the SAC members are farmers. Because the most immediate aspect of the Plan was the permit moratorium, and because agriculture will continue to be the biggest water user for the foreseeable future, most of the SAC's focus was on agricultural water use, management, and regulation.

2.3 Technical Advisory Committee

To assist the SAC in understanding the complex scientific issues involved in development of the Plan, a Technical Advisory Committee (TAC) was created by EPD in mid-2004. Experts were selected who were specialists in their field and who were familiar with the geological, bio-ecological, agricultural, and economic issues specific to southwest Georgia. The TAC consisted of the following individuals:

Dr. Steve Golladay, J.W. Jones Ecological Research Center, Baker County
Mr. Mike Harris, DNR Wildlife Resources Division, Non-Game Section, Social Circle
Mr. Kerry Harrison, Cooperative Extension Service, Tifton
Mr. Woody Hicks, J.W. Jones Ecological Research Center, Baker County
Dr. James Hook, University of Georgia/NESPAL, Tifton
Dr. Mark Masters, Director, Flint River Planning and Policy Center,, Albany
Mr. Rob Weller, DNR Wildlife Resources Division, Fisheries Section, Albany
Mr. Joe Williams, Farm owner, Crisp County
Mr. Rad Yeager, Superintendent, Stripling Irrigation Research Park, Camilla

Throughout the development of the Plan, the TAC provided scientific and analytical perspectives in review of the Plan and of EPD's models and conclusions. When called upon they provided independent data and analysis to EPD. They also prepared and presented information on the stream hydrology, hydrogeology, ecology, water use patterns and economy of the region to EPD and the SAC. However, their participation in the planning process should not be construed as an endorsement of the FRBP by the individual TAC members or by the institutions they represent. The TAC met approximately every month between SAC meetings, in order to address questions raised by the SAC at previous meetings and to discuss the on-going studies that were incorporated into this report.

2.4 Guiding principles of the Stakeholder Advisory Committee

The SAC consistently expressed a number of consensus opinions, which guided their deliberations and discussions of permitting and water management strategies. These opinions are listed and described below. Some relate to managing the water resources of the FRB under existing regulations, while others were expressions of how the Basin should be managed.

1. The lifting of the permit moratorium may mean that future water users may adversely impact existing users. Therefore, future permitting should be done such that existing users are protected.

2. Secure access to irrigation water is critical to the viability of a farm. Banks are reluctant to provide affordable financing if the availability of irrigation is unpredictable. Permitting strategies should not allow a reliable, predictable, and permitted water source to be interrupted.

3. Farmers in Georgia are currently practicing some of the most effective water conservation measures available. The steadily rising price of operating an irrigation system makes wasting water economically impractical. Further conservation, mandatory or otherwise, should be economically feasible to the farmer, and should convey positive conservation messages about Georgia farmers.

4. A number of other States, such as Florida, Texas, Kansas, and Nebraska manage water through regional water management districts. The structure of these varies, as does the level of regulatory authority, but the general concept of decentralized and local water management should be a future consideration for Georgia.

2.5 Conclusions about "safe yield"

As described in Sections 5 and 6 of this report, the combination of the USGS ground-water model, HSPF stream models, historical stream flow, and simulated future stream flow scenarios compared to Federal in-stream flow guidelines demonstrated that the amount of water *currently* withdrawn for agricultural irrigation in drought years increases both the magnitude and duration of low flows in streams of the FRB, thus further harming endangered species and potentially limiting the amount of water available for all users. This is especially true in Spring Creek and Ichawaynochaway Creek sub-basins. Expanded drought-year irrigation will worsen this situation; reduced irrigation will improve it. *In normal to wet years, the impact of irrigation on stream flow and aquifer* *levels is insufficient to jeopardize the availability of water for all users, or to jeopardize stream ecology.* Therefore, some parts of the lower FRB have already reached their drought-year "safe yield". If more withdrawal permits are issued for the lower FRB, more aggressive drought-year management strategies will have to be employed, mostly (if not exclusively) in those parts of the Basin closest to their safe yield.

2.6 EPD regulatory limits

As the permitting agency for farm water use in Georgia, EPD must meet the following current statutory requirements, described in more detail in Section 1 of this report:

1. All legitimate requests for **farm use** permits must be granted in the FRB once the Plan is adopted.
2. The permit moratorium must be lifted upon completion of the Plan.
3. EPD may issue permits for less than the amount requested by the permit applicant.
4. In issuing new permits, EPD may decrease the permitted withdrawal amounts of all other permitted users including "grandfathered" permits.
5. EPD may initiate provisions of the Flint River Drought Protection Act during severe drought years in an effort to maintain critical stream flow.
6. EPD cannot revoke permits for non-use once initial use has commenced.

In this context, and after having been exposed over a period of months to the ground- and surface-water models and their conclusions, the SAC evaluated the existing permitting procedures, for both ground and surface-water permits, with the goal of making consensus recommendations as to how farm-use permitting could resume while protecting existing users and the resource. The results of the SAC discussions, begun at the August 12, 2005, meeting and concluded at the November14, 2005, meeting, are presented here.

2.8 Consensus recommendations for permitting strategies

1. The largest scale on which water management and permitting decisions should be based should be a sub-basin level corresponding to the USGS HUC-8 designation. In the FRB these are:

G. Upper Flint
H. Middle Flint
I. Kinchafoonee-Muckalee Creeks
J. Lower Flint
K. Ichawaynochaway Creek
L. Spring Creek

Permitting decisions in these sub-basins will take into account the water use characteristics, hydrology, geology, surface-water and ground-water interactions, and the ecology unique to each sub-basin. Where necessary, and where data are available, permitting and management decisions should also take into account site-specific conditions and local stream impacts down to a HUC-12 scale.

2. In considering new and existing applications both ground-water and surface-water, the goal of EPD will be to evaluate the effect of the proposed water use on existing users, and issue the new permit in such a way that the new permit will not adversely impact the water available to existing users. This evaluation may result in EPD issuing a permit for less than the applicant requested; requiring the applicant to use a different aquifer than requested; requiring the applicant to drill in a different location to avoid causing drawdown in an existing permitted well or unacceptable impacts on an adjacent stream or surface-water withdrawal point; and imposing more stringent low-flow protection requirements on surface-water users than are currently recommended (such as protecting a flow higher than 7Q10 or other appropriate tabulations of low flow characteristics.)

Because of the variable characteristics of the Floridan aquifer, there may be parts of the FRB in which ground-water withdrawals have no significant impact on nearby users or on stream flow. In these areas, permits should be issued as requested by the applicant as long as all other requirements are met (such as proof of ownership, conservation measures, etc.).

3. Newly issued permits in the FRB (i.e. those issued after January 1, 2006 regardless of when an application was submitted) will require an economically feasible, state-of-the-art conservation plan that reduces the volume of water withdrawn, used, or applied as a condition of the permit. Such plans may include end-gun shut off switches, rain-gauge shut-off systems, and leak repair. Applicants and EPD shall refer to conservation measures recommended by the University of Georgia Cooperative Extension Service or the Georgia Soil and Water Conservation Commission.

In the event that a required conservation plan is not being followed, the permittee will be issued a notice of violation requiring correction of the problem and compliance with the conservation plan in such a way that irrigation during a growing season is not interrupted. However, the violator will have his or her permit suspended if the problem is not corrected before the next growing season.

4. If irrigation is decreased during a drought year by 20% of current use in Ichawaynochaway Creek and lower Flint River sub-basins, critical low-flow criteria will be met. If irrigation is decreased during a drought year in the Spring Creek sub-basin by 20%, it is assumed this will have a beneficial affect on water levels and stream ecology even though critical low-flow criteria may not be met. This will require application of the Flint River Drought Protection Act in such a way that enough irrigated acreage is temporarily converted to dry-land acreage, which can be done either through the voluntary auction process or non-voluntary irrigation suspension with compensation as defined by State law.

5. For new permit applications, EPD will require proof of ownership or a lease before a letter of concurrence is issued to the applicant. EPD will also require accurate

latitudinal/longitudinal, coordinates of a proposed well or surface-water pump location to be included on the permit application.

6. All existing permits known to be duplicate permits will be revoked by EPD. All existing permits for which initial use of water has not commenced will be considered null and void, and revoked.

2.9 Stakeholder recommendations for regulatory and statutory reform

In addition to recommendations for permitting strategies that could be enacted under current statutes and rules, the SAC recognized the need for changes to those statutes and Rules that would result in better management of water resources. Specifically:

1. In order to minimize or eliminate speculative farm-use permit applications, EPD should charge a permit application fee of $250. This money should be dedicated to assisting management of agricultural water use or as an incentive for conservation, and should not be put into the State general fund.

2. For existing permits, those that are 'grandfathered' as defined by the Water Quality Act and Groundwater Use Act should be exempt from being modified in any way in order to provide new users with sufficient water.

3. For declared drought years, the Flint River Drought Protection Act should be modified to allow focus on individual sub-basins, including areas with critical habitats that are host to endangered species:

a. Upper Flint
b. Middle Flint
c. Kinchafoonee-Muckalee Creeks
d. Lower Flint
e. Ichawaynochaway Creek

targeting would require stat'ory
Δ

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a. Upper Flint
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c. Kinchafoonee-Muckalee Creeks
d. Lower Flint
e. Ichawaynochaway Creek

f. Spring Creek

4. Funding for the Flint River Drought Protection Act should be expanded and assured beyond its current limits such funding is available to pay higher per-acre prices for suspension of irrigation. This would allow the State to suspend irrigation on high-water use lands as opposed to marginal farmland; increase the likelihood of taking more land out of irrigation; allow the EPD Director to require non-voluntary suspension of irrigation with fewer challenges; and offset the direct and indirect costs of reducing irrigation.

5. Ground-water users should be included in the FRDPA, at the same payment rates as surface-water users, where the best available science indicates that they would directly impact stream flow.

6. Future permitting decisions, policing, review, etc. should be made at a local level, such as by a regional water management district or authority similar to those operating in other states.

7. The state should consider subsidies for conversion of permits from surface-water to ground-water, as this may be a cost effective way to maintain adequate streamflow in some areas.

8. The state should consider using existing wells or installing and operating wells during extreme droughts to supplement the flow in Spring Creek and other tributaries to maintain streamflow and protect endangered species.

9. The statutory requirement that EPD "shall" issue all new permits should be re-evaluated in order to protect existing users and the resource.

10. Alternatives to issuing permits based on rated pump capacity should be explored.

sediments of the Claiborne Formation (Georgia Geologic Survey, 1976; McFadden and Periello, 1983). These **formations** comprise aquifers at depth, and are only **recharged** in the fall line Hills area where they are near the land surface (Davis et al, 1989).

The Clayton aquifer consists of Clayton Formation limestone exposed in stream valleys of the upper Ichawaynochaway and Muckalee sub-basins, but its exposed recharge area is very small (McFadden and Periello, 1983; Davis et al, 1989). This, combined with an increase in irrigation pumping which began in the late 1970's, caused dramatic declines in water levels of the Clayton aquifer. For this reason, no additional permits are being issued in the Clayton aquifer and water-levels have stabilized.

The Claiborne aquifer consists mostly of saturated sands of the Tallahatta Formation. In those areas where the Claiborne is relatively shallow, it is a viable alternative aquifer to the Floridan, although well yields rarely if ever match those of Floridan aquifer wells (McFadden and Periello, 1983). The Claiborne has a much larger recharge area than the Clayton, and has not experienced long-term potentiometric declines like the Clayton aquifer.

The southern half of the basin is underlain by the Ocala Limestone, a fossil-rich limestone that is the main water-bearing unit of the Floridan aquifer. The up-dip extent of the Ocala Limestone coincides with the approximate northwestern limit of the Dougherty Plain and Subarea 4. Thickness of the Ocala ranges from 0 ft at its up-dip boundary, to more than 300 ft along the southeastern side of Subarea 4 (Miller, 1986; Torak and others, 1993). Intensive weathering of the Ocala Limestone and the formations that once overlaid it has generated an extremely uneven upper surface of the remaining limestone, and a highly variable thickness of the weathered material that mantels the limestone (Hayes et al, 1983; Hicks and others, 1987). This **residuum** typically has a clay layer directly overlying the limestone, which locally acts as the upper semi-**confining unit** to the Floridan, although under most of Subarea 4 the Floridan functions as an unconfined or semi-**confined aquifer** (Miller, 1986: Torak and McDowell, 1996). Where present, the upper clay layer ranges from less than 5 ft thick to more than 50 ft thick in the down-dip parts of the FRB. Above the clay layer is sandy-clay residuum of higher **permeability** that transmits precipitation to the underlying Floridan aquifer. In most of the FRB, the Floridan aquifer is confined below by low-permeability sediments of the Lisbon Formation (Wagner and Allen, 1984; Torak and McDowell, 1996).

The Floridan aquifer receives annual recharge directly from seepage through the overlying residuum, and through the numerous and extensive sinkholes in Subarea 4 (Torak and McDowell, 1996). Like streams in the area, aquifer heads are highest in late winter and early spring due to direct and rapid recharge, low usage, and low **evapotranspiration**. The lowest seasonal levels of the Floridan aquifer occur in middle to late autumn (Fig. 3.4). If normal rainfall follows the periods of lowest stream and aquifer levels, the aquifer recharges to levels comparable to those of the previous year (Groundwater Conditions in Georgia, USGS annual report). This suggests that, in some parts of Subarea 4, the Floridan aquifer is semi-confined. It also reflects the extremely permeable nature of the sandy residuum above the Ocala Limestone.

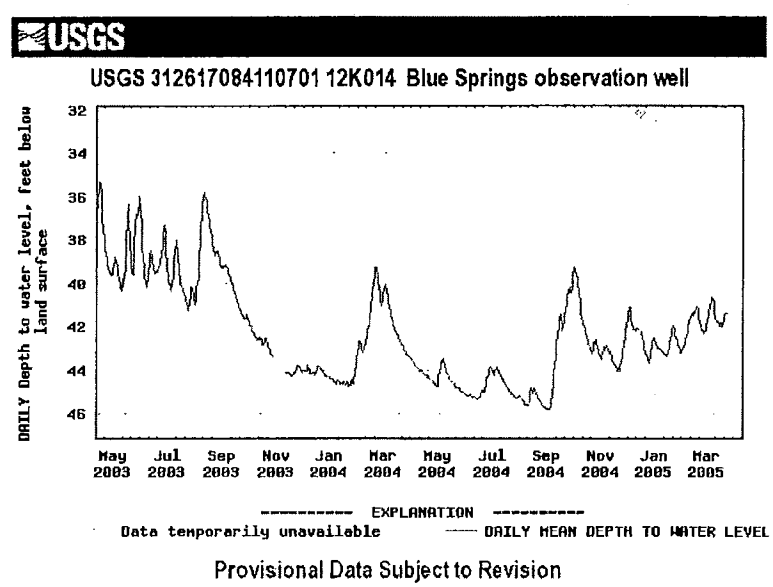


Figure 3.4: Hydrograph of well in Floridan aquifer in Subarea 4, showing typical seasonal variations in water level.

In most areas, the Floridan aquifer is a very prolific source of water because it has abundant cavities and fractures, widened by naturally acidic ground-water. For this reason, **transmissivity** values of the Floridan aquifer range from 2,000 to 1,300,000 ft^2/day (Torak and McDowell, 1996). Transmissivity values decrease towards the northern Subarea 4 boundary and the northwestern extent of the Floridan aquifer (Torak and McDowell, 1996) where aquifer yields will not support irrigation pumping. Yields are highest in the south and in areas adjacent to streams (Maslia and Hayes, 1988).

Because the Floridan aquifer is so highly transmissive and fractured, large ground-water withdrawals do not form deep cones of depression as in sandy, less transmissive aquifers. Instead, cones of depression in the Floridan aquifer are broad and shallow, and may be distorted by fracture zones into irregular or elongated shapes. Furthermore, withdrawals from the numerous irrigation wells in the Dougherty Plain region rarely create individual cones of depression (Torak, 1993). Because of the close spacing of the wells, their cones of depression overlap to create a regional lowering of the **potentiometric surface** rather than local declines adjacent to pumping wells (Torak and McDowell, 1996).

The high transmissivity and storage of the Floridan aquifer also causes rapid recovery of aquifer levels in many places. In other words, when pumping is initiated, there may be a rapid drawdown around the pumping well, but when the pumping ceases there is an equally rapid recovery as water flows quickly back into the area around the well with only a slight change in aquifer storage that is observed as a slight decline in static ground-water level (Fig. 3.5).

ATTACHMENT 5

USGS

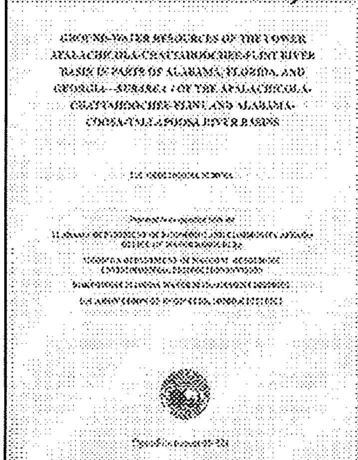
Water Availability and Competing Demands

Southwest Georgia Sound Science Initiative

Lynn J. Torak, Hydrologist

125 years of science for America ★ ★ ★ ★ ★ 1879—2004

Diversity and Complexity of Tasks– Subarea 4 Study, Torak and McDowell, OFR 95-321, 1996


GROUND-WATER RESOURCES OF THE LOWER APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN IN PARTS OF ALABAMA, FLORIDA, AND GEORGIA—SUBAREA 4 OF THE APALACHICOLA-CHATTAHOOCHEE-FLINT AND ALABAMA-COOSA-TALLAPOOSA RIVER BASINS

USGS

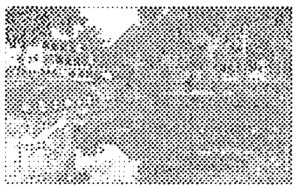
MODFE simulations

- Stream-aquifer interaction in Upper Floridan aquifer (limestone)
- Flow-system response to increased pumpage with streamflow variation
- Detailed water budgets for streams
- Identified pumpage effects on flow to Apalachicola River and Bay ecosystem
- October 1986 conditions
- Predicted that the Flint River would go dry!!!

Improving Understanding of Ground-Water and Surface-Water Relations

USGS

Stream-Aquifer Relations and the Potentiometric Surface of the Upper Floridan Aquifer in the Lower Apalachicola–Chattahoochee–Flint River Basin in parts of Georgia, Florida, and Alabama, 1999–2000

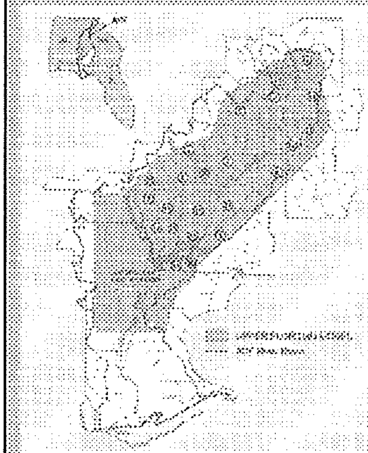


- Mosner, USGS WRIR 02-4244, 2002
- Comprehensive data collection, October 1999, April and August 2000; drought conditions
  - Ground-water levels–324 wells
  - Streamflow–74 gaging stations
  - Springflow–12 springs
  - Rainfall–4 weather stations
- Identified gaining/losing reaches; estimated gw seepage to streams; mapped water-level surface of Upper Floridan aquifer

USGS

USGS-0020260

Effects of Hydrologic Variability and Seasonal Ground-Water Withdrawal on Stream-Aquifer Relations, 1999-2005

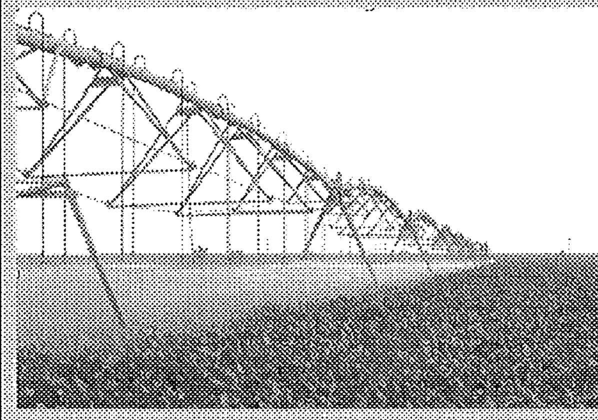


Field Data Collection—Well drilling and aquifer testing: 23 Sites

- Improve understanding of aquifer properties
- Fill data gaps prior to new model development
- Provide input to new MODFE model of growing season conditions

USGS

"...Lower ACF River Basin Study"

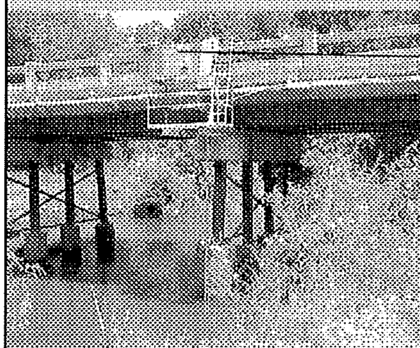


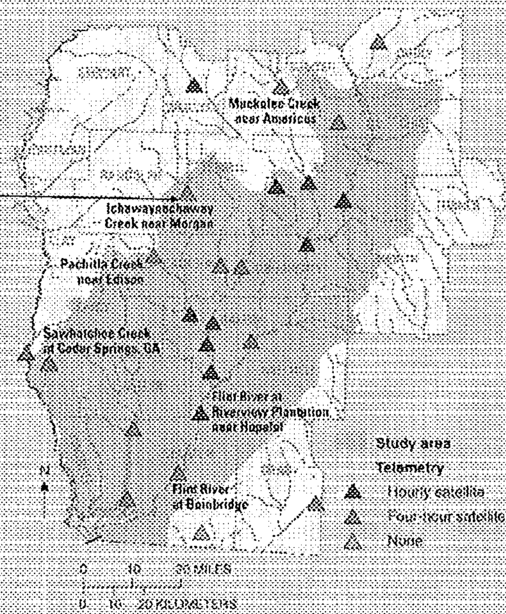
- Ag Water PUMPING II Study
- Real-Time Center-Pivot and Irrigation-System Monitoring
- Develop inputs to MODFE growing-season model
- Collaboration with the University of Georgia, College of Agriculture and Environmental Sciences, National Environmentally Sound Production Agriculture Laborabory, Tifton, Ga.

USGS

"...Lower ACF River Basin Study"

- Improve streamflow monitoring

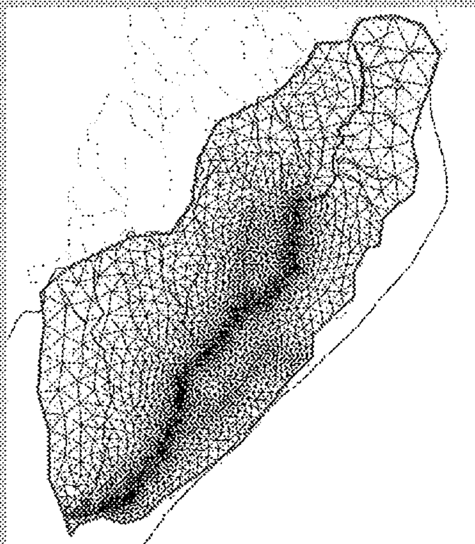




USGS

125 years of science for America 1879—2004

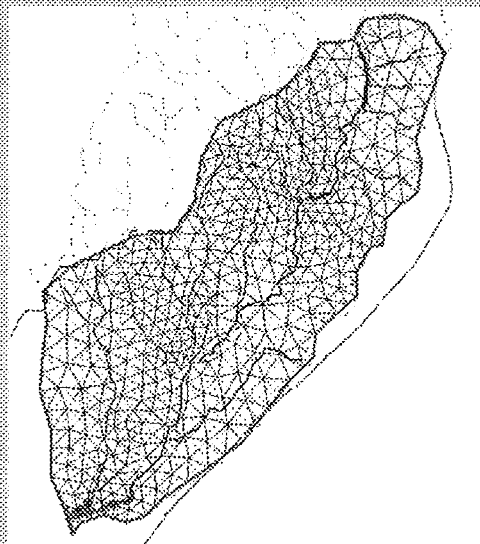
"...Lower ACF River Basin Study"



- Develop automated mesh-generation and model-input techniques
- Evaluate effects of irrigation pumpage on streams and aquifer

USGS

"...Lower ACF River Basin Study"



- Simulation of transient, growing-season pumpage and stream-aquifer interaction using USGS model MODFE
- Lower ACF River Basin in Georgia and parts of Florida and Alabama

USGS

ATTACHMENT 6

September US release: Thu, 6 Oct 2016, 11:00 AM EDT

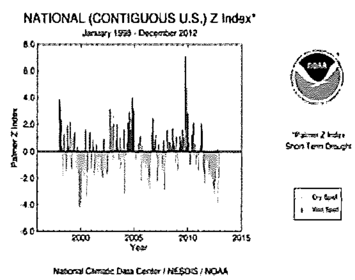
Drought - Annual 2012

NCEI added Alaska climate divisions to its nClimDiv dataset on Friday, March 6, 2015, coincident with the release of the February 2015 monthly monitoring report. For more information on this data, please visit the Alaska Climate Divisions FAQ.

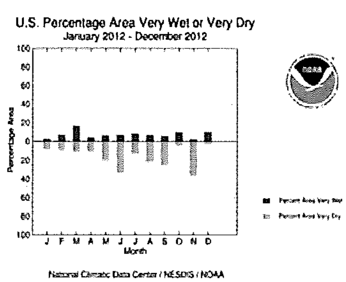
Issued 8 January 2013

The data presented in this drought report are preliminary. Ranks, anomalies, and percent areas may change as more complete data are received and processed.

Contents Of This Report:



National Drought Overview



On a month-by-month basis, 2012 was characterized by large areas of dry and, earlier in the year, large areas of wet weather. Eight months (all except January, February, October, and December) had ten percent or more of the country experiencing very dry (at the tenth percentile of the historical record or drier) precipitation anomalies, with five months (May, June, August, September, and November) having more than a fifth (20 percent) of the country very dry. June and November had a third of the country very dry. The percent area very wet (monthly precipitation totals at the 90^{th} percentile of the historical record or wetter) stayed under ten percent for all but one of the months in the year, with March having the largest percent area very wet (16%). When averaged together, the wet and dry anomalies resulted in the 20^{th} driest February, 23^{rd} driest May, 10^{th} driest June, 22^{nd} driest July, and 8^{th} driest November, nationally, in the 1895-2012 record. Large areas of the country also experienced unusually warm conditions. Ten percent or more of the contiguous U.S. was very warm (monthly temperatures at the 90^{th} percentile of the historical record or warmer) during every month except October. More than a fourth (25%) was very warm during eight months, with July (60%) and March (75%) having more than half of the country very warm. This persistent and anomalous heat resulted in the warmest month ever (July 2012), ranked 2012 as the warmest year on record, and (especially during the growing season) increased evaporation and intensified local drought conditions.

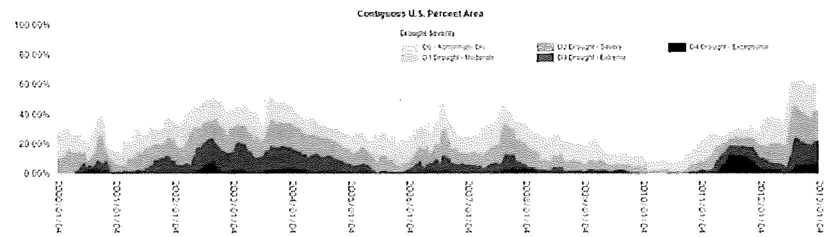
An important feature of the weather conditions in 2012 was the persistence of the areas of dryness and warm temperatures, the magnitude of the extremes, and the large area they encompassed. Dry weather affected parts of the West almost every month, especially the Intermountain Basin during April-July, the Southwest during April-June and October-November, and the Rockies during March-November. The Central Great Plains were plagued by dryness much of the year (especially March-November), with dryness especially acute during the summer across the Plains (June-August). Dry weather dominated across the Central Plains to Midwest agricultural areas during the critical May-July growing season, but the dryness lasted longer in parts of this region (for example, the Midwest during February-July). August-September saw very dry weather from the Pacific Northwest, across the Northern Rockies and Central to Northern Plains, and into the western Great Lakes. Dry weather afflicted the eastern U.S. early in the year, with the Southeast dry during January-April and the Northeast during February-April. Large areas of the country were very dry during May-June (from the West Coast to the Ohio and Tennessee valleys), August-September (from the Pacific Northwest to the western Great Lakes), and November (from the Southwest and Southern Plains to the Northeast and Southeast).

The hot temperatures exacerbated the impact of the dry weather. When maps of the dryness (Standardized Precipitation Index [SPI]) are compared to maps of the Palmer Z Index (which incorporates the effects of both dryness and heat), larger areas of monthly drought are evident on the Z Index maps for March (SPI, Z Index), April (SPI, Z Index), May (SPI, Z Index), July (SPI, Z Index), and November (SPI, Z Index).

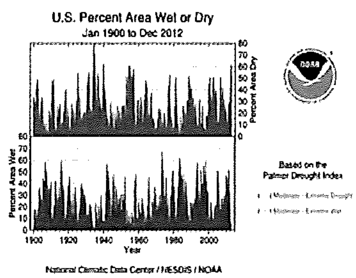
2012 Standardized Precipitation Index maps:	2012 Standardized Temperature Index maps:	2012 Palmer Z Index maps:
• January,	• January,	• January,
• February,	• February,	• February,
• March,	• March,	• March,
• April,	• April,	• April,
• May,	• May,	• May,
• June,	• June,	• June,
• July,	• July,	• July,
• August,	• August,	• August,
• September,	• September,	• September,
• October,	• October,	• October,
• November,	• November,	• November,
• December.	• December.	• December.

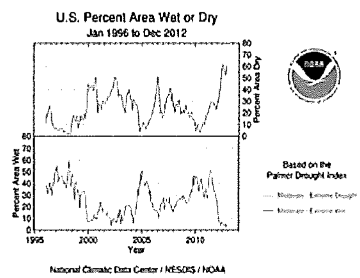
2012 U.S. Drought Monitor maps:	2012 Palmer Drought Severity Index maps:
• January,	• January,
• February,	• February,
• March,	• March,
• April,	• April,
• May,	• May,
• June,	• June,
• July,	• July,
• August,	• August,
• September,	• September,
• October,	• October,
• November,	• November,
• December.	• December.

The year started out with 31.9 percent of the contiguous U.S. in moderate to exceptional drought (based on the U.S. Drought Monitor [USDM]) manifested in two drought epicenters — areas of moderate to exceptional drought in the Southern Plains and moderate to extreme drought in the Southeast — with areas of moderate to severe drought in the Upper Mississippi Valley and moderate drought in the Far West. As the year progressed, the western drought expanded to link with the Southern Plains drought area and new drought areas developed along the East Coast, pushing the national drought area to 38.2 percent by May 1. Dryness during the late spring began to take its toll in the agricultural heartland by summer as drought intensified and expanded to cover much of the country from the Central Rockies to the Ohio Valley, and the Mexican border to the Canadian border, by the end of August. This solid mass of drought, which stretched from border to border and (by now) West Coast to Mississippi River, persisted through the fall. The percentage area in drought peaked at about 65.5 percent on September 25 (a new high in the 1999-2012 USDM record) and ended the year at 61.1 percent. The percent area of the contiguous U.S. in the worst drought categories (D3-D4, extreme to exceptional drought) peaked at 24.1 percent on August 7, which is also a record.



The percent area* of the contiguous U.S. experiencing moderate to extreme drought (based on the Palmer Drought Index) started the year at about 22.9 percent, grew steadily to a peak of about 61.8 percent during the summer, then contracted slightly during the fall, ending the year at about 51.8 percent. The Palmer Drought Index data go back 113 years.

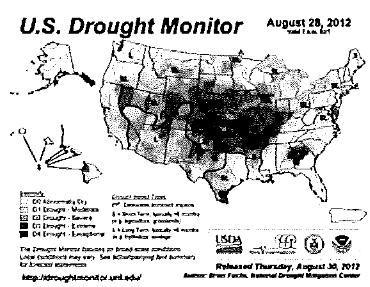




*This drought statistic is based on the Palmer Drought Index, a widely used measure of drought. The Palmer Drought Index uses numerical values derived from weather and climate data to classify moisture conditions throughout the contiguous United States and includes drought categories on a scale from mild to moderate, severe and extreme.

[top]

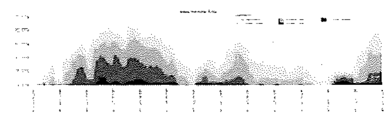
Regional Drought Overview



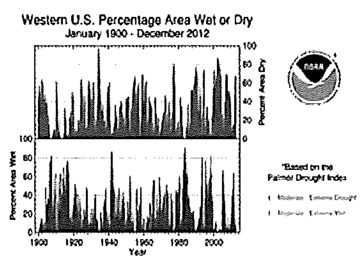
The year began with drought epicenters in the Southern Plains, Southeast, Upper Midwest, Far West, and Hawaii. As winter ended and spring began, dryness in the West spread to join the Plains and West drought areas while the Southeast drought crept up the East Coast. The spring months were quite dry with drought spreading or pockets of drought developing in several regions. The summer months were extremely dry across a large part of the central U.S., with the result being a merging of the drought epicenters in the West, Plains, and Midwest into one large drought area stretching from the West Coast to the Great Lakes. Beneficial autumn rains helped portions of the Midwest recover from drought, but dryness continued in the Plains where drought intensified. By the end of 2012, three drought epicenters remained — Hawaii, the Southeast, and one large area of drought stretching from the southern California coast across the West and Great Plains to the Midwest, with the worst drought conditions focused on the Plains states.

The dry weather (which lowered moisture supplies), coupled with intense spring and summer heat (which increased evapotranspiration and, thus, moisture demand), depleted soil moisture, lowered streamflow (May, June, July, August), reservoir and stock pond levels, and ravaged crops and livestock. By year's end, low river levels threatened commerce on the vital Mississippi River shipping lanes.

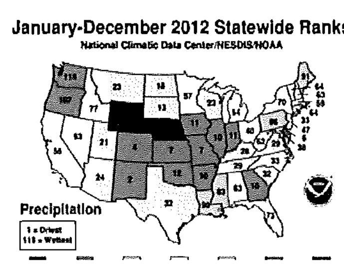
West:

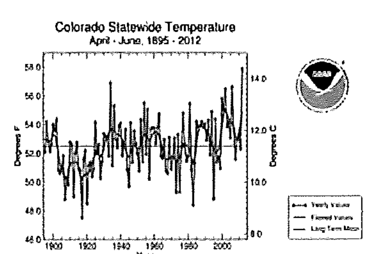

The percent area of the West in moderate to exceptional drought steadily grew during 2012, peaking at 77% in October.

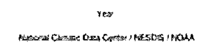
The West began the hydrologic year (water year, October-September) on a dry note, with below-normal precipitation and snowpack water content. As the wet season (October-April) ended, the southern portions of the West had significant precipitation and snow water content deficits, while the northern areas were not as bad off. Continued dryness and intense heat during the spring and summer caused numerous wildfires to break out, with Colorado especially hard hit. Record heat and near-record dryness occurred in the state, with April-June 2012 ranking as the hottest and third driest April-June on record. Wyoming was record dry for several time scales, including June-August, April-August, March-August, June-September, May-September, April-September, and several others. Utah was record dry in June and April-June. A total of four states (Colorado, Nevada, Utah, Wyoming) ranked in the top ten driest category for April-June, six states were in the top ten driest for January-June, and three for January-November, including Colorado and Wyoming (which were record dry) and New Mexico (second driest). The weather pattern shifted during summer and early autumn, bringing much-needed precipitation to the southern areas but drying out the northern states. Five western states (Idaho, Montana, Oregon, Washington, Wyoming) ranked in the top ten driest category for July-September, with Montana having the driest August-September and July-September on record. When last year's dryness is combined with this year's dryness, the last two years (December 2010-November 2012) in New Mexico ranked as the driest such 24-month period on record. For January-December 2012, three states (Wyoming [driest], New Mexico [second driest], Colorado [fourth driest]) ranked in the top ten driest category and three other states (Arizona, Montana, Utah) ranked in the driest third of the historical record.

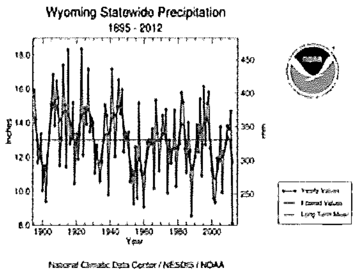


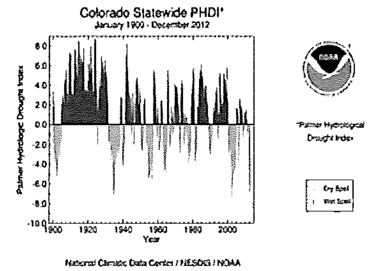
The percent area of the West in moderate to exceptional drought, as measured by the USDM, steadily grew during 2012, peaking at about 77.2 percent in October. Based on the Palmer Drought Index, which goes back to the beginning of the 20th century, moderate to extreme drought peaked at about 67.2 percent of the West during June. Both of these numbers were surpassed by the 2002-2003 drought and (for the Palmer index) earlier droughts.



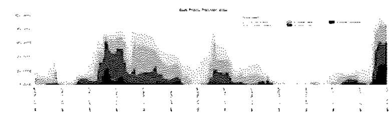








Great Plains and Midwest:

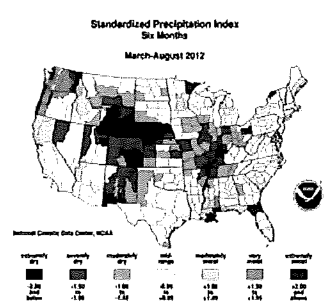


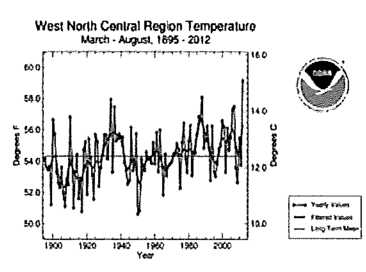
The percent area of the High Plains (Kansas to North Dakota) in moderate to exceptional drought skyrocketed during summer 2012, covering nearly the entire High Plains region by October.

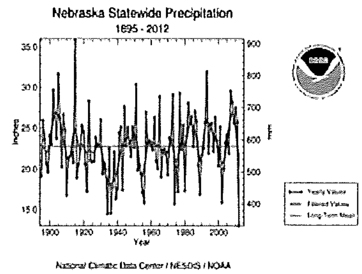
Last year, drought was centered in the Southern Plains. This year, the entire Plains region was afflicted by drought with a significant part of the Midwest sharing the misery. Dryness affected the Northern Plains during March, the Southern Plains during April, and the Southern to Central Plains during May, with different portions of the Midwest affected during each of those months. But that was just a prelude to even worse conditions. The entire Plains and Midwest were baked and moisture-starved during June and July. Beneficial rains came to parts of the Midwest and Southern Plains during August and September, and to the Northern Plains and Midwest in October, but widespread dry conditions returned in November.

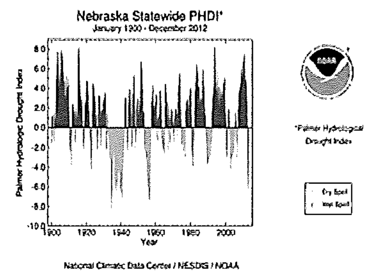
Record dryness occurred for several states in August and September. The persistence of drought gave several states record dry seasons, including Arkansas (April-June and other seasons), Kansas (May-July), Nebraska (June-August and other seasons), and South Dakota (July-September). Six states in the Plains and Midwest (Arkansas, Indiana, Iowa, Kansas, Missouri, Nebraska) ranked in the top ten driest category for January-November, with Nebraska having the driest January-November on record. For January-December 2012, five Great Plains and Midwest states ranked in the top ten driest category, including Nebraska which had the driest year on record.

The percent area of the Great Plains and Midwest in moderate to exceptional drought, as measured and defined by the USDM regions, rapidly increased during 2012. Nearly all of the Northern Plains was enveloped in drought by October, which is a record in the 13-year USDM history. Drought coverage also rapidly increased in the Midwest, peaking at about 73.7 percent in July, which is also a USDM record. In early 2012, the Southern Plains was recovering from the 2011 drought. The percent area in moderate to exceptional drought decreased to a low of about 32.3 percent in May 2012 before expanding again to peak at about 73.7 percent in July.

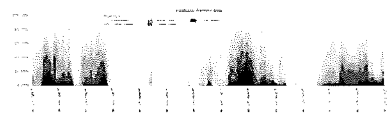






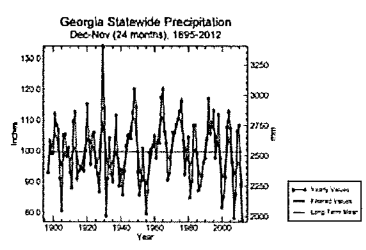


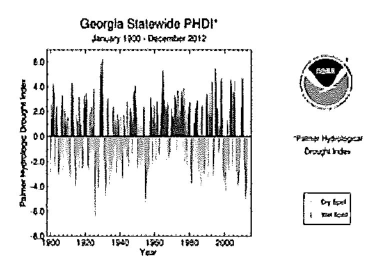
Southeast to Northeast:


The percent area of the Southeast in moderate to exceptional drought oscillated up and down during 2012.

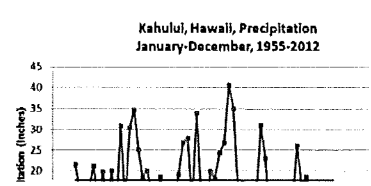
The precipitation pattern for the eastern U.S. fluctuated between wet and dry during 2012. The Southeast started the year on the dry side, with January-February ranking in the driest third of the historical record for several states. February-April was dry for the Northeast, with Connecticut having the driest February-April on record and most other states ranking in the top ten driest category. Three southeastern states (Alabama, Georgia, and Tennessee) ranked in the top ten driest category for April. The weather patterns, which brought drought to the Great Plains and Midwest during the late spring and summer, doused many of the eastern states with beneficial rainfall during this time. Although helpful, the rains were not enough to erase several years' of deficits in the Southeast. November was dry for all eastern states, with most ranking in the top ten driest category. The cumulative impact of the 2012 precipitation deficits gave Delaware the fourth driest January-November and Georgia, the epicenter of the Southeast drought, the eighth driest January-November. For the year (January-December), several states along the eastern seaboard were drier than normal, with Georgia ranking tenth driest and Delaware having the sixth driest year on record. The prolonged dryness in parts of the Southeast gave Georgia the driest December-November 24-month period (December 2010-November 2012) on record.

Parts of the Southeast have been in drought for the last two years. The percent area of the Southeast in moderate to exceptional drought, as measured by the USDM, hovered around 50 to 65 percent during the first five months of the year, then contracted during the summer and fall before expanding again at the end of the year. It peaked at about 69 percent at the beginning of May.

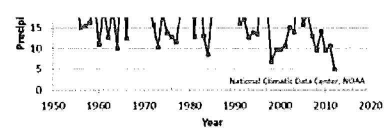




Hawaii and other Pacific Islands:

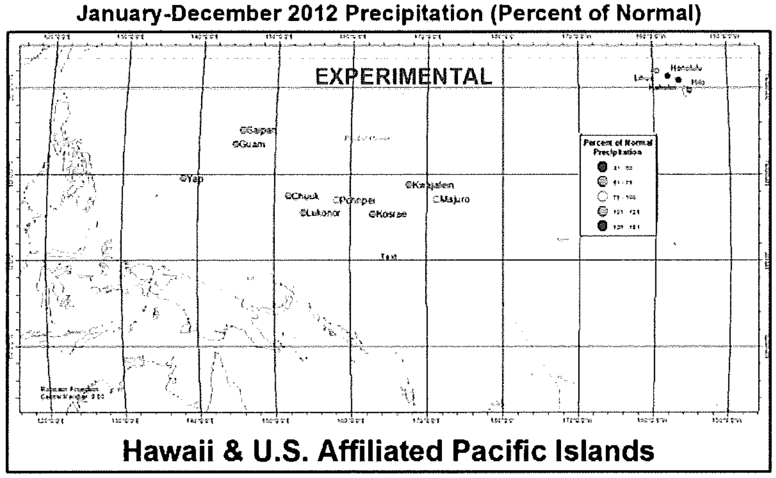


Drought in Hawaii was resurgent in 2012, with 47.4 percent of the state affected by moderate to exceptional drought on January 3, growing to 73.2 percent by December 4. The state has



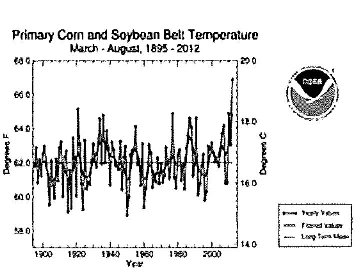
been in drought for the last four years, with the December 4, 2012 peak approaching the peaks of 2008-2010. Several locations had record to near-record dry conditions in 2012, with Kahului recording the lowest rainfall for the year based on data from 1955-2012, and Honolulu having the fifth driest and Hilo eighth driest year in their 1950-2012 records. Annual rainfall at other U.S.-affiliated Pacific Island stations during 2012 was near or above normal.

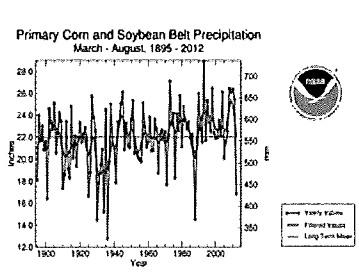
January-December 2012 Precipitation (Percent of Normal)

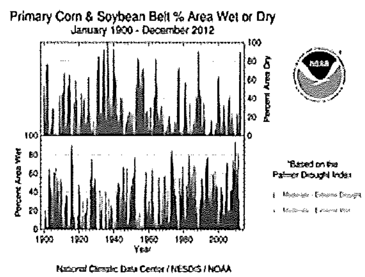


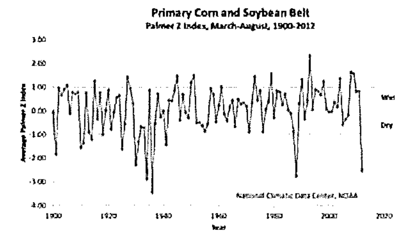
Agricultural Belts:

The spatial pattern of drought this year closely overlaid the agricultural area of the U.S. heartland, and the excessive temperatures and lack of rain during the critical growing season severely reduced corn and soybean crop yield. The Primary Corn and Soybean agricultural belt, collectively, experienced the warmest and seventh driest March-August in 2012, resulting in the fourth most severe Palmer Z Index for the season (behind 1936, 1934, and 1988). The extreme severity of the dryness and evapotranspiration demand over the growing season resulted in a rapid increase in the percent area of this agricultural belt experiencing moderate to extreme drought (as defined by the Palmer Drought Index) and moderate to exceptional drought (for the Midwest and High Plains as defined by the USDM). By August 2012, about 89.3 percent of the Primary Corn and Soybean Belt was experiencing moderate to extreme drought (based on the Palmer Drought Index), surpassing all previous droughts except those in 1988 and the 1930s. The August-October rains in the eastern part of this region were beneficial and helped reduce the intensity of the drought there, but they did little to shrink the overall drought area for the entire region, with the value down to only 54.9 percent by the end of the year. By year's end, January-December 2012 ranked as the tenth driest year on record.

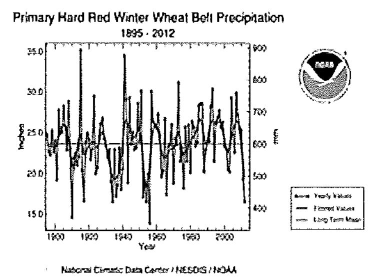




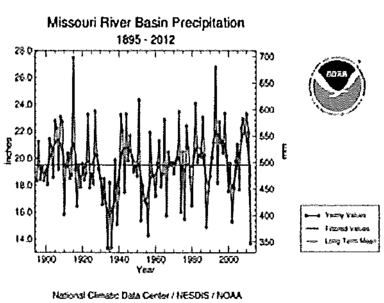


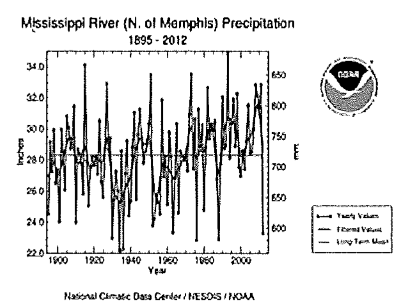


The growing season (October-April) has started out on a dry note for much of the Winter Wheat agricultural belt. October-December 2012 ranked as the 27th driest October-December in the 1895-2012 record, with November 2012 ranking as the 13th driest November. For the smaller Primary Hard Red Winter Wheat belt, November 2012 ranked 23rd driest and October-December tenth driest. By year's end, January-December 2012 ranked as the ninth driest year on record for the Winter Wheat belt and third driest for the Primary Hard Red Winter Wheat belt.



River Basins:





Several river basins have experienced unusually dry conditions during 2012, with the Upper Colorado having the driest year in the 1895-2012 record. As noted by the Midwest Regional Climate Center, drought has contributed to low water issues from the Great Lakes to the Missouri and Mississippi rivers, with navigation on the Mississippi River continuing to be a concern through December. The Missouri

2012 Precipitation Ranks (out of 118 years) for the Major River Basins in the Contiguous U.S.: Calendar Year (January-December) and Water Year to Date (October-December)

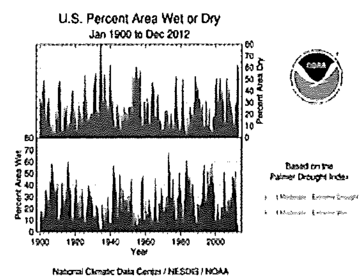
RIVER BASIN	JAN-DEC	OCT-DEC
Pacific Northwest	11th wettest	10th wettest
California	56th driest	36th wettest
Great Basin	41st driest	35th wettest
Lower Colorado	24th driest	33rd driest
Upper Colorado	driest	29th driest

River basin had the third driest year in 2012 (behind 1934 and 1936), the Arkansas-White-Red River basin had the ninth driest year, and the Upper Mississippi and Rio Grande both ranked tenth driest. For the Mississippi River and all of its tributaries north of Memphis, Tennessee, 2012 ranked as the sixth driest year on record (behind 1934, 1936, 1976, 1988, and 1930). The aggregate PDSI for the Missouri basin reached the lowest value since the 1950s, while the aggregate PDSI for the broader Mississippi and its tributaries was the lowest since only 1988.

Rio Grande	10th driest	5th driest
Texas Gulf Coast	41st driest	4th driest
Arkansas-White-Red	9th driest	11th driest
Lower Mississippi	48th driest	35th driest
Missouri	3rd driest	37th driest
Souris-Red-Rainy	35th driest	31st wettest
Upper Mississippi	10th driest	59th driest
Great Lakes	54th driest	26th wettest
Tennessee	38th driest	59th driest
Ohio	27th driest	55th wettest
South Atlantic-Gulf	53rd driest	46th driest
Mid-Atlantic	46th driest	37th wettest
New England	38th wettest	38th wettest

Historical Analogs:

As seen in the National Drought Overview section, the percent area of the contiguous U.S. experiencing moderate to exceptional drought (based on the USDM) reached 65.5 percent in September, a record in the 13-year USDM history. The percent area of the contiguous U.S. experiencing moderate to extreme drought, based on the Palmer Drought Index (which goes 113 years), peaked at about 61.8 percent in July. This is only slightly larger than the peak percent area values of the 1950s drought decade and is the largest value since December 1939. So, in terms of total area covered by drought, the 2012 drought closely resembles the 1950s droughts.



The geographical pattern (location and intensity of dryness) of the 2012 drought can be compared to the patterns of previous droughts by using statistical tools such as the correlation coefficient and mean absolute difference. In the two tables below, the 2012 climate conditions (Palmer Z Index, Palmer Hydrological Drought Index [PHDI], temperature [Temp], precipitation [Precip]) were compared two different ways. In the table to the left, each month (January-December) of 2012 was compared individually to the previous years (1900-2011) to find the year with the closest match to each individual month (January closest match to January 2012, and February closest match to February 2012, and March closest match to March 2012, etc.). In the table to the right, the 2012 annual average values were compared to the annual average values for each of the previous years. No consistent pattern in historical analogs can be found in the monthly comparison (left-hand table) due to normal month-to-month variability (climatic noise). However, when the month-to-month variability is averaged out (by computing annual values as in the right-hand table), a consistent pattern becomes evident — the drought years 1955 and 1956 are the closest historical analogs to the geographical pattern of drought in 2012, and 1998 (the second warmest year on record) and 2006 (third warmest year on record) are the closest historical analogs to 2012 for the spatial temperature pattern.

Top 5 Analog Years to 2012 (each month January-December compared individually)

Rank*	Z Index	PHDI	Temp	Precip
1	1966	**1955**	1991	1904
2	1974	**1956**	2006	1901
3	1901	1920	1921	1917
4	2002	1918	1946	1931
5	1988	1963	1990	1974

* Rank: 1 = most similar to 2012.

Top 5 Analog Years to 2012 (annual value compared)

Rank*	Z Index	PHDI	Temp	Precip
1	**1955**	**1955**	1998	**1955**
2	**1956**	**1956**	2006	1966
3	1988	2000	1921	**1956**
4	1933	2006	1999	1980
5	1939	1981	1931	1988

* Rank: 1 = most similar to 2012.

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Contacts & Questions

For additional, or more localized, drought information, please visit:

- The U.S. Drought Portal

Citing This Report

NOAA National Centers for Environmental Information, State of the Climate: Drought for Annual 2012, published online January 2013, retrieved on September 29, 2016 from http://www.ncdc.noaa.gov/sotc/drought/201213.

ATTACHMENT 7

Georgia Department of Natural Resources

Environmental Protection Division, Watershed Protection Branch
4220 International Parkway, Suite 101, Atlanta, Georgia 30354
Linda MacGregor, P. E., Branch Chief
404/675-6232
FAX: 404/675-6247

Memorandum

TO: Allen Barnes

THRU: Jim Ussery

Linda MacGregor

Tim Cash

FROM: Wei Zeng and Inchul

Re: Year 2011 Flint River Drought I

Date: February 17, 2011

Extra copy - revised wells tracked + records - starting @ flagged page + on attached

The purpose of the memorandum is to summarize the 2011 status of the Flint River Basin drought monitoring for compliance with the Flint River Drought Protection Act of 2000 (O.C.G.A. 12-5-540). The Flint River Drought Protection Act requires the Director of EPD to declare, on or before March 1 of each year, whether severe drought conditions exist or are likely to exist during the upcoming agricultural growing season. The decision is to be made on the basis of historical, mathematical, and meteorological indicators, or other scientific considerations. The decision to declare a severe drought and to implement drought protection measures is to follow the procedures set forth under the Chapter 391-3-28 Rules.

Established Protocol

The Flint River Drought Declaration Matrix (Table 1) was developed under contract to USGS to provide a technical basis for declaration of a severe drought prediction. The matrix contains three groups of criteria: February in-stream flow at Flint River at Newton, USGS Gage #2353000 (hydrological – surface water), forecast of precipitation for March, April, and May made by NOAA (meteorological - precipitation), and February groundwater levels (hydrological - groundwater).

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Environmental Protection Division, Watershed Protection Branch
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Memorandum

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Date: February 17, 2011

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There are four thresholds within each group indicating various levels of dryness. For example, if the February monthly average flow at Flint River at Newton is greater than or equal to historical median, then Criterion 1 (the wettest condition in the Surface Water group) is satisfied. On the other hand, if the February monthly average flow at Newton is less than the corresponding monthly 7Q10 value, then Criterion 4 (the driest condition in the Surface Water group) is satisfied.

Similarly, forecasted March through May precipitation meeting Criteria 5 through 8 indicates worsening precipitation conditions, and February mean groundwater well levels meeting Criteria 9 through 12 indicates worsening groundwater conditions.

For a declaration of probable severe drought, there has to be a "Below Normal" precipitation condition (Criteria 7 or 8 in the Precipitation group) together with either a February in-stream flow at Newton below historical median condition (Criteria 2, 3, or 4 in the Surface Water group), or a predominance of groundwater well levels below historical mean condition (Criteria 10, 11, or 12 in the Groundwater group).

The combination of Criteria that would trigger the implementation of the Flint River Drought Protection Act is shown in a reformatted matrix as shown in Table 2.

Current Status

1. Surface Water

The average February 2011 (data through February 17, 2011) stream flow at Flint River at Newton is 8,908 cfs. The observed flow time series is shown in Fig. 1. The February 7Q10 (derived from data collected for period 1939 through 2011) at this location is 3,546 cfs. The 20% non-exceedance monthly-average flow at this location is 6,688 cfs (period 1939 through 2011). The median monthly-average flow at this location is 10,275 cfs (period 1939 through 2011). These threshold values are listed in Table 3. The recorded stream flow is higher than the monthly median average flow, which means **Criterion 2** for the Surface Water Group is satisfied.

2. Precipitation

On February 17, 2011, the National Oceanic and Atmospheric Administration (NOAA) (National Weather Service – Climate Prediction Center) issued its three-month precipitation outlook (Fig. 2). This outlook forecasted higher than 33% probability of lower than normal precipitation for most of the southwest Georgia for the period between March and May 2011. This satisfies **Criterion 7** in the Precipitation Group.

3. Groundwater

February 2011 groundwater well levels and groundwater thresholds (February mean and 5% non-exceedance levels) are listed in Table 4. These groundwater thresholds (statistics) were calculated based on data collected in the period from 1980 to 2011. The data show that all nine (9) wells have water levels that are lower than their respective mean values. None of the wells are lower than their respective 5% non-exceedance levels. This satisfies **Criterion 10** in the Groundwater Group.

Fig. 3 shows the location of these wells in the lower Flint River Basin. Figs. 4 through 12 show the groundwater levels of these wells since year 2008 with historical median levels from USGS. All but one of these wells have water levels lower than their respective medians.

Recommendation

Criteria 2, 7, and 10 show some amount of dryness in the region coupled with a forecast of lower than normal precipitation. However, this combination does not warrant a declaration of a probable severe drought in the Flint River Basin (See Tables 1 and 2) and consequent implementation of the Flint River Drought Protection Act. Figure 13 shows a drought condition classified as Moderate by the U.S. Drought Monitor.

Based on the information compiled from various sources and the analysis that we have conducted, we recommend against a severe drought declaration in the Flint River Basin and thus **no** implementation of measures per the Flint River Drought Protection Act for year 2011.

Table 1. Flint River Drought Declaration Matrix (Established)

			1	2	3	4	5	6	7	8	9	10	11	12
Surface Water February mean discharge (Q) at USGS gage 02353000-Flint River at Newton	Q(Feb) ≥50%	1												
	50% > Q(Feb) ≥20%	2								2,8				
	20% > Q(Feb) ≥7Q10	3							3,7	3,8				
	7Q10 > Q(Feb)	4							4,7	4,8				
Precipitation Projection for March, April, and May (90 days): Source: NOAA CPC Seasonal Forecast	"Above" with probability exceeding 33.3%	5												
	"Near Normal" or "Climatology"	6												
	"Below Normal" with probability between 33.3% and 53.5%	7											7,11	7,12
	"Below Normal" with probability exceeding 53.5%	8										8,10	8,11	8,12
Ground Water February mean water level in 50% or 75% of 9 USGS Upper Floridan monitoring wells	WL(75% of wells) ≥Feb. Mean WL	9												
	5% WL ≤WL(75% of wells) < Feb. Mean WL	10												
	WL(50% of wells) ≤5% WL	11												
	WL(75% of wells) ≤5% WL	12												

(shaded)	Drought Protection Act **not** implemented
(blank)	Drought Protection Act implemented

Table 2. Flint River Drought Declaration Matrix (Reformatted)

Flint River Drought Declaration Matrix (Part 1)			Surface Water: February mean flow (Q) at USGS Flint River Gage 02353000 - Flint River at Newton			
			Q(Feb) >= Median	Q(Feb) < Median and Q(Feb) >= 20%-tile	Q(Feb) < 20%-tile and Q(Feb) >= 7Q10	Q(Feb) < 7Q10
			1	2	3	4
Precipitation: Projection for "Above" or "Below" Normal Precipitation in March, Aapril, and May (Source: NOAA Climatic Prediction Center seasonal forecast)	"Above" with probability exceeding 33.3%	5				
	"Near Normal" or "Climatology"	6				
	"Below Normal" with probability between 33.3% and 53.5%	7			X	X
	"Below Normal" with probability exceeding 53.5%	8		X	X	X

Drought Protection Act NOT implemented
Drought Protection Act implemented

Flint River Drought Declaration Matrix (Part 1)			Groundwater: February mean water level in 9 USGS monitoring wells in the Upper Floridan Aquifer			
			WL (75% of wells) >= Feb. Mean WL	Feb. Mean WL >= WL (75% of wells) >= 5%-tile WL	WL (50% of wells) <= 5%-tile WL	WL (75% of wells) <= 5%-tile WL
			9	10	11	12
Precipitation: Projection for "Above" or "Below" Normal Precipitation in March, Aapril, and May (Source: NOAA Climatic Prediction Center seasonal forecast)	"Above" with probability exceeding 33.3%	5				
	"Near Normal" or "Climatology"	6				
	"Below Normal" with probability between 33.3% and 53.5%	7			X	X
	"Below Normal" with probability exceeding 53.5%	8		X	X	X

Drought Protection Act NOT implemented
Drought Protection Act implemented

Note: Flint River Drought Protection Act implemented by the combination of "Below Normal" precipitation outlook AND either a drier than normal surface water condition or a drier than normal groundwater condition, as denoted by a light yellow color and a check in the table.

Table 3. Surface Flows and Thresholds for Flint River Drought Declaration Matrix (Average Flow at Newton is at 8,908 cfs for February 2011) – Criterion 2 met

Type of Threshold	February 7Q10	February 20% non-exceedance	**February 2011**	Median February Flow
Flow Rate (cfs)	3,546	6,688	**8,908**	10,275

Note: 1. Feb 2011 surface flows data are updated to Feb 16th.
2. The statistics are derived with data starting year 1939

Table 4. Groundwater Well Levels and Thresholds for Flint River Drought Declaration Matrix – Criterion 10 met

Well #	**13L180**	**12M017**	**11K003**	**13J004**	**12K014**	**10G313**	**08K001**	**08G001**	**09F520**
February 2011 Ave. (ft)	**-53.3**	**-30.1**	**-28.6**	**-53.1**	**-43.7**	**-57.7**	**-13.7**	**-37.8**	**-49.2**
Historic Feb. Mean (ft)	-48.9	-28.2	-25.9	-46.7	-39.8	-52.5	-4.9	-26.6	-46.0
Historic Feb. 5% Recurrence level (ft)	-58.5	-33.6	-37.7	-54.4	-45.6	-58.7	-22.2	-41.2	-49.7

Note: 1. Feb 2011 groundwater wells data are updated to Feb 16th.
2. The statistics are derived with data since year 1980
3. When the February 2011 observed well level is lower than a threshold, that threshold is highlighted.

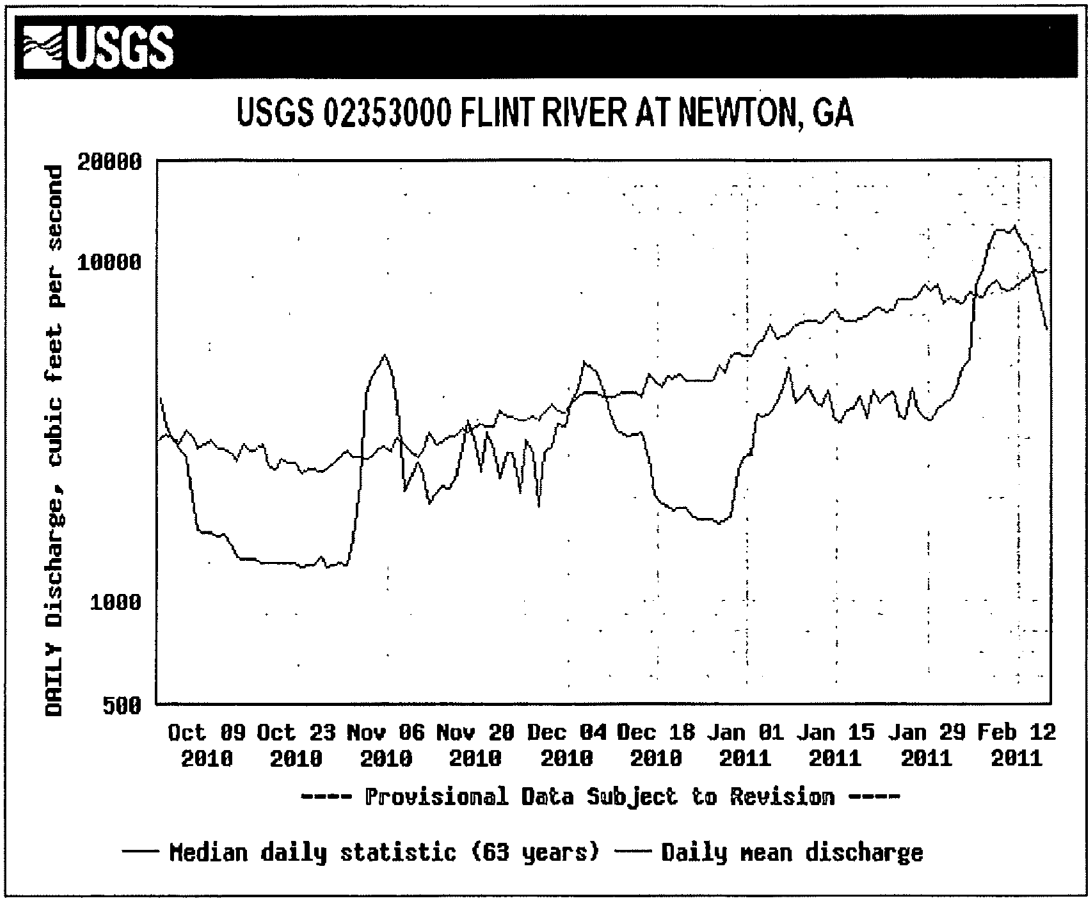


Fig. 1 Observed flow at Flint River at Newton, GA (USGS 02353000)

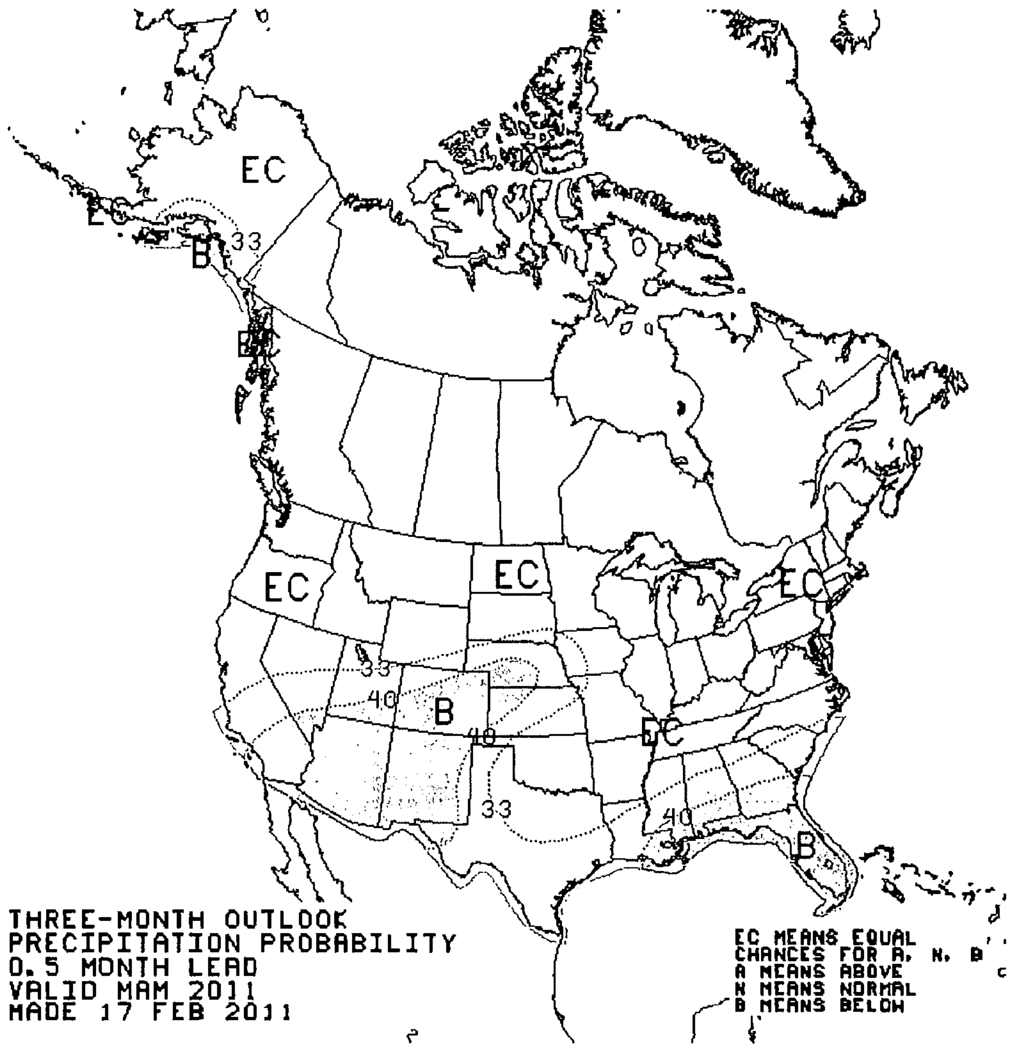


Fig. 2 NOAA precipitation out for the months of March, April, and May of 2011 for for Flint River Drought Declaration Matrix

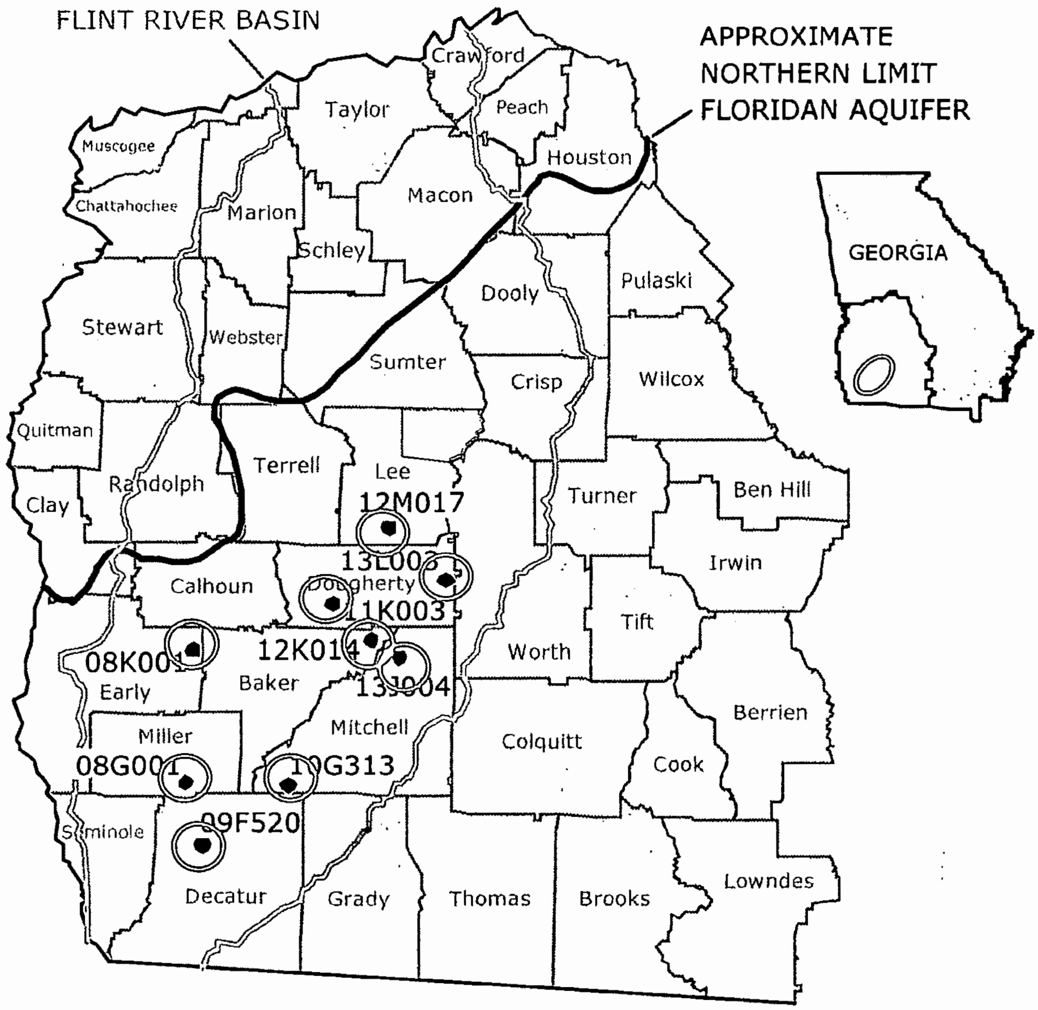


Fig. 3 Locations of the nine groundwater wells used in the determination matrix

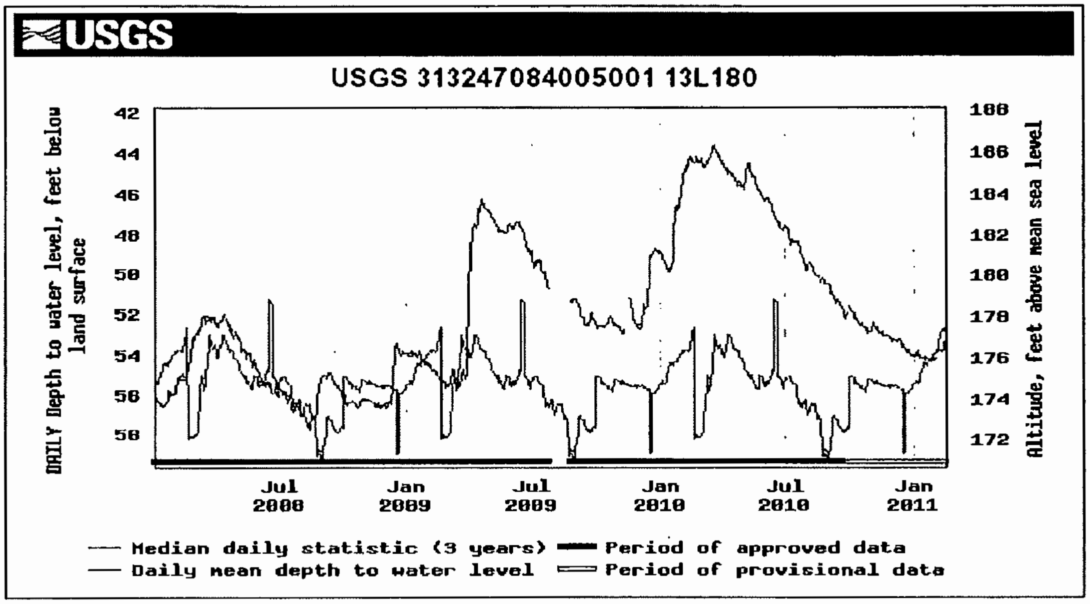


Fig. 4 Water level at USGS Well 13L180

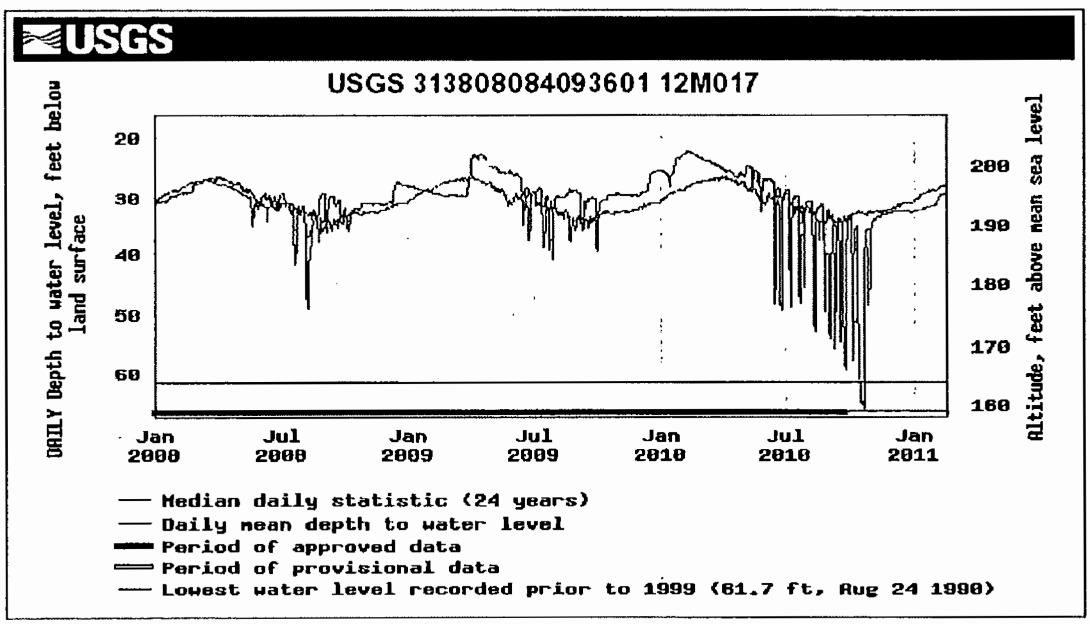


Fig. 5 Water level at USGS Well 12M017

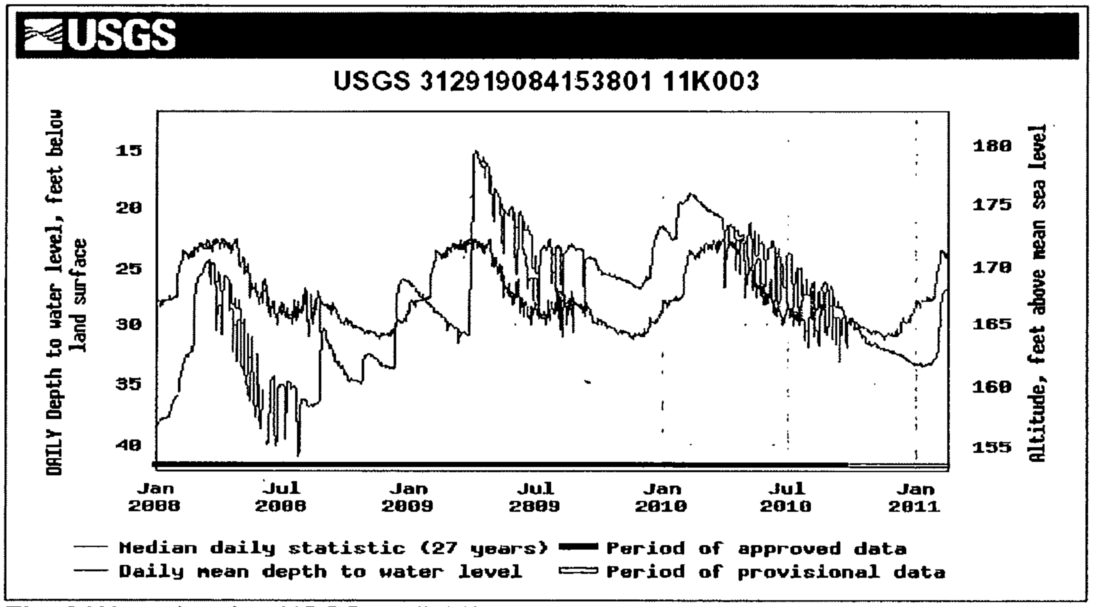


Fig. 6 Water level at USGS Well 11K003

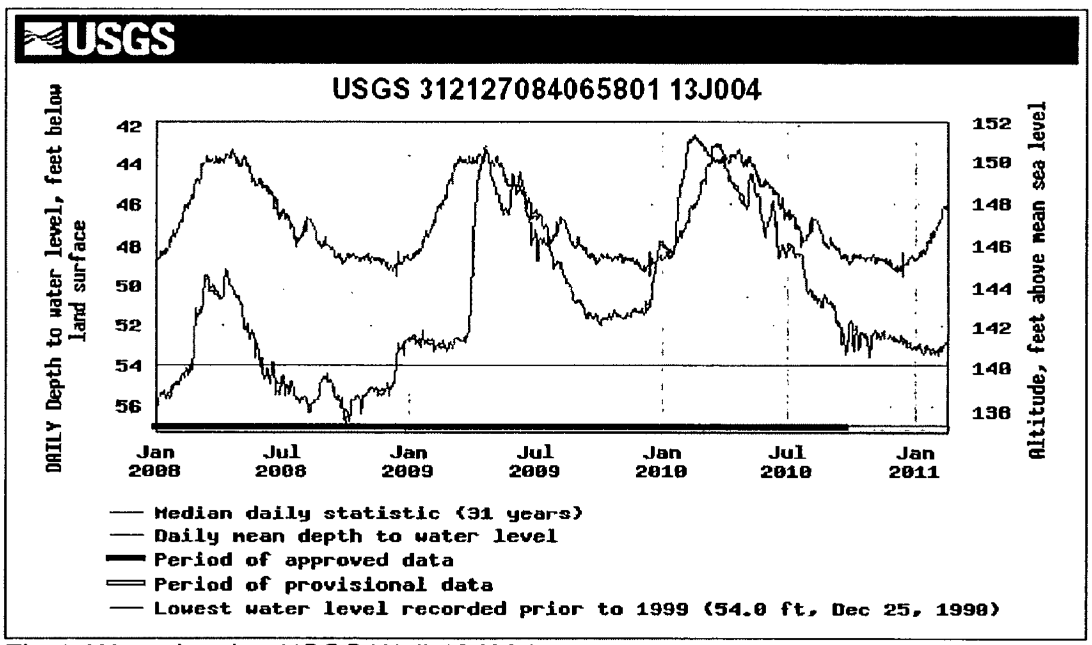


Fig. 7 Water level at USGS Well 13J004

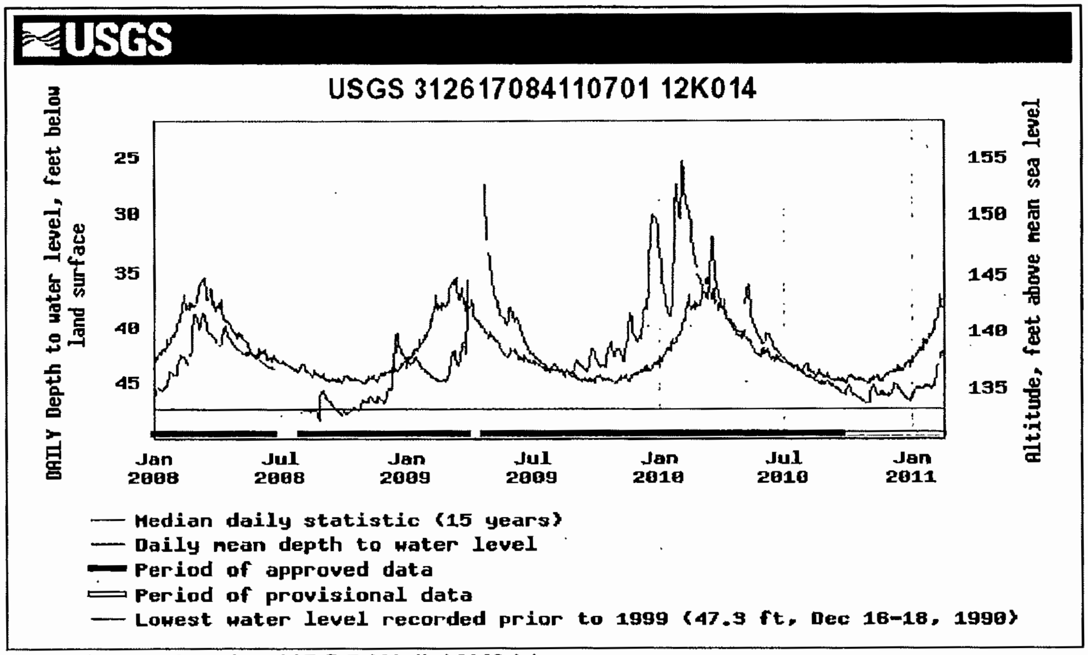


Fig. 8 Water level at USGS Well 12K014

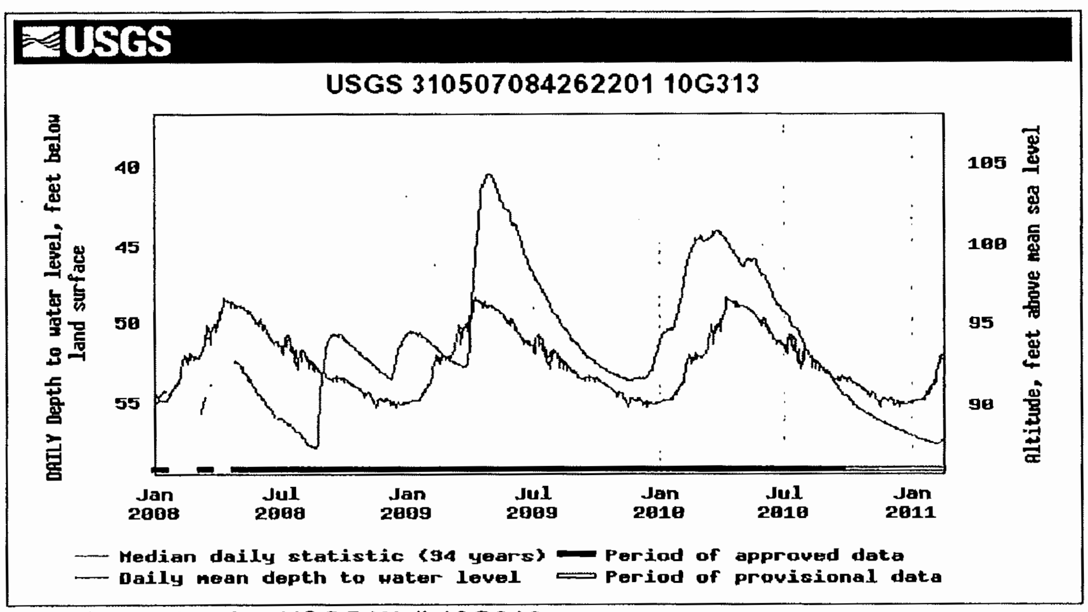


Fig. 9 Water level at USGS Well 10G313

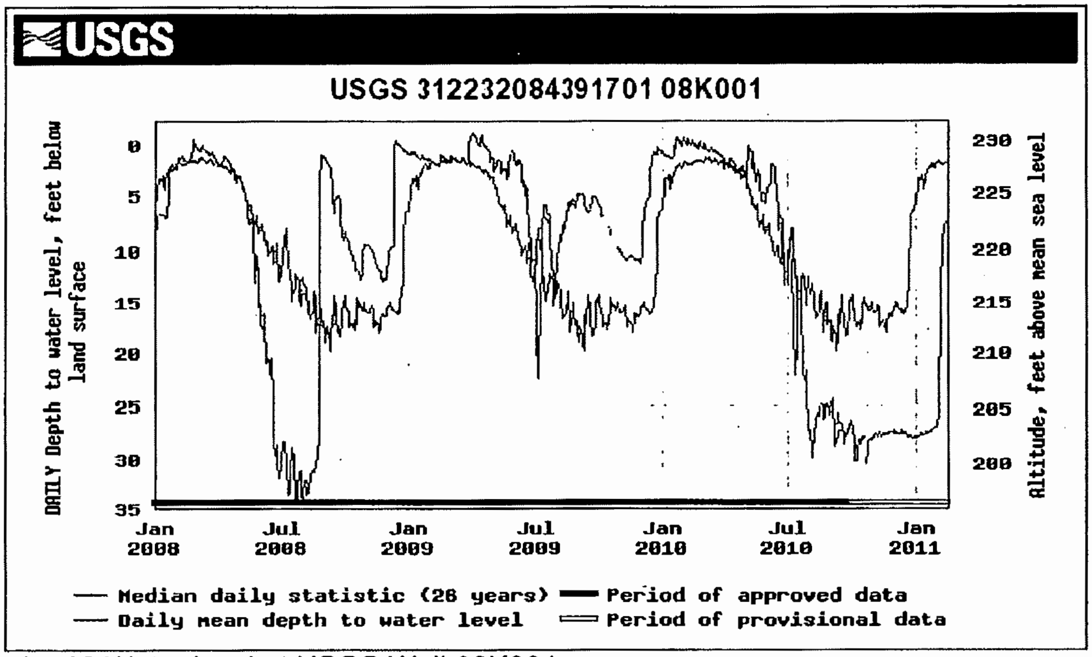


Fig. 10 Water level at USGS Well 08K001

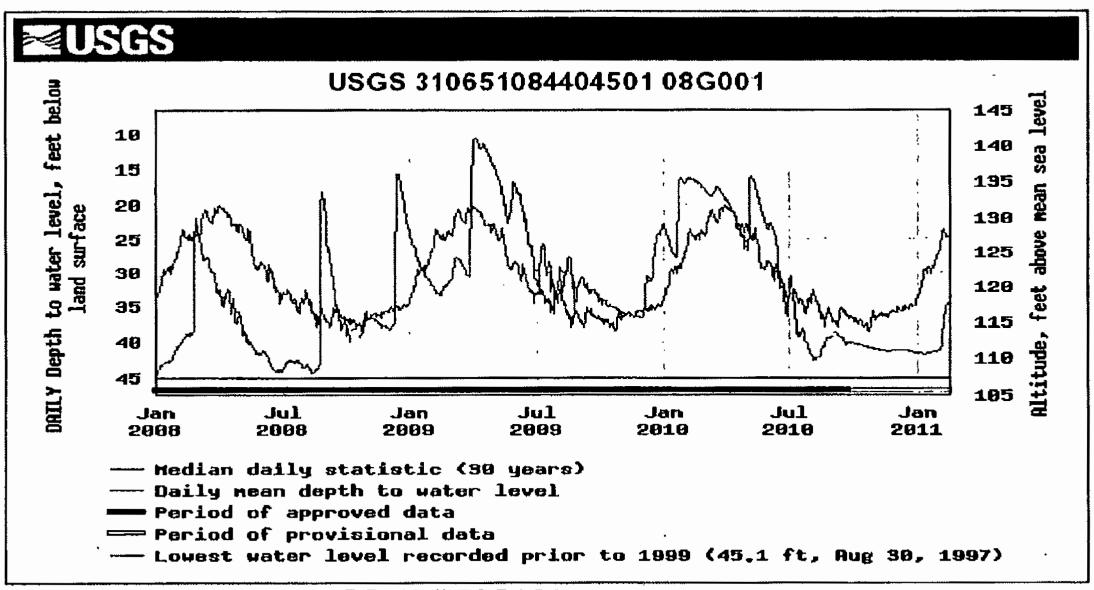


Fig. 11 Water level at USGS Well 08G001

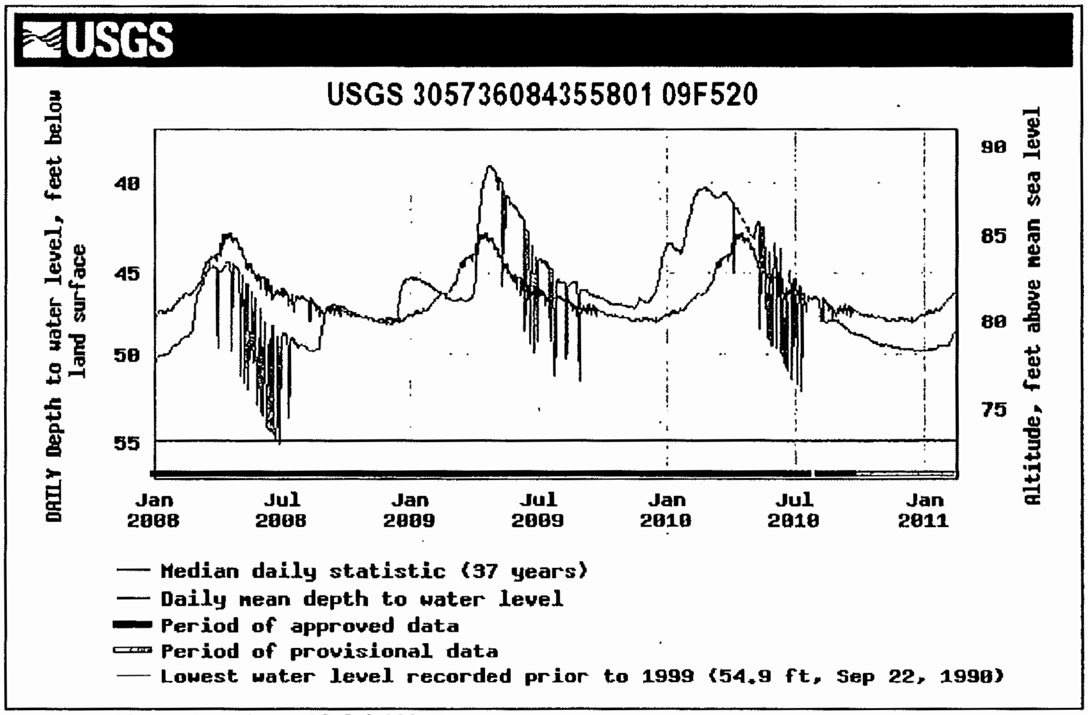


Fig. 12 Water level at USGS Well 09F520

U.S. Drought Monitor

February 15, 2011
Valid 7 a.m. EST

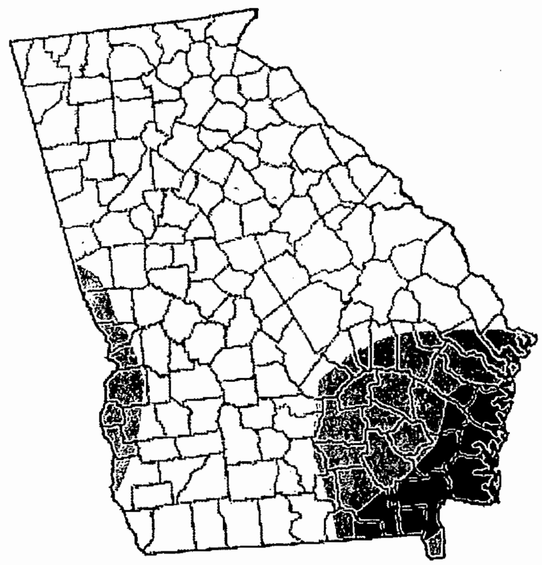
Georgia

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	76.22	21.87	6.18	0.00
Last Week (02/08/2011 map)	3.05	96.95	74.89	21.87	6.18	0.00
3 Months Ago (11/16/2010 map)	5.15	94.86	45.00	19.23	0.00	0.00
Start of Calendar Year (12/28/2010 map)	2.42	97.58	85.37	40.34	6.49	0.00
Start of Water Year (09/28/2010 map)	4.80	95.20	39.24	5.11	0.00	0.00
One Year Ago (02/09/2010 map)	100.00	0.00	0.00	0.00	0.00	0.00

Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional



The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, February 17, 2011
M. Rosencrans, CPC/NOAA

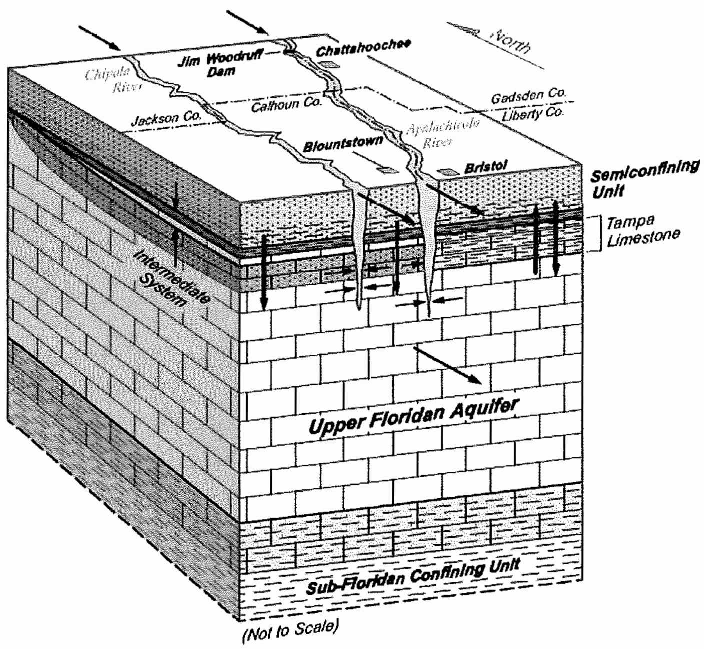
Fig. 13 Drought conditions as shown for the State of Georgia by the U.S. Drought Monitor – current

ATTACHMENT 8

GSI ENVIRONMENTAL

EXPERT REPORT OF SORAB PANDAY, PH.D.

State of Florida v. State of Georgia
Case No. 142 Original



Issued: 20 May 2016

Prepared for: The State of Georgia

GSI ENVIRONMENTAL

GSI Environmental Inc.

12801 Worldgate Drive, Suite 500, Herndon, Virginia 20170 tel. 713.522.6300

F.1.2.1 Georgia EPD Sustainable Yield Evaluations

In his discussions on sustainable yield simulation efforts of Georgia EPD, Dr. Langseth noted that, *"[t]he updated estimates for sustainable yield for the Upper Floridan aquifer in the Dougherty Plain based on the Jones and Torak MODFE model ranged from 365 cfs (237 mgd) to 505 cfs (328 mgd) …"* (Langseth, 2016, p. 42), and that the current pumping rates were much higher than this sustainable yield.

Dr. Langseth fails to explain that the Resource Assessment evaluation that he references was the first round of Georgia's Statewide Water Planning and was just a part of a comprehensive and on-going planning effort. It was intended to be a high level screening tool to identify local areas of potential issues within the ACF River Basin, so that subsequent analyses can be directed toward such issues. Sustainability triggers and metrics were considered at a basinwide scale with the intention of refining studies, as needed, in critical areas.

Details of this sustainable yield computation referenced by Dr. Langseth are provided by Georgia EPD (2010). In the computation, they adjusted the Jones and Torak (2006) steady-state model pumping rates by multiplying factors and ran the model to assess the pumping levels at which the sustainable yield criterion for streamflow had been met or exceeded. The trigger criteria included water level declines and baseflow reductions. Figure F-3 shows the stream reaches that exceeded the baseflow metric used to determine sustainable yield. As can be noted, the metric was triggered in one of the smaller streams located in the upstream reaches of the Lower ACF River Basin. Flow at a stream gage adjacent to this stream reach (USGS Station ID 02351890 in Muckalee Creek) is presented on Figure F-4. As shown, ***flows have increased post-1992 at this gage***. Monthly streamflow was 122.4 cfs in October 1999, and fluctuations have been similar for pre- and post-1992 conditions. I also examined baseflow to the impaired segment, as computed by the steady-state MODFE model of October 1999 conditions developed by Jones and Torak (2006), with no agricultural pumping. For that segment, the model indicated a baseflow of 1.7 cfs. ***For a sustainable yield trigger of 40% of the baseflow, this amounts to a baseflow reduction of less than 0.7 cfs. This amount is of absolutely no consequence to flow into Florida.***

CDM (2011) provides further details on the simulations. In addition to the Muckaloochee Creek baseflow trigger exceedance noted by Georgia EPD (2010), the CDM (2011) memorandum also depicts Mosquito Creek as having triggered the sustainable yield criterion for baseflow reduction (also shown in Figure F-4). However, I examined baseflow to this impaired segment in the steady-state MODFE model of October 1999 conditions with no agricultural pumping, and found that the baseflow value was less than 0.07 cfs which itself is a negligible value of no consequence to flow into Florida.

F.1.2.2 Spring Creek Flow Consideration

Dr. Langseth states that *"[t]he impact of pumping on streamflow is illustrated by the fact that Spring Creek occasionally runs dry due to high pumping rates during drought conditions. There is no record of Spring Creek having run dry from 1938 to 1980 (measured at the Iron City Gage. From 1980 to 2014, there were 424 days with no flow – zero cfs. In 2007, there were 152 days with zero flow and in 2011 there were 148 days with zero flow"* (Langseth, 2016, p. SS-5). However, Dr. Langseth fails to note or evaluate the following relevant points:

i) The Iron City Gage (USGS Station ID 02357000) is an upstream gage on Spring Creek. The gage further downstream, USGS Station ID 02357150, has not recorded any zero-

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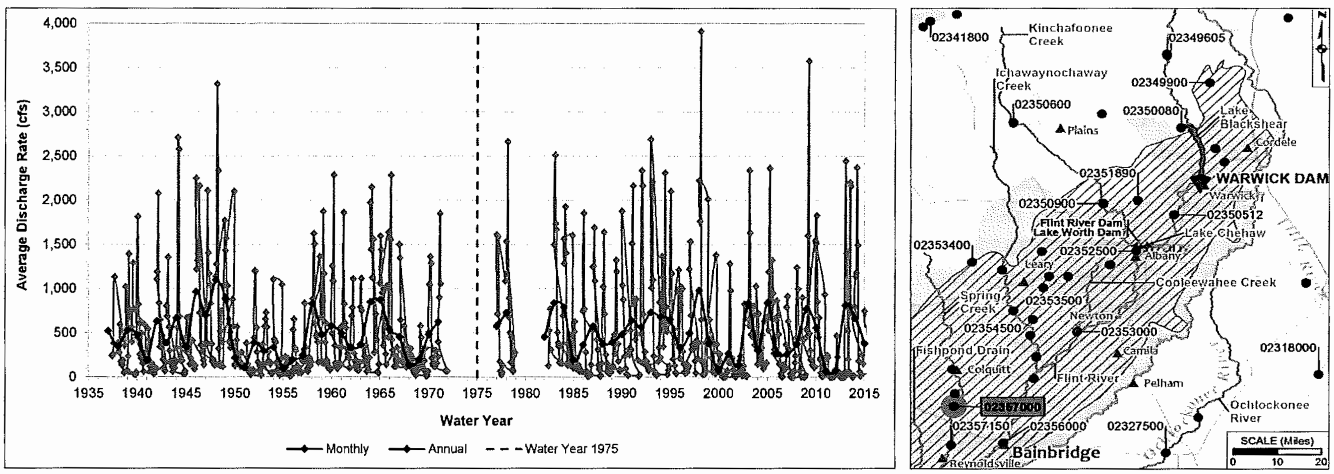
FIGURE F-5
MONTHLY AND ANNUAL AVERAGE STREAMFLOW AT SPRING CREEK (USGS STATION ID 02357000)

Expert Report of Sorab Panday, Ph. D.
State of Florida v. State of Georgia
Case No. 142 Original



Summary Statistics

USGS Station ID	Minimum		25th Percentile		Median		75th Percentile		Maximum		Average	
	Pre-1975	Post-1975	Pre-1975	Post-1975	Pre-1975	Post-1975	Pre-1975	Post-1975	Pre-1975	Post-1975	Pre-1975	Post-1975
Average Discharge Rate (cfs)												
Monthly	11	0	127	70	271	240	629	692	3,315	3,909	481	502
Annual	99	67	315	325	480	491	630	693	1,096	980	482	499

ATTACHMENT 9

Report of Dr. David L. Sunding

Economic Impacts of Reducing Water Consumption in the Chattahoochee and Flint River Basins of Georgia

Prepared for the State of Florida, Through Its Department of Environmental Protection and Its Counsel, Latham & Watkins LLP

February 29, 2016

THE Brattle GROUP

with smaller particles. Soils with smaller particles, such as those dominated by clay and silt components, drain less quickly and hold water in the root zone for a longer period of time.

35. The irrigated agricultural land in the ACF contains 53 individual dominant soil types or series. For the purposes of this report, I classify these soils into "coarse" and "fine" according to the particle size reported in the NRCS Soil Series Classification database.[32] Coarse soils include those with coarse-loamy, loamy, and sandy particles as well as "thermic" soils with unspecified particle size. Fine soils include those with clayey, fine, and fine-loamy particle size. Based on observations of water use in the Agricultural Metering Database, described in detail in subsequent sections and in Technical Appendix A to this report, this classification appropriately reflects observed irrigation depths across the ACF. Generally, farmers irrigating crops on fine soils used less water than those irrigating the same crops on coarse soils.[33] Figure 7 shows the distribution of coarse and fine soils for two representative counties in southwestern Georgia. The map reveals a substantial amount of detail in the spatial pattern of soil types across the landscape.

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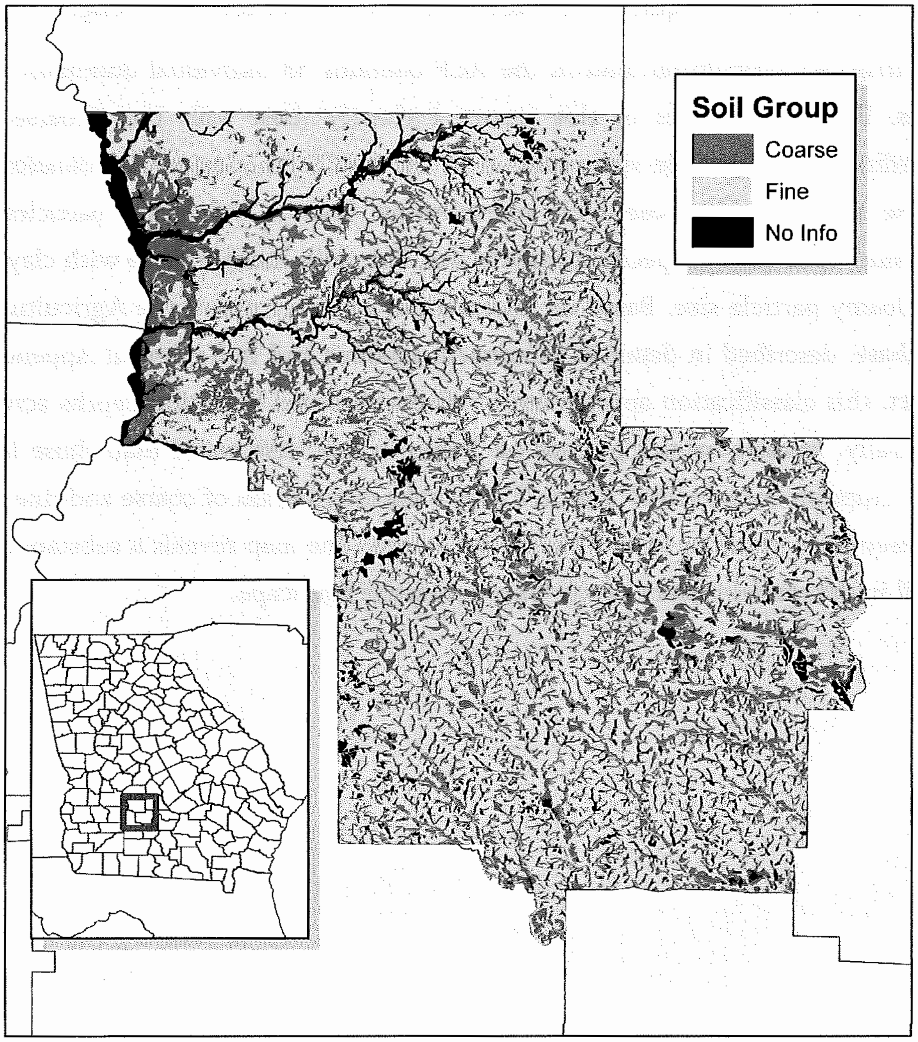
32 Available at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/?cid=nrcs142p2_053583

33 In two instances, I reclassified two relatively minor soil series where the pattern of applied water use in the ACF did not match expectations based on particle size. Fuquay and Pelham soils are classified as "fine" despite having loamy particle size, on the basis that observed irrigation depths tended to be more similar to other fine soils.

Figure 7: Map of Soil Types in Crisp and Turner Counties, Georgia



Source: SSURGO Soil Database, USDA Soil Series Classification Database

B. MAJOR CROPS

36. One of the main drivers of farmers' irrigation decisions is of course the crop being grown. According to projections made by the National Environmentally Sound Production Agriculture Laboratory (NESPAL) at the University of Georgia, for example, an acre of pecans uses almost six times the amount of water as an acre of soybeans in an average year. Given this variability, it is important to understand the pattern of irrigated land use in the

ATTACHMENT 10

ESTIMATING WATER USE FOR IRRIGATION USING A MODELING APPROACH

Dr. Gerrit Hoogenboom

Prepared for the State of Florida,
through Its Department of Environmental Protection,
and Its Counsel, Latham & Watkins LLP

Table 1. Soil components as a percent of irrigated crop area in the ACF (from The Brattle Group; only top 20 shown).

	Corn		Cotton		Peanut		Soy		Wheat	
Rank	Component	Pct of Total	Component	Pct of Total	Component	Pct of Total	Component	Pct of Total	Component	Pct of Total
1	Tifton	20.6%	Tifton	24.6%	Tifton	23.4%	Tifton	13.8%	Tifton	25.6%
2	Orangeburg	10.6%	Orangeburg	8.8%	Norfolk	10.4%	Greenville	10.4%	Orangeburg	9.5%
3	Norfolk	8.4%	Norfolk	8.7%	Orangeburg	9.5%	Faceville	9.7%	Greenville	9.4%
4	Greenville	8.0%	Lucy	6.2%	Lucy	6.9%	Orangeburg	7.8%	Faceville	7.7%
5	Faceville	7.0%	Greenville	5.5%	Wagram	6.5%	Lucy	7.0%	Norfolk	6.8%
6	Wagram	6.4%	Wagram	5.1%	Greenville	6.0%	Norfolk	6.7%	Red Bay	4.6%
7	Lucy	5.4%	Faceville	4.5%	Faceville	5.2%	Bonneau	6.1%	Lucy	4.4%
8	Troup	4.1%	Troup	4.4%	Troup	5.2%	Blanton	5.6%	Dothan	3.5%
9	Grady	3.9%	Dothan	4.1%	Blanton	3.8%	Dothan	4.7%	Blanton	3.3%
10	Goldsboro	3.9%	Goldsboro	3.5%	Goldsboro	3.2%	Troup	4.6%	Troup	3.0%
11	Red Bay	3.8%	Grady	3.3%	Bonneau	2.9%	Wagram	3.9%	Grady	3.0%
12	Bonneau	3.0%	Blanton	3.1%	Red Bay	2.9%	Fuquay	3.6%	Goldsboro	2.5%
13	Blanton	2.7%	Bonneau	2.4%	Grady	2.8%	Red Bay	3.1%	Wagram	2.5%
14	Dothan	2.3%	Red Bay	2.3%	Dothan	1.8%	Grady	2.0%	Fuquay	1.6%
15	Irvington	1.3%	Fuquay	1.8%	Irvington	1.2%	Lakeland	1.5%	Bonneau	1.6%
16	Ocilla	0.8%	Irvington	1.3%	Fuquay	1.0%	Goldsboro	1.2%	Irvington	1.6%
17	Fuquay	0.7%	Clarendon	1.0%	Clarendon	0.6%	Nankin	1.1%	Nankin	1.2%
18	Americus	0.6%	Nankin	0.7%	Nankin	0.5%	Irvington	0.8%	Carnegie	0.8%
19	Carnegie	0.5%	Ocilla	0.7%	Lakeland	0.5%	Clarendon	0.6%	Lakeland	0.8%
20	Rains	0.5%	Rains	0.6%	Marlboro	0.5%	Cowarts	0.6%	Clarendon	0.7%

b. Peanuts

i. Input Parameters

33. In my DSSAT model runs for peanuts, I assumed that peanuts were planted in early May at a plant density of 18 plants/m^2 and a row spacing of 90 cm (Prostko, 2015). The variety was "Georgia Green," a dominant variety developed by the University of Georgia that has been grown in Georgia for several years. The genetic coefficients for the variety Georgia Green required for the model were obtained from the standard DSSAT model as found in the peanut cultivar file. For the analysis there were a total of 88 scenarios, referred to as "treatments" in the figures. When comparing different scenarios or options, it is important that the same weather conditions are being used. To illustrate that I used the same weather data for each scenario, I show in a box plot (Figure 2) that rainfall ranged from 249 to 889 mm for an approximate growing season duration of 140 days. Due to the large number of treatments/scenarios, the x-axis label is not very clear. Precipitation in Georgia is extremely variable as demonstrated by the cumulative probability distribution function shown in Figure 3. Each point in this graph represents a different year, with the smallest amount shown on the bottom left, i.e., 249 mm, and the highest amount shown on the top right, i.e., 889 mm.

34. Peanuts are harvested as pods, with the seeds in a shell. Although the market price is based on a certain percentage of moisture of the seeds and the shells, the model predicts dry weight, which can be corrected to the standard market shell moisture. In Figure 3 and following figures treatments 1-11 represent the Tifton Loamy Sand; treatments 12-22 represent the Orangeburg Sandy Loam; treatments 23-33 represent the Norfolk Loamy Sand; treatments 34-44 represent the Greenville Sandy Clay Loam; treatments 45-55 represent the Faceville Loamy Sand; treatments 56-66 represent the Wagram Sand; treatments 67-77 represent the Lucy Sand; and treatments 78-88 represent the Troup Sand.

ii. Results

35. Peanuts are extremely sensitive to the precipitation received during the growing season (Figure 3) as well as the water holding capacity of the soil. For rainfed (no supplemental irrigation), yield for the Tifton Loamy Sand ranged from around 819 to 5,407 kg/ha; for the Orangeburg Sandy Loam, yield ranged from 888 to 6,231 kg/ha; for the Norfolk Loamy Sand, yield ranged 825 to 6,033 kg/ha; for the Greenville Sandy Clay Loam, yield ranged from 955 to 6,549 kg/ha; for the Faceville Loamy Sand, yield ranged from 455 to 4,102 kg/ha; for the Wagram Sand, yield ranged from 575 to 3,418 kg/ha; for the Lucy Sand, yield ranged from 638 to 4,889 kg/ha; and for the Troup Sand, yield ranged from 664 to 4,604 kg/ha (Figure 4). This yield variability under rainfed conditions illustrates that supplemental irrigation often increases yields. In some years, supplemental irrigation is not required to achieve high yields. But, there are other years when rainfall is insufficient to meet the demand of the peanut crop and thus causes a decrease in yield due to drought stress.

36. For fully irrigated crops, there is no difference in yield among soils, while for the rainfed yield the differences are significant (Figure 5). Depending on the soil type, some of the higher input scenarios do not show much difference in yield. For instance, for the first soil (Tifton Loamy Sand) the yield is very similar for the last four irrigation treatments. Similar responses can be found for the other soils, although the sandier soils (last three soils) still show a yield response at the higher irrigation threshold levels (Figure 4).

37. These yield responses also correspond to the supplemental irrigation amounts that are required to reach these high yield levels (Figure 6). Especially the Wagram Sandy soil shows extremely high water requirements under non-stress conditions. For all soils, the water requirements increase with the higher threshold value. However, it is important to understand that supplemental water requirements vary across years. The higher the threshold variable and potential yield goal, the larger the range between the minimum and maximum amount of water required for irrigation. In Figure 7, an example is shown for the Tifton Loamy Sand (top) and a Troup Sand (bottom), showing the differences among soils.

38. As expected, peanut pod yield is extremely responsive to supplemental irrigation. Summarized across years and scenarios the response is linear up to an amount of 300 mm (Figure 8). When all years and scenarios are considered the response is more scattered, but the variability is less with the increase in the amount of supplementary irrigation applied (Figure 9). The results are shown for the Tifton Loamy Sand only, but the other soils show a very similar response. These outcomes are important and can be used for further studies, such as by Dr. Sunding for his analysis and report. I have reviewed his use of the DSSAT outputs, and find that his use of outputs for only the drier weather years is sound.

c. Corn

i. Input Parameters

39. In my DSSAT model runs for corn, I assumed that corn was planted in early April at a plant density of 7.7 plants/m^2 and a row spacing of 76 cm (Lee, 2015). The variety was "Pioneer 31G98," a Pioneer Hybrid that has been popular in the southeastern United States. Crop model specific information for this corn hybrid was obtained from a publication by Persson et al. (2009), who used the Georgia Statewide Variety Trials to determine the genetic coefficients for this corn hybrid. For the analysis, there were a total of 88 scenarios, referred to as "treatments" in the figures. To illustrate that I used the same weather data for each scenario, the precipitation is summarized as a box plot (Figure 10) showing that rainfall ranged from 57 to 757 mm for an approximate growing season duration of 108 days, about one month shorter than the peanut growing season discussed in the previous section. The minimum amount of rainfall for corn was significantly lower than the minimum amount of rain found for peanut. Due to the large number of treatments/scenarios, the x-axis label is not very clear. Precipitation in Georgia is extremely variable as demonstrated by the cumulative probability distribution function shown in Figure 11. Each point in this graph represents a different year, with the smallest amount of rainfall shown on the bottom left, i.e., 57 mm, and the highest amount of rainfall shown on the top right, i.e., 757 mm.

40. Corn is harvested as dry grain with the seeds attached to the cob but mechanically removed during harvest. Although the market price is based on a fixed moisture percentage of the grain, the model predicts dry weight, which can be corrected to the standard market grain moisture content. In Figure 12 (bottom) and following figures treatments 1-11 represent the Tifton Loamy Sand; treatments 12-22 represent the Orangeburg Sandy Loam; treatments 23-33 represent the Norfolk Loamy Sand; treatments 34-44 represent the Greenville Sandy Clay Loam; treatments 45-55 represent the Faceville Loamy Sand; treatments 56-66 represent the Wagram Sand; treatments 67-77 represent the Lucy Sand; and treatments 78-88 represent the Troup Sand.

i. Results

41. Corn is sensitive to the total amount of precipitation received during the growing season, especially during the grain filling period (Figure 11) as well as the water holding capacity of the soil. For rainfed (no supplemental irrigation), yield for the Tifton Loamy Sand ranged from around 1,111 to 9,558 kg/ha for the Orangeburg Sandy Loam yield ranged from 892 to 9,464 kg/ha; for the Norfolk Loamy Sand yield ranged 961 to 9,952 kg/ha; for the Greenvile Sandy Clay Loam yield ranged from 665 to 9,997 kg/ha; for the Faceville Loamy Sand yield ranged from 0 (crop failure) to 7,706 kg/ha; for the Wagram Sand yield ranged from 992 to 8,505 kg/ha; for the Lucy Sand, yield ranged from 988 to 8,374 kg/ha; and for the Troup Sand yield ranged from 988 to 8,374 kg/ha (Figure 12). This yield variability under rainfed conditions illustrates that supplemental irrigation often increases yield, as the model simulated at least one crop failure due to limited rainfall. Although there are some years for which supplemental irrigation is not required to increase yields, there are many other years for which rainfall is

insufficient to meet the demand of the corn crop and thus causes a decrease in yield due to drought stress. In addition, under rainfed conditions, yield does not reach the yield potential compared to non-stressed conditions.

42. For fully irrigated crops, there is no difference in yield among soils, while for the rainfed yield the differences are significant (Figure 13). Depending on the soil type, some of the higher input scenarios do not show much difference in yield. For instance, for the first soil (Tifton Loamy Sand) the yield is very similar for the last six irrigation treatments. Similar responses can be found for the other soils, although the sandier soils (last three soils) still show a yield response at the higher irrigation threshold levels (Figure 12).

43. These yield responses also correspond to the supplemental irrigation amounts that are required to reach these high yield levels (Figure 14). Especially the Wagram Sandy soil shows extremely high water requirements under non-stress conditions, similar to what was found for peanut. For all soils, the water requirements increase with the higher threshold value. However, it is important to understand that supplemental water requirements vary across years. The higher the threshold variable and potential yield goal, the larger the range between the minimum and maximum amount of water required for irrigation. In Figure 15, an example is shown for the Tifton Loamy Sand (top) and the Troup Sand (bottom) to demonstrate this more explicitly.

44. As expected, corn seed yield is extremely responsive to supplemental irrigation. Summarized across years and scenarios, the response is linear up to an amount of 225 mm of irrigation (Figure 16). When all years and scenarios are considered the response is extremely scattered, and the variability does not seem to change with the increase in the amount of supplementary irrigation applied (Figure 17). The results are shown for the Tifton Loamy Sand only, but the other soils show a very similar response. As stated earlier for peanuts, these results are critical for further economic analyses, including for Dr. Sunding's report.

a. Cotton

i. Input Parameters

45. In my DSSAT model runs for cotton, I assumed that cotton was planted in early May at a plant density of 14 plants/m^2 and a row spacing of 90 cm (Collins et al., 2015). The variety was "Deltapine 555 BG/RR," a Deltapine variety that has been popular in the southeastern United States. The genetic coefficients for the variety Deltapine 555 BG/RR were obtained from the standard DSSAT model as found in the cotton cultivar file. For the analysis there were a total of 88 scenarios, referred to as "treatments" in the figures. To illustrate that I used the same weather data, the precipitation is summarized as a box plot (Figure 18) showing that rainfall ranged from 248 to 880 mm for an approximate growing season duration of 135 days, similar to the peanut growing season discussed in the prior section. The minimum amount of rainfall for cotton was significantly higher than the minimum amount of rain found for corn, partially due to the one month later planting and the longer growing season duration. Due to the large number of treatments/scenarios, the x-axis label is not very clear. Precipitation in Georgia is highly variable as demonstrated by the cumulative probability distribution function shown in Figure 19. Each point in this graph represents a different year, with the smallest amount of rainfall shown on the bottom left, i.e., 248 mm, and the highest amount of rainfall shown on the top right, i.e., 880 mm.

ii. Results

46. Cotton is harvested as seed cotton that includes the actual cotton seed and lint. After harvest, the lint is normally separated from the seed during the ginning process. Both cotton lint and cotton seed are sold for a range of applications. In the analysis shown here I used seed cotton, i.e. the seed and the lint combined. For economic analysis, the lint itself has a higher market value and we assumed that 38% of seed cotton was lint, based on literature values. In Figure 20 (bottom) and following figures treatments 1-11 represent the Tifton Loamy Sand; treatments 12-22 represent the Orangeburg Sandy Loam; treatments 23-33 represent the Norfolk Loamy Sand; treatments 34-44 represent the Greenville Sandy Clay Loam; treatments 45-55 represent the Faceville Loamy Sand; treatments 56-66 represent the Wagram Sand; treatments 67-77 represent the Lucy Sand; and treatments 78-88 represent the Troup Sand.

47. Cotton is also highly sensitive to the total amount of precipitation received during the growing season (Figure 19) as well as the water holding capacity of the soil, although it is considered an indeterminate crop that continues to grow. For rainfed (no supplemental irrigation), yield for the Tifton Loamy Sand ranged from around 571 to 3,603 kg/ha; for the Orangeburg Sandy Loam, yield ranged from 616 to 3,920 kg/ha; for the Norfolk Loamy Sand, yield ranged 558 to 3,731 kg/ha; for the Greenvile Sandy Clay Loam, yield ranged from 656 to 4,110 kg/ha; for the Faceville Loamy Sand, yield ranged from 129 to 3,222 kg/ha; for the Wagram Sand, yield ranged from 537 to 3,135 kg/ha; for the Lucy Sand, yield ranged from 499 to 3,358 kg/ha; and for the Troup Sand, yield ranged from 410 to 3,367 kg/ha (Figure 20). This yield variability under rainfed conditions illustrates that supplemental irrigation often increases yields, as the model simulated at least one year with a near crop failure due to limited rainfall.

Although there are some years for which supplemental irrigation is not required to increase yields, there are many others years for which rainfall is insufficient to meet the demand of the cotton crop and thus causing a decrease in yield due to drought stress. In addition, under rainfed conditions, yield will not reach the yield potential of non-stressed conditions.

48. For fully irrigated crops, there is no difference in yield among soils, while for the rainfed yield the differences are significant (Figure 21). Depending on the soil type, some of the higher input scenarios do not show much difference in yield. For instance, for the first soil (Tifton Loamy Sand) the yield is very similar for the last six irrigation treatments. Similar responses can be found for the other soils, although the sandier soils (last three soils) still show a yield response at the higher irrigation threshold levels. However, the response is somewhat less at the high irrigation levels compared to corn (Figure 20).

49. These yield responses also correspond to the supplemental irrigation amounts that are required to reach these high yield levels (Figure 22). Especially the Wagram Sandy soil shows extremely high water requirements under non-stress conditions, similar to what was found for peanut and corn. For all soils the water requirements increase with the higher threshold value. However, it is important to understand that supplemental water requirements vary across years. The higher the threshold variable and potential yield goal, the larger the range between the minimum and maximum amount of water required for irrigation. In Figure 23 an example is shown for the Tifton Loamy Sand (top) and the Troup Sand (bottom) to demonstrate this more explicitly.

50. As expected, cotton yield is very responsive to supplemental irrigation. Summarized across years and scenarios, the response is linear up to an amount of 225 mm of irrigation (Figure 24). When all years and scenarios are considered the response is extremely scattered, and the variability does not seem to change with the increase in the amount of supplementary irrigation applied although the variability is slightly less at higher irrigation amounts (Figure 25). The results are shown for the Tifton Loamy Sand only, but the other soils show a very similar response. As stated previously for peanuts and corn, these results are critical for further economic analyses, including for Dr. Sunding's report.

b. Soybeans

i. Input Parameters

51. In my DSSAT model runs for soybean, I assumed that soybean was planted on May 20 at a plant density of 29 plants/m^2 and a row spacing of 76 cm (Whitaker et al., 2014). The variety was Generic Maturity Group 5, representing the Maturity Group 5 cultivars that have a similar response to photoperiod. The genetic coefficients for the variety "Generic Maturity Group 5" were obtained from the standard DSSAT model as found in the soybean cultivar file. For the analysis there were a total of 88 scenarios, referred to as "treatments" in the figures. To illustrate that I used the same weather data, the precipitation is summarized as a box plot (Figure 26) showing that rainfall ranged from 244 to 772 mm for an approximate growing season duration of 127 days. The minimum amount of rainfall was significantly higher than the minimum amount of rain found for corn and somewhat similar to cotton, partially due to the one month later planting and the longer growing season duration for soybean compared to corn. Due to the large number of treatments/scenarios, the x-axis label is not very clear. Precipitation in Georgia is highly variable as demonstrated by the cumulative probability distribution function shown in Figure 27. Each point in this graph represents a different year, with the smallest amount of rainfall shown on the bottom left, i.e., 244 mm, and the highest amount of rainfall shown on the top right, i.e., 772 mm.

52. Soybean is harvested as grains or seeds that develop in a shell, referred to as a pod. During harvest, the seeds are automatically separated from the shell. In Figure 28 (bottom) and following figures, treatments 1-11 represent the Tifton Loamy Sand; treatments 12-22 represent the Orangeburg Sandy Loam; treatments 23-33 represent the Norfolk Loamy Sand; treatments 34-44 represent the Greenville Sandy Clay Loam; treatments 45-55 represent the Faceville Loamy Sand; treatments 56-66 represent the Wagram Sand; treatments 67-77 represent the Lucy Sand; and treatments 78-88 represent the Troup Sand.

ii. Results

53. Soybean is highly sensitive to the total amount of precipitation received during the growing season (Figure 27) as well as the water holding capacity of the soil. Soybean is a determinate crop and very sensitive to photoperiod or the length of the daily light period (daylength). Under long days, flowering is normally delayed. The actual sensitivity is also affected by the maturity group of the variety that is being planted. For rainfed (no supplemental irrigation), yield for the Tifton Loamy Sand ranged from around 321 to 3,093 kg/ha, for the Orangeburg Sandy Loam, yield ranged from 196 to 3,343 kg/ha; for the Norfolk Loamy Sand, yield ranged 181 to 3,225 kg/ha; for the Greenvile Sandy Clay Loam, yield ranged from 183 to 3,425 kg/ha; for the Faceville Loamy Sand, yield ranged from 111 to 2,520 kg/ha; for the Wagram Sand, yield ranged from 263 to 2,043 kg/ha; for the Lucy Sand, yield ranged from 267 to 2,690 kg/ha; and for the Troup Sand, yield ranged from 252 to 2,724 kg/ha (Figure 20). The yield levels for soybean are significantly lower than yields for the other crops, partially due to soybean's later planting in May. This yield variability under rainfed conditions illustrates that supplemental irrigation often increases yield, especially as the model simulated at least

one year with a near crop failure due to limited rainfall. Although there are some years for which supplemental irrigation is not required to increase yields, there are many other years for which rainfall is insufficient to meet the demand of the soybean crop and thus causing a decrease in yield due to drought stress. In addition, under rainfed conditions yield will never reach the yield potential of non-stressed conditions.

54. For fully irrigated crops, there is no difference in yield among soils, while for the rainfed yield the differences are significant (Figure 29). Depending on the soil type, some of the higher input scenarios show little difference in yield. For instance, for the first soil (Tifton Loamy Sand) the yield is very similar for the last four or five irrigation treatments. Similar responses can be found for the other soils, although the sandier soils (last three soils) still show a yield response at the higher irrigation threshold levels. However, the response is somewhat less at the high irrigation levels compared to soybean (Figure 28).

55. These yield responses also correspond to the supplemental irrigation amounts that are required to reach these high yield levels (Figure 30). Especially the Wagram Sandy soil shows extremely high water requirements under non-stress conditions, similar to what was found for peanut, corn, and cotton. For all soils the water requirements increase with the higher threshold value. However, it is important to understand that supplemental water requirements vary across years. The higher the threshold variable and potential yield goal, the larger the range between the minimum and maximum amount of water required for irrigation. In Figure 31 an example is shown for the Tifton Loamy Sand (top) and the Troup Sand (bottom) to demonstrate this more explicitly.

56. As expected, soybean yield is extremely responsive to supplemental irrigation. Summarized across years and scenarios, the response is linear up to an amount of 300 mm of irrigation (Figure 32). When all years and scenarios are considered the response is extremely scattered, with the variability slightly decreasing with an increase in the amount of supplementary irrigation applied (Figure 33). The results are shown for the Tifton Loamy Sand only, but the other soils show a very similar response. As stated earlier with regard to peanuts, corn and cotton, these results are critical for further economic analyses, including for Dr. Sunding's report.

No. 142, Original

In The
Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

Before the Special Master

Hon. Ralph I. Lancaster

CERTIFICATE OF SERVICE

This is to certify that the STATE OF GEORGIA'S OPPOSITION TO FLORIDA'S MOTION IN LIMINE REGARDING EXPERT TESTIMONY OF DR. SUAT IRMAK has been served on this 30th day of September, 2016, in the manner specified below:

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