THE REGIONAL ECONOMIC IMPACT OF IRRIGATION REDUCTION AUCTION AND THE FEASIBILITY OF DEEP WELL DRILLING AS A SOLUTION IN THE LOWER FLINT RIVER BASIN

by

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(Under the Direction of Jeff Mullen)

ABSTRACT

With prolonged drought occurring more frequently in Georgia, water management in the Flint River Basin (FRB) will face challenges involving intensive groundwater pumping for agricultural purposes and the effects on streamflow conditions. In the past, Georgia's Environmental Protection Division (EPD) implemented irrigation reduction auctions to encourage farmers to reduce irrigation to conserve water. However, these auctions were considered unsuccessful and problematic. EPD summarized the previous auctions and recommend drilling deeper aquifers as source switching to conserve water. This paper looks at the feasibility of a standard field switching to a deeper aquifer as a water resource. The simulation builds to compare the cost of buyout auction with source switching. The cost of buyout auction has a regional economic impact estimated by IMPLAN. The results show that both auction and source switching have advantages under different conditions. The methods used in this paper can be used for water management practices within Georgia and potentially around the world.

INDEX WORDS: Groundwater management, drought, water auction, aquifer, simulation, Flint River Basin, IMPLAN

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Chapter 1: Introduction

1.1 Background

Water supplies have long been considered abundant in Georgia, while concerns about the impact of drought have often plagued the Western states. However, with a growing population, increased agricultural water use, and changing environment and climate, the state of Georgia has seen its water demand increase significantly. Most of the state's irrigated agricultural production takes place in the Flint River Basin (FRB). Water for agriculture in the FRB draws from both surface and groundwater sources. The complicated withdrawal of water via numerous wells in a specific area near a stream has the potential to impact stream flows. While sourcing from groundwater is essential for agricultural activities in the FRB, it is not without its drawbacks. To address the issue, it is necessary to conduct an assessment of the impact of groundwater pumping on stream flow patterns and surface water supply.

The FRB covers approximately 8,460 square miles, extending 212 miles from Hartsfield-Jackson International Airport to the southwestern corner of Georgia, where it merges with the Chattahoochee River to form the Apalachicola River (Couch and McDowell, 2006). The US Geological Survey divides the FRB into smaller sub-basins, or watersheds (USGS, 2012). Six HUC-8 watersheds are located within the FRB. These include the Upper Flint, Middle Flint, and Lower Flint, as well as the Kinchafoonee-Muckalee, Ichawaynochaway, and Spring Creeks. Each HUC-8 has distinct hydrologic characteristics (which will be addressed in greater detail in subsequent discussions of water use), water-related impacts, and permitting strategies (Couch and McDowell, 2006).

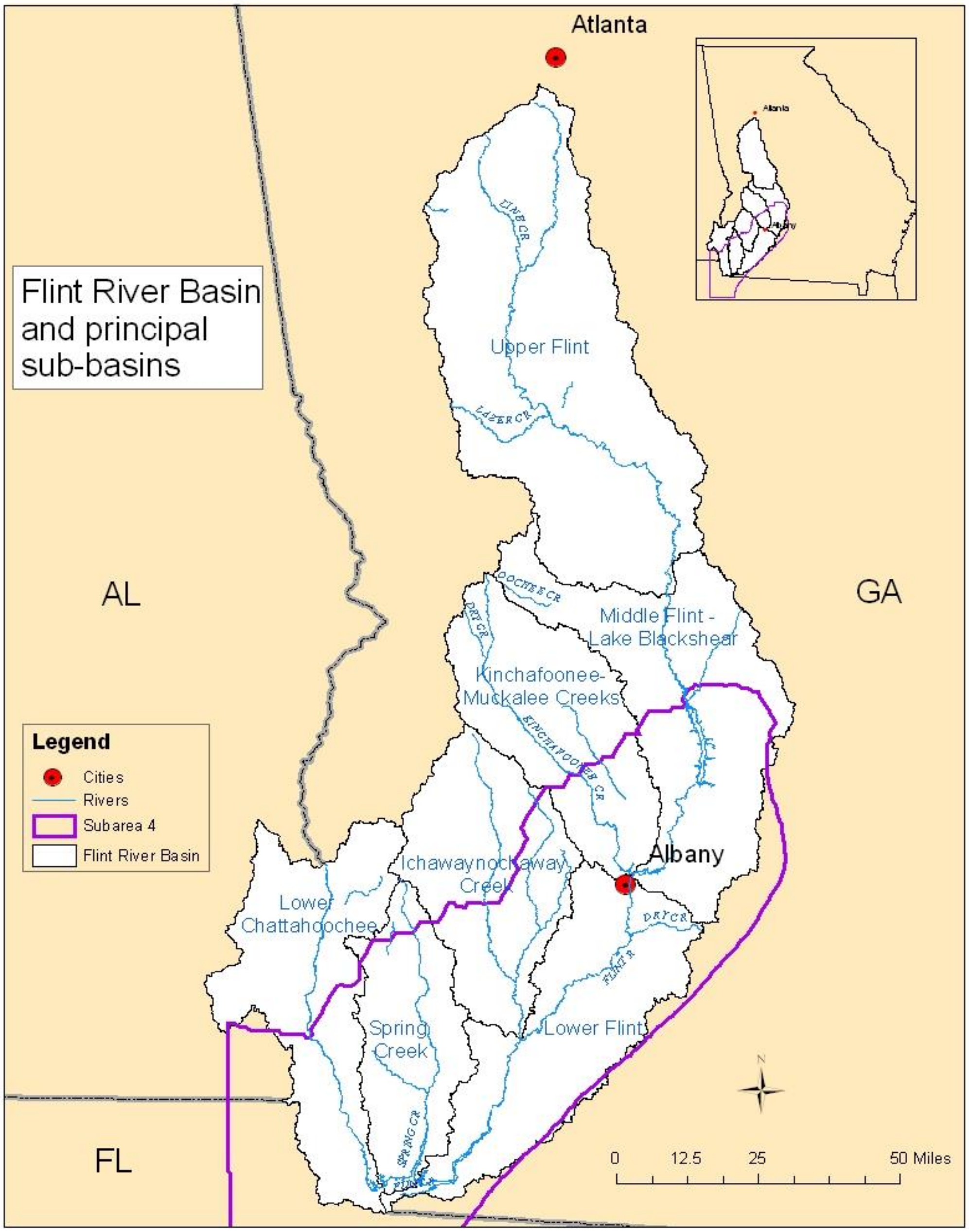

Figure 1.1 The Flint River Basin (Couch and McDowell, 2006)

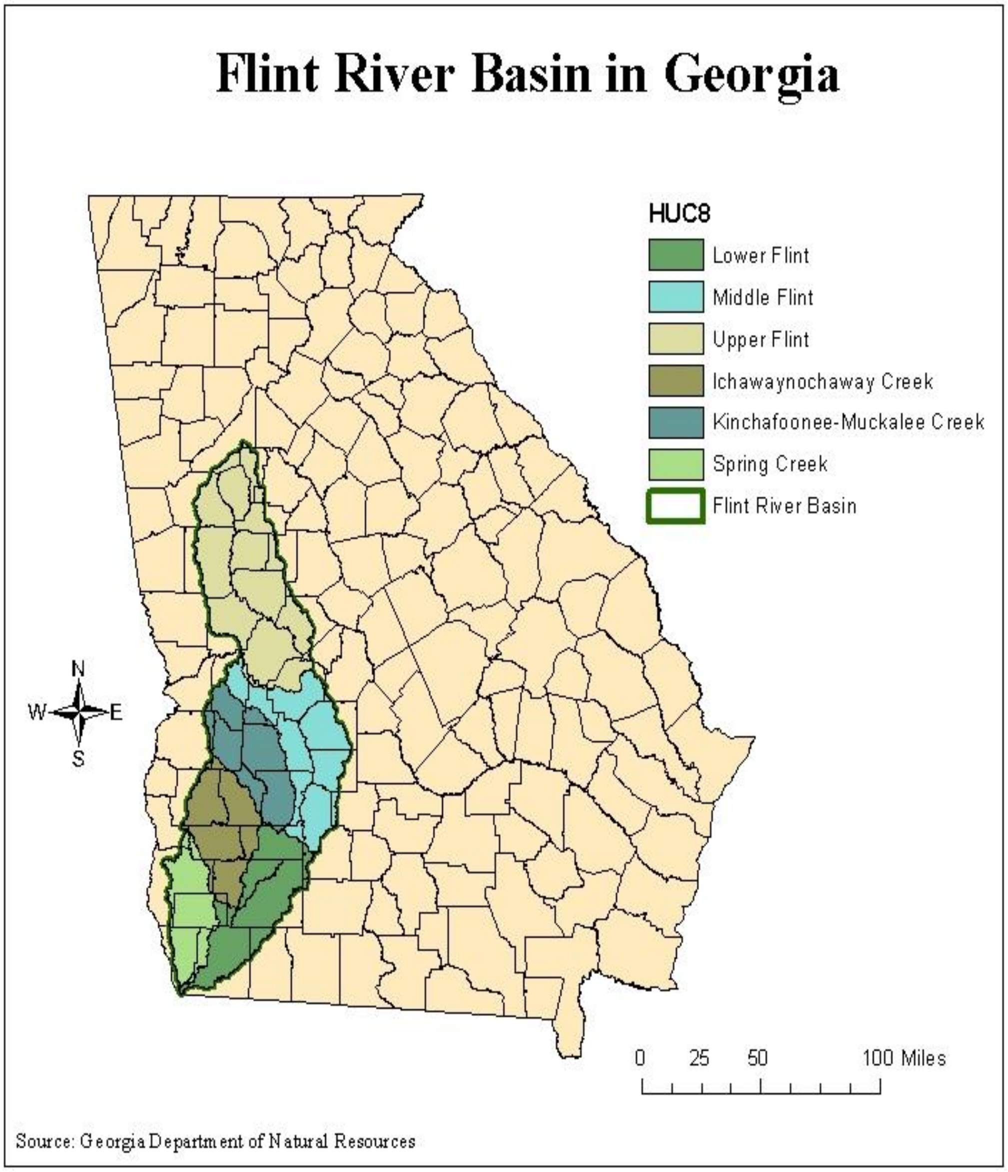

Figure 1.2 HUC8 Watersheds in the Flint River Basin (Couch and McDowell, 2006)

1.2 Aquifers in the Flint River Basin

Variations in precipitation, evapotranspiration, and normal drainage or discharge are the primary causes of water level changes. Generally, water levels increase steadily during wet periods and gradually fall during dry periods. Usually, precipitation improves well yields. In Georgia, aquifer water levels usually fluctuate seasonally in a cyclical pattern. Water levels rise during the winter and spring months because of increased precipitation. Water levels then decline during the summer and fall due to increased agricultural harvesting, increased evapotranspiration rates, and reduced aquifer recharge (Gordon and Painter, 2018). The pumping of groundwater impacts the volume of groundwater stored and the speed at which water is discharged from an aquifer (Taylor and Alley, 2001).

The Flint River Basin overlays four major aquifers: Cretaceous, Clayton, Claiborne, and Floridan (Gordon and Painter, 2018). Each aquifer is separated from others from above and below by layers of clay or silt that obstruct vertical water movement through them. The aquifers are oriented southeastward and overlap one another; the oldest and lowest layer is the north of the Fall Line. To the south is the youngest and shallowest layer (Georgia DNR, 2004). The Clayton and Claiborne aquifers are highly pumped as reservoirs of agricultural irrigation, public supply, and industrial uses. The overuse has resulted in significant decreases in the Clayton aquifer's water supply. In the early 1990s, the Georgia Environmental Protection Division (EPD) banned new permits in the Clayton aquifer (Peck and Gordon, 2013).

The Cretaceous aquifer is the deepest of the four main aquifers. It consists of layers of sand, shell, and gravel, as well as kaolin deposits. It is a highly efficient and abundant water source for agricultural and municipal uses in the Lower FRB's northern section. Variations in precipitation and pumping patterns have had an impact on the water levels in the Cretaceous aquifer (Georgia

DNR, 2004). Pumping from the Cretaceous aquifer may have led to a noticeable effect on the flow of streams in many river basins. Counties including Dooly Lee, Macon, Marion, Stewart, Sumter, Taylor, and Webster—all located in the Upper Flint area just below the Fall Line—rely on the aquifer for agricultural irrigation. Near the Fall Line, the Cretaceous aquifer system is unconfined, but becomes constrained when the Claiborne and Clayton aquifer systems begin. Wells in this aquifer usually range from 30 to 750 feet and produce between 50 and 1,200 gallons per minute (GPM) (Gordon and Painter, 2018).

The Clayton aquifer is located above the Cretaceous aquifer, composed of sand in the north and limestone in the south. It is a highly active aquifer located in the lower FRB's northwest corner. Unlike other aquifers, it has a tiny outcrop region and therefore receives little recharge from rainfall. The combination of Clayton's high productivity and limited recharge area has led to a precipitous drop in its water levels (Georgia DNR, 2004). Well depths in this aquifer vary from 400 to 800 ft, while yields vary between 250 and 600 GPM but can exceed 2,150 GPM (Gordon and Painter, 2018).

The Claiborne aquifer lies under the Clayton aquifer. Similar to the Cretaceous, it is a generally sandy aquifer. However, it includes more fine-grained sediment, making it less productive in the northern part of the lower FRB than the Cretaceous. The Claiborne aquifer is highly productive in parts of Sumter, Dooly, and Lee counties, and is relied upon for industrial and agricultural water uses (Georgia, 2004). Precipitation and local and regional pumping activity have the greatest influence on water levels. The Claiborne aquifer has a greater outcrop area than the Clayton when there is adequate rainfall. Well depths vary from 20 to 450 ft. The yield varies between 150 and 600 GPM, but can exceed 1,500 GPM (Gordon and Painter, 2018). The groundwater in the Claiborne aquifer is typically of the hard calcium bicarbonate form.

The Floridan aquifer, which located above the Claiborne aquifer, is one of the world's most active. It is composed of a very fossiliferous limestone, and has a high degree of secondary porosity and permeability (Georgia, 2004). The Floridan aquifer is spread over most of the Dougherty Plain, and therefore recharges fully each year, provided there is adequate rainfall (Miller, 1986). The aquifer typically recharges if rainfall is adequate within the year (Clarke et al., 1990). Water well depths vary between 40 and 900 ft, and yields range between 1,000 and 5,000 gallons per minute, with the potential to reach 11,000 GPM (Gordon and Painter, 2018). The detail of each aquifer in Georgia is organized and listed in table 1.1.

Table 1.1 Aquifer Description

Aquifer	Description	Depth (ft)	Yield (Gal/min)	May exceed (Gal/min)
Surficial aquifer	Unconsolidated sediments and residuum; unconfined	11 - 300	2 - 25	75
Upper and Lower Floridan aquifers	Limestone, dolomite, and calcareous sand; confined	40 - 900	1,000 - 5,000	11,000
Claiborne aquifer	Sand and sandy limestone; confined	20 - 450	150 - 600	1,500
Clayton aquifer	Limestone and sand; confined	40 - 800	250 - 600	2,150
Cretaceous aquifer	Sand and gravel; confined	30 - 750	50 -1,200	3,300
Crystalline-rock aquifers	Granite, gneiss, schist, and quartzite; confined and unconfined	40 - 600	1 - 25	500

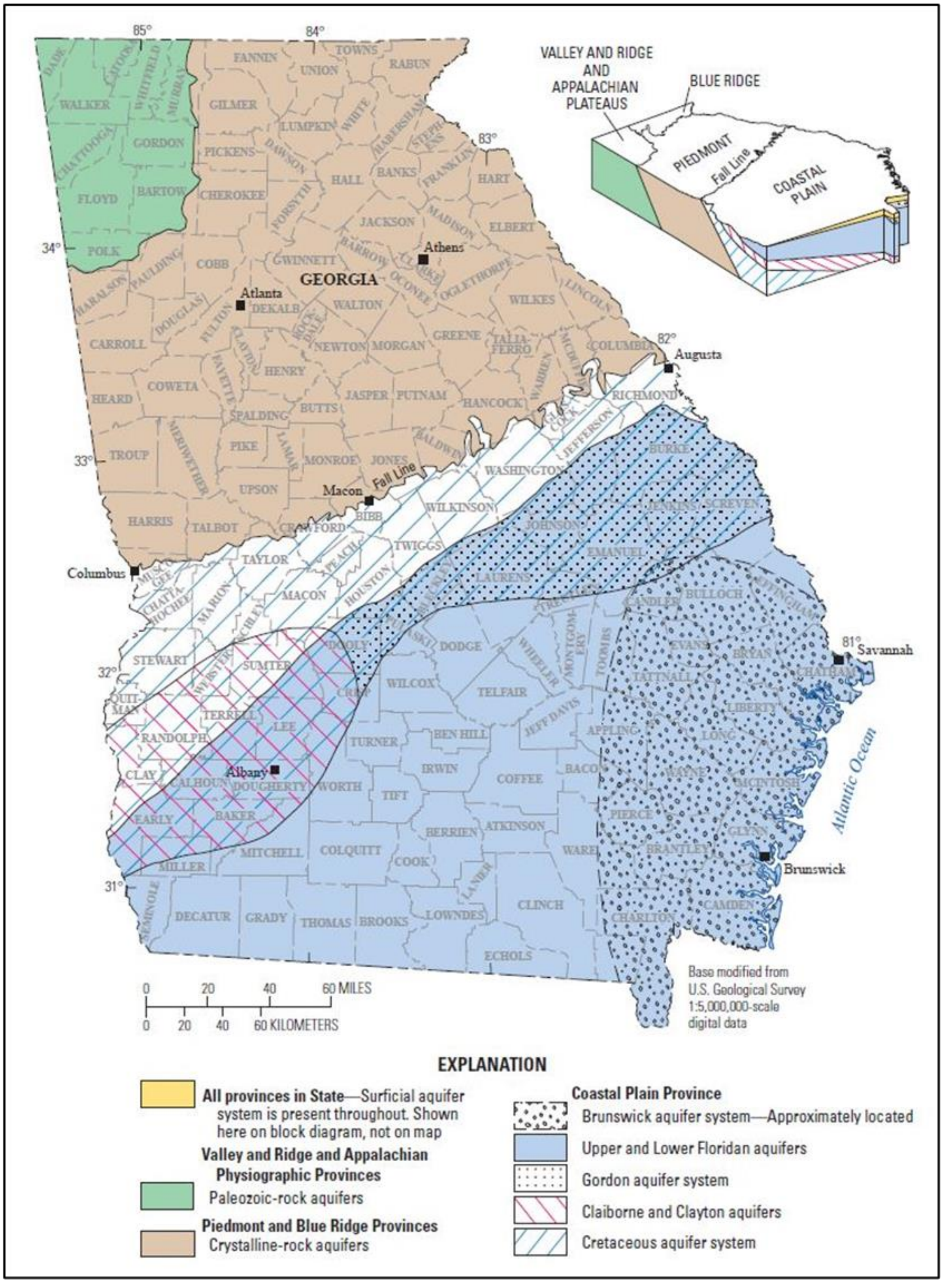

Figure 1.3 Major Aquifers in Georgia (Gordon and Painter, 2018)

1.3 Surface and Groundwater Connection:

Understanding the nature of groundwater and surface water connections in the Flint River Basin is important, as hydrologic interaction between surface and groundwater has become a point of contention in the context of Georgia drought management. Groundwater management is linked to management of surface waters, especially in regions such as southwest Georgia, where groundwater provides baseflow and serves as the primary source of agricultural water use.

Groundwater and surface water are not separate elements of the hydrologic system; they coincide across various physiographic and climatic landscapes. Thus, the growth or contamination of one often affects the other (Sophocleous, 2002). Reduced streamflow can change river morphology, decrease assimilative capability, change stream temperature, endanger aquatic biota, and reduce nutrient loading to downstream populations (Golladay et al. 2004). Since surface water and groundwater are hydraulically connected in southeastern Coastal Plain streams, they must be considered components of the same hydrologic structure when dealing with water management problems in the Coastal Plain area. Groundwater release from the Upper Floridan aquifer helps restore baseflow. The resulting streamflow provides thermal refuge for marine life in times of draught, and provides a supply of high-quality water that helps reduce the impact of pollution drainage directly into the river (Opsahl et al. 2003).

1.4 Agricultural Water Usage

In the Flint River Basin (FRB), more water is used to irrigate crops than in any other region in Georgia. This is especially the case during drought seasons. Since the 1970s, when center-pivot irrigation systems were introduced, the Upper Floridan aquifer has become the main irrigation water supply in southwestern Georgia. Between 1970 and 1976, groundwater withdrawals for irrigation increased by more than 100% in Georgia. Around 80% of the irrigation water used in the Lower FRB is derived from the Upper Floridan aquifer (Hicks et al., 1987). The primary crops grown in the FRB are corn, cotton, peanuts, and soybeans (Wolfe and Stubbs, 2013). According to the USDA Agricultural Census, the farmland in FRB had 1,520,252 acres, but only 625,035 acres irrigated (USDA, 2013).

Agricultural irrigation in the FRB encompasses as much as 90% of the water used during the April-September growing season (Couch and McDowell, 2006). During this period, groundwater withdrawals for irrigation contributed to reducing steam flow in the FRB (Torak and McDowell, 1995; Albertson and Torak, 2002). Approximately 160,000 acres are irrigated using surface water in the FRB, while around 403,000 acres are irrigated using groundwater (Gordon and Painter, 2018). With the exception of the Upper Flint River basin, the FRB relies heavily on groundwater. These withdrawals totaled 501 MGD in 2010, accounting for 84% of all self-supplied water withdrawals in the FRB. Agricultural withdrawals accounted for 80% of groundwater usage (Lawrence, 2016). These agricultural withdrawals were most significant in the Lower Flint River (143.4 MGD), Spring Creek (118.2 MGD), and Ichawaynochawar Creek (96.59 MGD) sub-basins, which accounted for 71% of all agricultural withdrawals in the FRB (Lawrence, 2016). The remaining 29% of withdrawals came from the Middle Flint River sub-basin (71.25 MGD), Kinchafoonee-Muckalee Creek (64.08 MGD), and the Upper Flint River sub-basins (7.9 MGD; Lawrence, 2016).

An annual average of nearly 474 MGD of groundwater and 200 MGD of surface water was withdrawn from the Flint River Basin in 2010 (Lawrence, 2016). A small percentage of water is withdrawn from the surficial aquifer system in the FRB. Most of the groundwater is withdrawn from the Floridan aquifer. Table 1.2 illustrated the percentage of groundwater withdrawal from aquifers in each sub-basin (Lawrence, 2016).

Table 1.2 Resource of groundwater in sub-basins

Sub-Basin	Crystalline-rock	Cretaceous	Claiborne	Floridan	Clayton
Upper Flint River	84%	16%	-	-	-
Middle Flint River	-	26%	28%	26%	20%
Kinchafoonee-Muckalee Creek	-	20%	20%	2%	58%
Lower Flint River	-	-	10%	80%	10%
Spring Creek	-	-	25%	65%	10%
Ichawaynochaway Creek	-	-	40%	20%	40%

1.5 Endangered Species in Flint River:

Over the last decade, the Flint River has been listed as one of the most endangered rivers in the United States (Gagnon et al., 2004). Withdrawals of surface and groundwater in the FRB hurt stream ecology and the habitat of endangered aquatic species. Maximum irrigation pumping in the Lower Flint occurred during periods of reduced summer flows, exacerbating low-flow conditions such as raised stream temperatures and decreased dissolved oxygen levels (Gagnon et al., 2004). Historically, the lower Flint River basin tributary streams had a diverse mussel fauna, including at least 29 species, six of which were native to the Flint River basin (Clench and Turner, 1970). The US Fish and Wildlife Service (USFWS) has designated six of these mussel fauna as protected species in the FRB. Due to habitat destruction, four species have been listed as endangered, and two as threatened under the the Endangered Species Act. The two threatened species are the purple bankclimber (Elliptio sloatianus) and the Chipola slab shell (Elliptio chipolaensis). The four endangered species includes the fat threeridge (Amblema neislerii), oval pigtoe (Pleurobema pyriforme), shinyrayed pocketbook (Lampsilis subangulata), and Gulf moccasinshell (Medionidus penicillatus). Mussels process nutrients in freshwater environments and thus provide a valuable service to the ecosystem (Howard and Cuffey, 2006). The US Fish and Wildlife Service designated 1,863 kilometers of riverways in the lower ACF as Valuable Habitat for federally listed mussels due to low flows, extreme drought, and diminishing mussel populations (Rugel et al. 2016). Additionally, Lower Flint has a significant number of gulf striped bass. During summer, the bass also seek thermal refuge in the cold waters of Blue-hole Springs, which are dependent on sufficient ground-water discharge. Groundwater withdrawals can decrease aquifer head, reduce spring flow, and reduce or eliminate thermal refuge for bass. Surface water withdrawals have a more direct effect than groundwater withdrawals (Couch and McDowell, 2006).

1.6 Climate in Flint River Basin:

The average annual rainfall in the Flint River basin is between48 to 57 in/yr. Most precipitation occurs from early November to mid-April (UGA Weather Network, 2020). Extreme temperatures range from as low as 10°F to as high as 110°F, but usually last no longer than a few days. In the Upper Flint region, the average temperature for the month of January ranges between 31°F and 55°F. The average temperature for July ranges between 67°F and 96°F. In the Lower Flint region, the average temperature for January ranges from 34°F to 62°F. The average temperature for July ranges from 71°F to 96°F (UGA Weather Network, 2020). On the other hand, droughts are a common phenomenon in Georgia's climate, and the state has experienced prolonged drought conditions in the following years: 1986-1988, 1998-2002, 2007-2009, 2011-2013, and 2016-2017 (NDMC, 2019).

1.7 Moratorium on New Permit Applications in Flint River Basin:

In October 1999, Georgia EPD initiated the Flint River Basin Water Development and Conservation Plan ("the Plan") in response to prolonged drought and increased the number of farm-use permit applications from southwest Georgia (Couch and McDowell, 2006). Meanwhile, scientific studies predicted severe impacts on streamflow in the FRB owing to withdrawals from streams and from the Floridan aquifer. The Plan was designed to efficiently manage the water resources in the FRB, while sustainably meeting the irrigation water needs of the regional farmers.

The goals of the Plan, combined with the need to protect drought-year streamflow, required a much more precise evaluation of farm-use applications. Initiation of this plan allowed Georgia EPD to suspend issuance of permits until plan completion, after which time all permits had to be consistent with the Plan. EPD faced pressure to carefully and accurately evaluate and process a large number of farm-use permit applications. In addition to this pressure, from 1998 through 2002, Georgia experienced an ongoing drought. One of the responses to the water problem was the implementation of a moratorium on the farm-use permit application for use of the Floridan aquifer in southwest Georgia and on all agricultural surface water withdrawal permits for the entire Flint River (Couch and McDowell, 2006). This moratorium would remain in place until the FRB Plan was adopted.

Before the period 1988–91, the applications for farm-use permits received by EPD were fewer than 200 per year. During the period 1988–91, the number of applications exceeded 15,000. However, after 1991, the rate of application submittal greatly declined until 1999, when the permit moratorium was announced (Couch and McDowell, 2006). Prior to the moratorium, farm-use permits in southwest Georgia were easily obtained. No market existed in Georgia to openly trade water use permits. The moratorium imposed in 1999 had a negative effect and created scarcity for the quantity of available irrigation water in the FRB (Spurgeon and Mullen, 2005). Agricultural production is the largest use of water in the FRB. Agriculture is the economic engine of southwest Georgia, and water is necessary for successful agriculture. For this reason, the permit moratorium was only a temporary aspect of the Plan (Couch and McDowell, 2006). Because agriculture will continue to be the biggest use of water for the foreseeable future, Georgia EPD needed to develop long-term water management strategies in the Plan. In 2006, the moratorium on new farm-use water permits was lifted after the Plan was released.

In July 2012, the Georgia EPD placed the second moratorium on certain new permit applications for groundwater withdrawal from the Upper Floridan aquifer, as well as on permit applications for surface water pumping from the Spring Creek, Ichawaynochaway Creek, and Muckalee Creek subbasins in the FRB. Additionally, the moratorium prohibited modification of current permits to increase withdrawals or expand the number of irrigated acres. Aquifers under the Upper Floridan, such as the Claiborne and Cretaceous, may become viable alternative groundwater sources in the future, as fewer wells have been drilled in these aquifers. However, data on their respective heights, thicknesses, water quality, and water-bearing characteristics are scarce (Gordon and Gonthier, 2017).

1.8 Irrigation Reduction Auction in 2001 and 2002 Background and Result:

In 2000, the Georgia legislature passed the Flint River Drought Protection Act (O.C.G.A. 12-5-540-550) in response to the state entering its third consecutive year of drought. The Georgia EPD was worried that the current water use permits would reduce river flows. This would be detrimental to Basin ecological environments in general, and endangered species in particular. The Drought Protection Act was designed to decrease irrigated acreage during the drought period. If a drought is declared, the Georgia EPD Director must determine the number of acres to be removed from irrigation to protect the river flows (Petrie et al., 2004). The Director also implements an auction-like process in which farmers voluntarily forego irrigation lands covered by their water use permit for the drought year in exchange for a one-time payment.

The first auction was conducted on March 17, 2001, at eight places in the FRB. On the day before the auction, qualified permit holders could register at any one of the eight auction locations. At the start of the auction, permit owners were asked to submit an offer indicating per-acre price at which they were willing to suspend irrigation on all acres covered by the approved permit. If the offer was accepted, the participant received their proposed per-acre price multiplied by the number of acres covered by the permit (Petrie et al., 2004). In cases where offers are accepted, farmers are still free to plant crops their land, but must forego irrigation on the indicated acreage in exchange for the payment. While planting without irrigation is possible, harvest yields suffer, so it is unlikely the land associated with an accepted offer will be used for agricultural purposes. There were five rounds of this back-and-forth auction in 2001, with the EPD director ultimately deciding which offers to accept or reject, beginning with the lowest bids.

The first irrigation reduction auction had an available budget of $10 million and an acreage target of 100,000 acres (Petrie et al., 2004). The EPD's target objective was to pay an average of $100 per acre to reach the goal of 100,000 acres ($10 million/100,000 = $100/acre). Qualified participants were limited to those with surface permits; groundwater permit holders were barred from participating in the program at that year. Finally, 576 permits covering a collective 98,170 acres were declared eligible for participation in the 2001 auction (Petrie et al., 2004). Of those eligible participants, only 194 farmers registered to have accepted offers for 347 permits covering a total of 61,806 acres (Petrie et al., 2004).

About 85% of the acreage was offered at $100 to $500 (Petrie et al., 2004). In the fifth and final round, the EPD director decided to accept all offers at $200/acre or less. A total of 33,006 acres, including 34% of eligible acres or 53% of registered acres, were removed from irrigation at a cost of $4,478,842. The implied average price therefore was $135.70 per acre ($4,478,842/33,006 = $135.70/acre; Petrie et al., 2004).

686 permits were declared eligible for the 2002 auction (Petrie et al., 2004). In this auction, the Georgia EPD notified all eligible participants that it would entertain all offers of $150 per acre or less. The lowest-priced offers were approved first until the target acreage was approached. Overall, a total of 40,861 acres were removed from irrigation, and the total cost amounted to $5,228,574. The average price was $127.96/acre ($5,228,574/40,861 acres = $127.96/acre; Petrie et al., 2004). The average accepted price was lower in the 2002 auction than in 2001 ($127.96/acre less than $135.70/acre). The amount of removed irrigation acreage in 2002 was also more than in 2001 (40,861 acres versus 33,006 acres).

Both auctions succeeded in removing farmland from irrigation, but the auctions conducted under the Act were noticeably problematic and inconsistent. The eligibility requirement of the first auction stipulated only that participants own a surface-water permit, with no condition of recent use. As a result, many participants were paid for land which had long been left fallow or which was not typically irrigated in the first place. This loophole was closed in the 2002 auction, as only limited permit holders who had irrigated in the past three years were allowed to participate. Both the 2001 and 2002 auctions failed to remove from irrigation agricultural land which was responsible for the greatest water use (Couch and McDowell, 2006). Additionally, both auctions allowed surface water permit holders to participate and excluded groundwater permit holders.

Nevertheless, in 2006, the EPD modified the regulations to include groundwater permit holders as qualified participants (Couch and McDowell, 2006).

1.9 Problem Statement:

In 2001, the Georgia legislature enacted the Flint River Drought Protection Act to protect streamflow in a year of significant drought. Reduced streamflow posed a threat to the ecological environment–endangered species in particular—in the FRB. The EPD implements an auction-like process in which farmers voluntarily forego irrigation on the lands covered by their water-use permit in exchange for a one-time payment. After two irrigation reduction auctions in 2001 and 2002, part of the farmland in the FRB was successfully suspended from irrigation, but this was not without regional economic impacts.

In 2006, Georgia EPD issued the FRB Plan, which outlines development and conservation for the FRB. The Plan summarizes the irrigation reduction auctions of 2001 and 2002 and mentions the program's inefficiency. In 2001 and 2002, both auctions failed to remove from irrigation agricultural land which was responsible for the greatest water use. One of the recommendations provided by EPD was that the state should consider using existing wells or installing and operating deeper wells ("Source switching") during extreme droughts to substitute the use of surface water in maintaining streamflow and protecting endangered species (Couch and McDowell, 2006).

Floridan aquifer in the FRB is relatively close to the land surface. There is a potential for reductions in streamflows due to groundwater withdrawals from Floridan aquifer. This concern is exacerbated during drought conditions when streamflows are much lower than usual and irrigation rates are high to maintain viable crops. Aquatic wildlife is adversely affected as water levels in rivers decrease, and smaller streams may dry up completely (L. Elliot, Jaime. P and Jacob La., 2008). In addition to the Floridan aquifer, the Lower FRB is also home to the Claiborne and

Cretaceous aquifers. Withdrawals from aquifers other than the Floridan do not significantly impact streamflow (Couch and McDowell, 2006). Claiborne aquifer is a viable alternative aquifer to the Floridan, although well yields rarely match those of Floridan aquifer wells (McFadden, 1983). Source switching could be an alternative solution for irrigation reduction auction. However, a deeper well is more susceptible to breakages and, because these aquifers have lower yields than the Floridan, they may more readily run dry if over-subscribed.

1.10 Objective:

The overall objective of this paper is to compare the cost-effectiveness of two water management policies: irrigation reduction auction and source switching. A methodology will be developed to estimate the expected present value of the cost of these two water conservation policies over a 25-year time horizon. The study area is the lower FRB, and the cost comparisons are based on a standard 150-acre field using currently available data. The methodology will account for the likelihood that an auction will need to be held and the probability that a well switched to a deeper and lower-yielding aquifer will be inoperable during the growing season.

Chapter 2: Methodology

2.1 Introduction:

In this chapter, a methodology is introduced to estimate the expected present value of cost for two water management policies: an irrigation reduction auction and source switching. While both of these policies aim to avoid steam flow impacts from irrigation withdrawals during times of drought, the methodology developed here can be used to determine which is more cost-effective.

2.2 Present Value of Policy Costs

In this study, we compare the economic costs associated with two policy options for protecting water resources during drought: irrigation reduction auctions and source switching. For both policies, the costs were estimated for a standard 150-acre field in Georgia. The present value of the costs of each policy over a 25-year time horizon is shown in equation 2.1.

$$PV_{p,T} = \sum_{t=0}^{24} \frac{C_{p,t}}{(1+r)^{t}} \qquad (2.1)$$

$PV_{p,T}$: Present value of policy p from years 0 to 24

$C_{p,t}$: Cost of policy p in year t

r: Discount rate

2.3 Costs of Irrigation Reduction Auctions

The costs of irrigation reduction auctions include both direct payments to farmers and regional economic impacts resulting from taking a 150-acre field out of production. Because the regional economic impacts can vary based on the location of the field, cost estimates for the irrigation reduction auctions are developed at the county level, as shown in equation 2.2.

$$C_{Auction,c,t} = P_{Auction,t} + EI_{Auction,c,t} \qquad (2.2)$$

$C_{Auction,c,t}$: The cost of an auction in county c, year t

$P_{Auction,t}$: Auction direct payments in year t

$EI_{Auction,c,t}$: Regional economic impact of an auction in county c, year t

While the auction payments are a distinct cost, the regional economic impact has several components. First, there is the reduction in the value of agricultural production, also known as the direct economic impact ($EI_{Ag\ Direct}$), resulting from the fallowing of a field. Next, the lost economic activity in the agricultural sector affects the purveyors of goods and services needed to (a) prepare the field; (b) sow, grow, protect, and harvest the crop; and (c) process, store, market, and distribute the harvested product. These impacts are referred to as the indirect economic impact ($EI_{Ag\ Indirect}$). However, the firms and employees that support agricultural production also purchase goods and services outside the agricultural sector (e.g., gasoline, electricity, accountants, restaurants), so when the agricultural sector expands or contracts there are also effects on the larger economy. These are referred to as the induced economic impact ($EI_{Ag\ Induced}$). Furthermore, the contraction (expansion) of economic activity in the agricultural sector subsequently leads to a reduction (increase) in tax revenues (ΔTR). Note that from a policy cost perspective, a reduction in tax revenues is a positive cost.

There is, however, a counterbalance to the lost economic activity of the agricultural sector from the auction—the farmer receives a direct payment that boosts household income. That payment is a direct cost of the auction in year t ($P_{Auction,t}$), but it also boosts household income for the farmer and generates indirect and induced economic impacts as the farmer spends that money. That spending also ultimately affects tax revenues. These costs are accounted for in equation 2.3:

$$EI_{Auction,c,t} = (EI_{Ag\ Direct,c,t} + EI_{Ag\ Indirect,c,t} + EI_{Ag\ Induced,c,t} + \Delta TR_{Ag,c,t}) - (EI_{HH\ Direct,c,t} + EI_{HH\ Indirect,c,t} + EI_{HH\ Induced,c,t} + \Delta TR_{HH,c,t}) \quad (2.3)$$

$EI_{Ag\ Direct,c,t}$: Direct economic impact due to the change in the value of agricultural production in county *c*, year *t*

$EI_{Ag\ Indirect,c,t}$: Indirect economic impact due to the change in value of agricultural production in county *c*, year *t*

$EI_{Ag\ Induced,c,t}$: Induced economic impact due to the change in value of agricultural production in county *c*, year *t*

$\Delta TR_{Ag,c,t}$: Change in tax revenue due to the change in value of agricultural production in county *c*, year *t*

$EI_{HH\ Direct,c,t}$: Direct economic impact due to the change in value of household income in county *c*, year *t*

$EI_{HH\ Indirect,c,t}$: Indirect economic impact due to the change in value of household income in county *c*, year *t*

$EI_{HH\ Induced,c,t}$: Induced economic impact due to the change in value of household income in county *c*, year *t*

$\Delta TR_{HH,c,t}$: Change in tax revenue due to the change in value of household income in county *c*, year *t*

It is important to remember that the costs of the auction are realized only if the auction is actually held. So when we consider the cost of the auction as a policy, we need to consider the expected county-level cost of the auction (i.e., the sum of the yearly auction cost times the probability of the auction being held in any given year). The expected county-level cost of the auction over a 25-year horizon is represented by equation 2.4:

$$E\left[C_{Auction,c}\right] = \sum_{t=0}^{24} Pr(Auction_t) \times (P_{Auction,t} + EI_{Auction,c,t}) \qquad (2.4)$$

2.4 Costs of Source Switching

In this study, source switching refers to switching either from a surface water source to a groundwater source, or from a more hydrologically connected groundwater source to a less hydrologically connected groundwater source. The aquifer system in the Lower Flint River Basin is naturally stratified, with the deeper aquifers being less hydrologically connected to the surface water than are the shallower aquifers. As such, source switching in this study entails digging deeper wells.

Digging deeper wells generates both fixed and variable costs. The fixed costs (FC) are the costs of drilling, lining, and capping the well. The variable costs (VC) of source switching are the extra energy costs required to pump water from a greater depth. Because one must incur these fixed and variable costs when source switching (a new well must be dug and more energy must be expended to raise water from a deeper well), in this study we refer to these as certain costs. Both FC and VC are functions of well depth, although the FC are a function of the actual depth of the well (*Depth*) while the VC are a function of the depth of the new well compared to the old well (*ΔDepth*)[1] and the amount of water pumped. The certain costs of source switching are shown in equation 2.5:

$$Certain\ cost_{Switch,c,t} = FC_{c,t}(Depth_c) + VC_{c,t}(\Delta Depth_c, Water_{c,t}) \qquad (2.5)$$

There are, however, other costs that may or may not be incurred by owners of a deeper well. As a well gets deeper, there are more opportunities for breakages or malfunctions. More importantly, the deeper aquifers in the lower FRB have lower yields than the Floridan aquifer

[1] If the original source is surface water, then the VC are also a function of the depth of the well, as the original "well" had no depth.

(see Table 1.1.). As such, wells in those aquifers have a higher likelihood of running dry as the number of wells withdrawing from them increases, especially if they are concentrated in a relatively small area. In this study, we refer to a well that is inoperable, either through over-drafting or due to breakage or malfunction, as "well failure." We consider the costs of well failure to be an uncertain cost. The costs of source switching consist of the certain and uncertain costs, as shown in equation 2.6:

$$C_{Switch,c,t} = Certain\ cost_{Switch,c,t} + Uncertain\ cost_{Switch,c,t} \quad (2.6)$$

Although the economic impacts of well failure are independent of well depth, the probability of failure is not. The probability of well failure can, in fact, be considered an increasing function of the depth of the well. Given that, we can rewrite equation 2.6 as the expected value of source switching and a function of well depth:

$$E\left[C_{Switch,c,t}(Depth_c)\right] = FC_{c,t}(Depth_c) + VC_{c,t}\left(\Delta Depth_c, Water_{c,t}\right) + PrF(Depth_c) \times EI_{Failure,c,t} \quad (2.7)$$

In equation 2.7, $FC_{c,t}$ and $VC_{c,t}$ are defined as above, *PrF* is the probability of well failure, and $EI_{failure,c,t}$ is the regional economic impact of well failure in county *c* at time *t*. As $FC_{c,t}$, $VC_{c,t}$, and *PrF* are all increasing functions of well depth, the costs of source switching also strictly increase with well depth. It is important to note, however, that the costs of source switching are also a function of the economic impact of well failure. The economic impact of well failure reflects both the productivity of the land in the county and the strength of the economic linkages between farm production and other sectors of the economy. As such, a shallower well in one county may have higher expected costs of source switching than a deeper well in another county.

2.5 Comparing Policy Costs

Cost-effectiveness is an economic measure used to compare alternative options for achieving a given objective. Cost-effectiveness is, essentially, the cost of implementing the option divided by the units of desired outcome generated by the option. For example, a business firm can calculate the cost-effectiveness of a marketing strategy by dividing the cost of the strategy by the number of sales that strategy is likely to generate. The firm could do the same for alternative marketing strategies and then determine the most cost-effective among them.

In this study, we compare two water management policies that will have the same outcome—namely, the avoidance of stream-flow impacts associated with the irrigation withdrawals of a 150-acre field in the Lower Flint River Basin. The irrigation auction accomplishes this goal by prohibiting water withdrawals, whereas source switching accomplishes it by diverting irrigation withdrawals into aquifers that are not hydrologically connected to the streams. Because the two policies have the same outcome, the denominator of their respective cost-effectiveness measure is the same and can, therefore, be ignored. The relative cost-effectiveness of the two policies is determined entirely by the relative cost of each.

Equations 2.4 and 2.7 represent the expected costs of each policy. The challenge is to find the conditions under which one policy is unambiguously more cost-effective than the other. We begin by equating the present value of the expected costs of the policies, as shown in equation 2.8:

$$\sum_{t=0}^{24} Pr(Auction_t) \times (P_{Auction,t} + EI_{Auction,c,t}) / (1+r)^t = \sum_{t=0}^{24} \big[FC_{c,t}(Depth_c) + VC_{c,t}(\Delta Depth_c, Water_{c,t}) + PrF(Depth_c) \times EI_{Failure,c,t}\big] / (1+r)^t \qquad (2.8)$$

For a given probability of having an auction, equation 2.8 can be rearranged to find the probability of well failure for which the present value of expected costs over a 25-year horizon is the same. We refer to this as the threshold probability of well failure (*PrF**). If the actual probability of well failure is greater than *PrF**, then the auction has a lower present value of expected costs than source switching—in other words, the auction is more cost-effective. Source switching is more cost-effective when the probability of well failure is less than *PrF**.

We can identify *PrF** for any given likelihood of having an auction. In the past 20 years, for example, there have been two irrigation reduction auctions, so setting Pr(auction) to 10% may seem reasonable. However, there have not been any auctions in the last 18 years, so setting Pr(auction) considerably lower than 10% may also seem reasonable.

Alternatively, we can use equation 2.8 to identify, for a given PrF, the probability of having an auction that equates the present value of expected costs for the two policies (*PrA**). If the likelihood of needing to hold an auction in any given year is greater than *PrA**, then source switching is more cost-effective, and vice versa.

We can also use equation 2.8, with a slight modification, to investigate a different question. Imagine that the state of Georgia decides to pay for source switching in year 0. By doing this, the state has avoided the costs of an auction in the future. But the present value of the costs of the auction depends critically on when in the future the auction is held. If the auction is held in year 0 the present value of the cost is much higher than if the auction is held in year 20, due to discounting. We can calculate a unique *PrF** that equates the present value of expected costs of source switching implemented in year 0 to the present value of the costs of an auction held in any given year of the 25-year horizon.

2.6 Calculating Auction Costs

As shown in equation 2.2, the auction has two major cost components: direct payments and regional economic impacts. The regional economic impacts can be further broken down into direct, indirect, induced, and tax revenue effects associated with lost agricultural production and direct payments from the auction. The regional economic impacts are estimated using IMPLAN from 2012.

2.7 Direct Auction Payments

The direct auction payments are straightforward to calculate. We simply inflate the average payment per acre from the 2002 auction to the baseline year of 2012.

2.8 Regional Economic Impacts

Based on the direct economic impacts of a policy, IMPLAN generates county-level estimates of indirect and induced effects as well as changes in tax revenues. The task at hand, then, is to determine the direct economic impacts of taking a standard 150-acre irrigated field out of production in each county.

Irrigated land in the Lower Flint River Basin is dominated by four major row crops: cotton, peanuts, corn, and soybeans. To estimate the lost value of production from a standard 150-acre field in each county, we calculate the share of harvested acres for each of these crops in the county using equation 2.9. We then multiply each share by 150 acres, the crop price, and the yield, as in equation 2.10, to get the direct economic impact associated with the crop. Adding up the crop-specific direct economic impacts gives the total direct economic impact of taking the field out of production.

$$S_{c,y} = \frac{HA_{c,y}}{\sum_Y HA_{c,y}} \qquad (2.9)$$

$$EI_{Ag\ Direct,c,y,t} = S_{c,y} \times 150 \times P_{y,t} \times Q_{y,t} \qquad (2.10)$$

$$EI_{Ag\ Direct,c,t} = \sum_Y EI_{Ag\ Direct,c,y,t} \qquad (2.11)$$

$S_{c,y}$: Share of crop *y* in county *c*

$HA_{c,y}$: Harvested acres of crop *y* in county *c*

$P_{y,t}$: Price of crop *y* in year *t*

$Q_{y,t}$: Yield per acre of crop *y* in year *t*

The direct household economic impacts of the auction payments are simply the payment per acre times 150 acres. The indirect and induced economic impacts and the changes in tax revenues associated with these payments are generated by IMPLAN.

2.9 Calculating Source Switching Costs

As shown in equation 2.6, the costs of source switching consist of certain and uncertain costs. The certain costs are FC and VC, and the uncertain cost is the economic impact of well failure. The regional economic impact of well failure is also estimated by IMPLAN from 2012.

2.10 Fixed Cost

The FC of source switching is the cost of drilling, lining, and capping the well. Equation 2.12 shows the estimate of FC, where $C_{Drilling,c,t}$ is the cost per foot of drilling, lining and capping the well, and $Depth_c$ is the average depth (feet) to the aquifer in county c.

$$FC_{c,t} = C_{Drilling,c,t} \times Depth_c \qquad (2.12)$$

2.11 Variable Cost

The VC is a function of the depth of the well and the amount of water pumped. To estimate the marginal cost of pumping water from different depths, we modify the engineering relationship among depth, pressure, and total dynamic head (TDH) in Rogers (1999), to reflect the change in pumping costs due to source switching:

$$\Delta TDH_c = psi \times 2.31 + \Delta Depth_c \qquad (2.13)$$

Where *psi* is the pumping pressure and $\Delta Depth_c$ is the difference between the depth to the water table of the new source and the original source. If the original source was surface water,

$\Delta Depth_c$ is simply the depth to the water table of the aquifer. The value of *psi* is taken from the literature (Rogers, 1999).

Equation 2.14 calculates the amount of water pumped, in acre-feet, to irrigate a standard field that has four selected crops.

$$Water\ pumped_{c,t} = \sum_{y=1}^{4} WD_{c,y,t} \times 150 \quad (2.14)$$

Where $WD_{c,y,t}$ is water application rate (acre-feet/acre) for crop *y* in county *c* in year *t*.

Equation 2.15 is used to derive the extra fuel consumed due to source switching, where Fuel usage is the number of units of fuel needed to lift one acre-foot of water by one foot (unit/acre-foot/foot). Fuel usage depends on the type of fuel used.

$$\Delta Total\ fuel\ consumed_{c,t} = Fuel\ usage \times \Delta TDH_c \times Water\ pumped_{c,t} \quad (2.15)$$

The fuel used for the pump could be natural gas, electricity, or diesel, but we assume electricity is the only fuel type used in this study.

$$VC_{Switch,c,t} = \Delta Total\ fuel\ consumed_{c,t} \times P_{Electricity,t} \quad (2.16)$$

The VC of source switching is the extra pumping cost, which equals the change in total fuel consumed times the fuel price. This estimate of pumping cost is imperfect; it does not contain the cost of distribution once the water has been raised to surface level. Unfortunately, a lack of additional data prevents us from making the estimate more accurate.

2.12 Economic Impacts of Well Failure

When a well failure occurs, farmers are unable to irrigate. The inability to irrigate a field due to well failure leads to the same lost value of production as the irrigation reduction auction, and the same regional economic impact. In both cases, a field that was previously producing does not harvest any crops[2]. The regional economic impacts of well failure, then, are equal to the regional economic effects of lost agricultural production (see equation 2.3). Equation 2.17 is also estimated using the 2012 IMPLAN model for Georgia.

$$EI_{Failure,c,t} = (EI_{Failure\ Direct,c,t} + EI_{Failure\ Indirect,c,t} + EI_{Failure\ Induced,c,t} + \Delta TR_{Failure,c,t})$$
$$= (EI_{Ag\ Direct,c,t} + EI_{Ag\ Indirect,c,t} + EI_{Ag\ Induced,c,t} + \Delta TR_{Ag,c,t}) \qquad (2.17)$$

$EI_{Failure\ Direct,c,t}$: Direct economic impact of failure occurred in county *c*, year *t*

$EI_{Failure\ Indirect,c,t}$: Indirect economic impact owing to the failure in county *c*, year *t*

$EI_{Failure\ Induced,c,t}$:: Induced economic impact owing to the failure in county *c*, year *t*

$\Delta TR_{Failure,c,t}$: Change in tax revenue owing to the failure in county *c*, year *t*

2.13 Methodology Concluding Remarks

In this chapter a methodology was developed to estimate the expected present value of the cost of two water conservation policies: an irrigation reduction auction and source switching. Because the two policies generate the same end result –avoided stream flow effects from irrigation withdrawals – the relative expected present value of their costs also reflects the relative cost-effectiveness of the two policies. It was further shown how the methodology can be used to identify threshold levels for the probability of well failure and the probability of an auction that equate the cost-effectiveness of the policies. The threshold probabilities can then be used to identify the conditions under which one policy is more cost-effective than the other.

[2] Of course, the direct economic impacts of well failure depend on when the well fails. If the well fails prior to planting then the impacts are the same as the irrigation reduction auction. If the well fails after planting, however, the impacts would be reduced as the farmer has already spent money to purchase inputs. In this study we only consider well failure that occurs before planting.

Chapter 3: Data

3.1 Introduction

In the previous chapter, we developed general models for estimating the present value of expected costs for irrigation reduction auctions and source switching. In this chapter, we explain which data sources and assumptions were employed to parameterize and estimate those models for the Lower Flint River Basin in Southwest Georgia.

3.2 Establishing the Baseline Year

We designed the models developed in the preceding chapter to estimate the present value of expected costs over a 25-year time horizon. To operationalize the model, a baseline year must be established. The main consideration used in this study was the availability of data for the regional economic analyses. We estimated the regional economic impacts of both policies using IMPLAN. The most recent county-level IMPLAN data available for free[3] were from 2012. Given that, we set year 0 to 2012 and estimated the present value of the expected cost models in 2012 dollars.

3.3 Irrigation Reduction Auctions

The costs of irrigation reduction auctions have two components (see equation 2.2): direct payments and regional economic impacts. To estimate the direct payments for this study, we used the average value paid ($128/acre) to farmers in the 2002 auction. That value is inflated to

[3] IMPLAN data are extremely expensive, and funds to purchase more recent data were not available to support this study.

2012 dollars using the U.S. inflation calculator (2021), resulting in a price of $164/acre and a total payment for a standard field of $24,566 in year 0. We inflated that price at an annual rate of 3% (Federal Reserve Bank, 2021) to determine nominal payments made after year 0. We also entered the direct auction payments into the regional economic impacts as household income through $EI_{HH\ Direct,c,t}$ in equation 2.3.

Estimating the direct economic impacts from the lost agricultural production in county c in year t ($EI_{Ag\ Direct,c,t}$) requires estimates of the average share of acreage of a standard field for each crop ($S_{c,y}$). Using data from the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS), the "irrigated harvested acre" of selected crops are found in the 2012 Census of Agriculture at the county level in Georgia and used to establish the Sc,y, as shown in equation 2.9. Table 3.1 illustrates the detail of irrigated harvested acres for each crop in each county.

Table 3.1 2012 Crop Irrigated Harvested Acreage in Lower FRB (Acres)

	Corn	**Cotton**	**Peanut**	**Soybean**
Baker	6,185	11,800	9,508	370
Calhoun	6,877	5,538	14,591	516
Clay	994	3,969	1,585	810
Colquitt	1,546	24,694	7,920	153
Decatur	5,218	24,063	27,995	1,263
Dougherty	1,908	601	2,540	130
Early	5,635	13,225	13,952	1,620
Grady	3,808	1,357	2,431	322
Lee	4,119	1,160	5,964	580
Miller	5,577	11,776	11,704	1,180
Mitchell	8,661	24,082	21,555	1,229
Randolph	4,528	6,670	11,318	0
Seminole	7,621	15,087	11,781	975
Terrell	7,168	10,173	9,450	501
Worth	5,707	25,777	13,991	204

Total	75,552	179,972	166,285	9,853

From 2007 to 2012, agriculture in the FRB consisted primarily of corn, cotton, peanut, and soybean, along with pecans and supplementary horticultural products (USDA, 2014). However, we did not study pecans in this paper because pecans are perennials that take a few years to mature. The planting of pecans is considered a long-term investment as opposed to a field of soybeans that could be replaced the following year. Not watering pecans during a severe drought causes damage that could significantly affect the production of an orchard in future years.

The 2012 Census of Agriculture – County Data was used to collect the total irrigated acres in the study area. The 15 target counties had 514,166 total irrigated acres (USDA: County summary, 2012). The irrigated harvested corn, cotton, peanuts, and soybeans occupied 14.69%, 35.00%, 32.34%, and 1.92%, respectively, of total irrigated acres in the studied counties. Together, these four crops account for 83.95% of total irrigated acres in the study counties.

Calculating the direct economic impacts ($EI_{Ag\ Direct,c,t}$) requires the price ($P_{y,t}$) and yield per acre ($Q_{y,t}$) of each crop. We derive the prices and yields from the 2012 Farm Gate Value Report published annually by The Center for Agribusiness and Economic Development at the University of Georgia's College of Agricultural and Environmental Science (Wolfe & Stubbs, 2013). The average price of corn ($P_{Corn,\ 2012}$) is \$7.5 per bushel, cotton ($P_{Cotton,\ 2012}$) is \$0.91 per pound, peanuts ($P_{Peanuts,\ 2012}$) is \$0.28 per pound, and soybeans ($P_{Soybeans,\ 2012}$) is \$14.25 per bushel. The report also summarized the yield of each crop at the county level and the details shown in table 3.2.

Table 3.2 2012 Crop Yield in Lower FRB

County	Corn (Bu/Acre)	Cotton (Lb/Acre)	Peanuts (Lb/Acre)	Soybeans (Bu/Acre)
Baker	185	1,100	4,700	50
Calhoun	200	1,035	5,200	45
Clay	185	850	4,550	30
Colquitt	165	1,154	4,675	28
Decatur	205	1,175	4,700	55
Dougherty	200	1,100	5,200	44
Early	200	1,100	4,975	40
Grady	173	1,100	4,700	45
Lee	215	1,000	4,700	37
Miller	205	1,285	4,550	45
Mitchell	215	1,350	6,000	63
Randolph	205	1,200	4,880	45
Seminole	205	1,151	4,700	55
Terrell	180	1,027	4,550	37
Worth	180	1,027	4,550	37
Average	**195**	**1,110**	**4,842**	**44**

3.4 Economic Impact Analysis Using IMPLAN

IMPLAN is an input-output analysis, which quantifies the secondary demands that are served across sectors within a given regional economy due to a primary economic impact. A regional economic impact study was conducted using IMPLAN Online to determine the effect on the local economy of removing a certain acreage from irrigation. IMPLAN data is collected from a variety of publicly-available government sources, including the United States Department of Commerce, the Bureau of Economic Analysis (BEA), the United States Bureau of Labor Statistics (BLS), and the United States Census Bureau (Clouse, 2021). IMPLAN's regional economic study data for the United States is accessible at the regional level, covers several data years, and includes analysis on up to 536 industries (Clouse, 2021). The IMPLAN model takes into account industrial and commodity output, wages, labor income, household consumption, and domestic and foreign trade. Multipliers for indirect effects indicate economic activity produced along the supply chain due to the purchasing of intermediate inputs from supplier companies. By contrast, multipliers for induced effects reflect the impact of spending by businesses, employees, households, and governments. The sum of direct and indirect economic results is used to measure the overall economic impact (Clouse, 2021).

IMPLAN data can be costly, and this paper received no external funding. Luckily, the U.S. 2012 IMPLAN dataset for the state of Georgia was provided by Brian Barlow, who is the Director of Business Development at IMPLAN, with a one-month student free trial. The Georgia 2012 dataset was chosen since it was the most recent one available, and 2012 was also a year of severe drought. Counties that have both Floridan and Claiborne aquifers in the lower FRB are selected in the IMPLAN model (i.e., Colquitt, Grady, and Seminole in the Lower FRB are not included due to only having the Floridan aquifer). Each county is regarded as a distinct area of research to estimate the economic impact. It is assumed that any 150-acre field in a given county would have the same economic impact if irrigation was removed from it. The "Total Impact Summary" (employment, labor income, value-added, and output) and "State/Local Tax Revenues" IMPLAN results were used in the analysis.

Because four crops (corn, cotton, peanuts, and soybeans) represent about 84% of the irrigated acreage in the study area, the IMPLAN analysis is focused on those four crops. Each of those crops is represented by a different industry sector in IMPLAN. Cotton is the only crop for which IMPLAN Online has a specific industry sector, “Cotton farming.” The "Oilseed farming" sector was used to represent soybeans, "Grain farming" was used for corn, and "All other crop farming" was used for peanuts. Famers may continue planting on the land if they agree to the buyout offer as long as they do not irrigate (i.e., rely exclusively on rainwater), but in this study, we assume that no harvest occurs on the cropland for the entire year. Local purchasing power (LPP) was set at 100%, while output and GDP deflators were set to one. This is because setting the LPP below 100% can result in an unexpected reduction of direct results, and we want to maintain 2012 values for accuracy. The database of IMPLAN lists the "Total output" for each industry before running industry change activities, which is the initial output in table 3.3. The reduced output in table 3.3 is derived from direct economic impact ($EI_{Ag\ Direct,c,y,t}$) in equation 2.10. Table 3.3 details the initial output and reduced output for each county used for IMPLAN inputs. After we input the reduced output in the table and set all parameters mentioned above, IMPLAN analyzes and outputs the result.

The output of the IMPLAN model are estimates the regional economic impact at the county level when a standard field is out of production. The economic impact has industry, employment, and state & local tax loss. The industry loss includes value-added and reduced output value in corn, cotton, soybeans, and peanuts. The impact also has two aspects—indirect and induced. The indirect impact ($EI_{Ag\ Indirect,c,t}$) is an impact on related industries, such as reduced demand for fertilizer, transportation, and labor. The induced impact ($EI_{Ag\ Induce,c,t}$) is an impact outside the agricultural industry (e.g., gasoline, restaurants, and entertainment). Employment loss refers to the reduced number of jobs lost due to a field out of production. Tax loss ($\Delta TR_{Ag,c,t}$) includes reductions in employee compensation, proprietor income, production and export taxes, and household and corporation-related taxes.

The second economic impact (EI_{HH}) occurred after the farmer decided to suspend irrigation and received auction payment. We select household income activity in the IMPLAN model to estimate the impact. Household income activity is appropriate to model a change in income isolated from industrial production. IMPLAN will automatically deduct personal savings. Household spending of income on imported goods and services will also be treated as leakage.

The input used for activity is $24,566, which is the payment for a standard field out of production. The local purchase power has been set at 100% to make the full economic impact locally. After we set increased household income as input for each county and run activity, IMPLAN outputs indirect and induced effects ($EI_{HH, Indirect,c,t}$ + $EI_{HH, Induce,c,t}$) and tax revenue changes ($\Delta TR_{HH,c,t}$). The results of the IMPLAN analysis are listed in Appendix C.

Table 3.3 IMPLAN Inputs in Four Industries

Baker			Calhoun		
Crop	Initial output	Reduced output	Crop	Initial output	Reduced output
Corn (Grain farming)	$14,687,780	$46,199	Corn (Grain farming)	$19,697,830	$56,221
Cotton	$18,441,380	$63,589	Cotton	$14,293,560	$28,428
Peanuts (All other crop)	$15,001,980	$67,361	Peanuts (All other crop)	$13,460,340	$115,786
Soybeans (Oilseed farming)	$260,192	$1,419	Soybeans (Oilseed farming)	$174,117	$1,803
Decatur			**Dougherty**		
Crop	Initial output	Reduced output	Crop	Initial output	Reduced output
Corn (Grain farming)	$20,676,620	$20,557	Corn (Grain farming)	$2,698,419	$82,892
Cotton	$40,813,040	$65,929	Cotton	$591,013	$17,424
Peanuts (All other crop)	$25,787,120	$94,402	Peanuts (All other crop)	$1,108,766	$107,113
Soybeans (Oilseed farming)	$2,358,313	$2,536	Soybeans (Oilseed farming)	$0	$2,361
Early			**Lee**		
Crop	Initial output	Reduced output	Crop	Initial output	Reduced output
Corn (Grain farming)	$13,570,320	$36,823	Corn (Grain farming)	$14,736,340	$84,267
Cotton	$28,131,450	$57,671	Cotton	$8,848,426	$13,393
Peanuts (All other crop)	$20,462,650	$84,667	Peanuts (All other crop)	$8,422,523	$99,577
Soybeans (Oilseed farming)	$1,107,111	$4,023	Soybeans (Oilseed farming)	$1,788,171	$3,880
Miller			**Mitchell**		
Crop	Initial output	Reduced output	Crop	Initial output	Reduced output
Corn (Grain farming)	$12,045,060	$42,537	Corn (Grain farming)	$14,834,200	$37,727
Cotton	$23,202,140	$68,312	Cotton	$46,528,190	$79,920
Peanuts (All other crop)	$14,079,780	$73,970	Peanuts (All other crop)	$21,056,650	$97,824
Soybeans (Oilseed farming)	$1,094,672	$3,754	Soybeans (Oilseed farming)	$1,226,323	$2,981
Randolph			**Terrell**		
Crop	Initial output	Reduced output	Crop	Initial output	Reduced output
Corn (Grain farming)	$14,390,830	$46,379	Corn (Grain farming)	$20,163,220	$53,185
Cotton	$8,651,196	$48,523	Cotton	$23,581,660	$52,254
Peanuts (All other crop)	$10,369,210	$103,026	Peanuts (All other crop)	$10,111,410	$66,169
Soybeans (Oilseed farming)	$2,384,228	$0	Soybeans (Oilseed farming)	$2,034,887	$1,452
Worth					
Crop	Initial output	Reduced output			
Corn (Grain farming)	$14,283,260	$25,300			
Cotton	$70,074,140	$79,108			
Peanuts (All other crop)	$24,963,100	$58,532			
Soybeans (Oilseed farming)	$407,392	$353			

3.5 Source Switching

The costs of source switching can be divided into two parts (see equation 2.6): certain and uncertain costs. Certain costs also have two components: the fixed (FC) and variable costs (VC). The FCs are the unavoidable costs (see equation 2.12), and the next subsections introduce the average drilling cost ($C_{Drilling,c,t}$) and depth ($Depth_c$). The VCs are the extra energy costs to pump water from a greater depth (see equation 2.16), and the subsection lists the data source for VCs. The uncertain cost ($EI_{Failure,c,t}$) does not require additional data to estimate because the economic impact of well failure is equal to the impact of lost agricultural production from an auction, as stated in equation 2.17.

3.6 Drilling Cost Estimation

From 2010 to 2015, irrigation source switching was a noticeable trend across Georgia's agricultural regions. Irrigators in Georgia were switching from surface water to groundwater supplies (Manganiello, 2017). The transition from surface to groundwater in Georgia was due to a moratorium on new surface water withdrawals in the Flint River Basin. It prompted irrigators to explore new groundwater wells across the state. Many farmers agree that groundwater is a more reliable source that can ensure steady crop yields while reducing the risk of decreasing surface flows (Manganiello, 2017). As an alternative to reinstating irrigation buyout auctions in times of extreme drought in Georgia, the EPD could compensate farmers for switching their wells from surface to groundwater or digging deeper wells from the Floridan to the Claiborne aquifer as appropriate. This could result in more effective long-term water management strategies for streamflow in the FRB than a water permit auction, which is a more temporary option. Counties where it would be possible to switch from the Floridan to Claiborne in lower FRB are Baker, Calhoun, Decatur, Dougherty, Early, Lee, Miller, Mitchell, Randolph, Worth, and Terrell. Rather than allocate money to an irrigation reduction auction, the EPD could approach farmers and offer to pay for converting their wells from surface to groundwater or from the Floridan to another deeper aquifer.

The construction of a well on the Claiborne aquifer is slightly more complicated than the construction of a well on the Floridan aquifer because the loose sands of the aquifer must usually be screened to prevent the collapse of the well. To construct a well, a standard Claiborne aquifer well is first drilled to the surface of the aquifer and casing is installed and grouted. A hole is drilled into the aquifer and screens are placed opposite the water-producing sands, which are accurately measured from geophysical logs. Depending on the intended use of the well, the screened interval may or may not be filled with gravel. Gravel-packed wells have better yields. Following completion of drilling, the well is developed to remove drilling fluids from it as well as the aquifer (McFadden, 1983).

To determine the cost of drilling a new or deeper well, well drillers in the Flint River Basin region were contacted via email from the "Georgia Licensed Water Well Contractor" list. I received feedback from four well drilling firms in the region that provided cost estimates for drilling small and large agricultural wells. For example, the cost of constructing a 250 GPM well is normally between $27,500 and $32,500, while a 1,000 GPM well costs between $110,000 and $130,000 on average. Despite these average figures, the costs of constructing a new well will often exceed the budget by two to three times if drilling conditions are far more difficult than anticipated due to the rockiness of the underground surface, as this makes the drilling process more strenuous. Table 3.4 below illustrates some of the various costs associated with drilling a new agricultural well, the average cost per foot, and GPM.

Unfortunately, the four local well-drilling firms responded that a deeper well could not be dug directly using an existing well. Instead, an entirely new well would need to be built by drilling a deeper hole and having a longer well casing and pipe to reach the deeper source. The well pump would most likely also have to be larger, along with changes to other well equipment to fit the well hole and pumping rate dimensions. Deepening an existing well is more expensive than drilling a new well. The drilling process of a new well is also less complicated than deepening an existing well. An existing well requires extra equipment such that it can be cleaned ahead of any effort to deepen it. The cost of the cleaning process is often higher than the cost of the drilling process. Overall, the costs and time involved in essentially drilling a new well would most likely vary by county, and the aquifer depths would vary by region. The cost of source switching in Sumter County will not be the same as source switching in Calhoun County. Source switching within counties may not even be uniform as permit holders have separate permitted acres, GPM of a well, and could lie on different soil types. Nonetheless, to estimate the cost to use for simulation, the drilling cost per foot is assumed constant across all counties. Variation in estimated drilling costs across counties is solely a function of well depth.

Table 3.4 Costs of Well Drilling for One Field

Labor/Parts	Costs
Submersible pump and motor	\$10,000-\$30,000
Miscellaneous Parts	\$5,000-\$20,000
Piping and power	\$2,000-\$10,000
Water and Electrical Service Line	\$11.50 per/L. ft
Drilling Rate per foot	\$35-\$55
Pump and Related Equipment	\$110-\$130
Each GPM	\$110-\$130
Drilling per foot (All costs; $C_{Drilling,c,t}$)	\$120/V. ft

3.7 Drilling Depth Estimation

As part of the U.S. Geological Survey's (USGS) program, National Water Information System (NWIS) provides groundwater data to researchers and the public. The data is collected at over 1.5 million sites around the country. It is designed to assist in rapidly finding relevant information about water data. The types of data collected generally fit into two categories: surface water and groundwater (USGS, 2021). Surface-water data, such as gage height and streamflow, are collected at major rivers and lakes. Groundwater data, such as water quality and water level, are collected at monitoring wells and springs (USGS, 2021).

The groundwater information for the lower FRB is obtained from NWIS, including the location of the monitoring sites, site code, drilling depth/aquifer, groundwater level (below the surface), and water quality. There are two main types of monitoring sites: active sites and inactive sites. An active site has the latest information, which is updated every three hours. The inactive points are out-of-service and only have historical data but can still be used as a reference. The information about valid sites, including code, depth, water level, and period, is collected at the county level listed in Appendix D. According to the map of major aquifers in GA (see figure 1.3), the distribution of aquifers in the Upper FRB is relatively separate. Only a few aquifers overlapped in Upper FRB, and most groundwater is withdrawn from the Crystalline-Rocks or Cretaceous aquifers. It is why counties in Upper FRB are not studied in this paper, and counties in the Lower FRB with both Floridan and Claiborne aquifers are selected.

Accessing a deeper water source increases risk and the probability of failure. The actual cost of drilling is challenging to predict. Though private drilling firms typically provide a quote after an initial field exploration and aquifer test, the final price is usually much higher than the quoted price due to unpredicted failures during the drilling process. The actual cost cannot be accurately predicted due to the unpredictable position of an aquifer. Take the Floridan aquifer as an example; the drilling depths range from 10 ft to 900 ft below the surface to source groundwater. Therefore, an available way to estimate costs is to rely on the average well depth and water level in each county. The average well depths of monitoring wells are used as the drilling depth ($Depth_c$) in equation 2.12, and the differences of average water level are used as $\Delta Depth_c$ in related pumping cost estimation.

3.8 Variable Cost

VCs are the amount of water pumped from a greater depth. Equation 2.13 estimates the total dynamic head (TDH), which has three components: pressure, constant value, and depth. We used the difference of average water levels from different aquifers as the difference in depth ($\Delta Depth_c$). Around 150 feet depth in a well, the pressure is 45 *psi* (Rogers, 1999). We assumed the *psi* was constant in this study.

To calculate water pumped in equation 2.14, water application rates ($WD_{c,y,t}$) for crop *y* in county *c* in year *t* are required. We determined water application by using DSSAT model projections for each crop in each county (Hook et al., 2010). We obtained DSSAT values for major crops based on models that use the 50-year meteorological record (1958–2007) for each county or their nearest NOAA-cooperating weather station and planted at the median date recommended by the Cooperative Extension Service for each county, with runs averaged for three common soils of each county's primary soil associations (Hook et al., 2010). In the DSSAT models, the irrigation management strategy was to provide 25 mm of water whenever the soil moisture level inside the root zone decreased below 70% over the course of a growing season (Hook et al., 2010). The water application rates in the report are classified according to weather conditions, including the 10th, 25th, 50th, 75th, and 75th percentiles (Very Wet, Wet, Median, Dry, and Very Dry, respectively). We used the 50th percentile of the cumulative distribution functions of the water application rate in the simulation exercise for determining the water pumped. Appendix B lists the tables of estimated results for water application rates and water pumped.

We used equation 2.15 to calculate the extra fuel consumed owing to deeper water pumped. The only unknown component in the equation is fuel usage. The total energy needed to lift 1 acre-foot to a height of 1 foot is 2,718,144 foot-lbs. The energy needed to pump 1 acre-foot of water at a head of 1 foot is 1.55 kWh/acre-foot/foot (Rogers, 1999). Additionally, 1.55 kWh/acre-foot/foot represents the fuel input required per foot of head for each acre-foot of water pumped. The 1.55 kWh/ac-ft/ft is set on fuel usage in the equation. We assume it is constant in every county.

The price of electricity ($P_{electricity,t}$) is a required component to calculate the VCs of source switching (see equation 2.16). Georgia Power charged farm facilities $0.12/kWh on average for electricity, $0.18/kWh on-peak, and $0.06/kWh off-peak in 2021. The value is deflated to 2012 dollars using the U.S. inflation calculator (2021), resulting in $0.10/kWh on average for electricity, $0.15/kWh on-peak, and $0.05/kWh off-peak. These prices applied to individually owned farm facilities when used in the growing or the harvesting of agricultural products, livestock, or poultry (Georgia Power, 2021). We assumed all pumps in Georgia were electric and that the cost of electricity was constant in county *c*. We set the average price of electricity at $0.10/kWh in 2012 in the simulation. The tables of TDH, annual pumping fuel costs based on average electricity price, are detailed in Appendix B.

3.9 Data Concluding Remarks

In this chapter, we explain the data source and assumptions used in the methodology. Variables are set to 2012 values because we used the 2012 IMPLAN database. The data used for estimating the depth in source switching comes from monitoring wells.

Chapter 4: Results and Conclusion

4.1 Introduction

In the previous chapters, we developed general models to compare the cost-effectiveness of each policy, and explained the data sources employed by those models. This chapter presents the results of the simulation and provides some recommendations for future water management. The chapter also lists the deficiencies and limitations of the study.

4.2 Simulated Results

The simulation's purpose is to compare the relative cost-effectiveness of two water management policies during drought: irrigation reduction auctions and source switching. To explore the relationship between the probability of holding an irrigation buyout auction (*PrA*) and the threshold probability of well failure (*PrF**) over a 25-year horizon (from 2012 to 2036) we increase the *PrA* from 1% to 20%. For a given *PrA*, the corresponding *PrF** percentages are presented in Table 4.1. The first row lists the given *PrA*s, and the first column lists the 11 counties of the study are in the Lower FRB. If the actual *PrF* is less than the threshold *PrF**, then source switching has a lower present value of expected cost so source switching is more cost-effective than an auction, and vice versa.

The values of *PrF** less than zero in Table 4.1 have been bolded. Because a probability cannot be negative, the minimum actual probability of failure is zero. So, when the threshold probability of failure (*PrF**) is negative, the actual probability of failure cannot be less than the threshold. In these circumstances, a buyout auction will always be more cost effective than source switching. Focusing on Baker county in Table 4.1, we see that if the probability of holding an irrigation buyout auction (*PrA*) is 1% or less, i.e., we expect an auction to be needed once every 100 years, then the auction is a strictly dominant policy in Baker county. In fact, this is the case for every county in the study area, with the exception of Randolph county, when *PrA* is 1%.

In Decatur county, the probability of holding an auction can be as high as 6% and the auction will still be the strictly dominant policy. In Dougherty county the auction is strictly dominant up to an auction probability of 10%; that is, even if you were to hold an irrigation buyout auction every 10 years, it would still be a more cost effective option than source switching in Dougherty county.

For positive values of *PrF**, no policy is strictly dominant. However, we can get a sense of which policy is likely to be more cost effective by comparing each threshold probability of failure to its associated probability of an auction. The highlighted cells in Table 4.1 show the scenarios in which source switching will be the dominant policy as long as the actual probability of failure is simply less than the probability of holding an auction. If we assume the possibility of well failure due to breakage/well malfunction is trivial then the probability of well failure is due exclusively to the risk of over-drafting the aquifer, a risk that is dependent on the volume and location of withdrawals that are switched to the new source. As such, the probability of well failure is relatively manageable compared to the climate-driven probability of an auction.

To explore the management considerations for prioritizing source switching, we first need to understand the county-level irrigation withdrawals during times of drought.

Table 4.1 Threshold Probability of Well Failure (PrF*)

Pr(Auction) County	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%
Baker	**-2.00%**	**-0.79%**	0.41%	1.62%	2.83%	4.03%	5.24%	6.44%	7.65%	8.86%	10.06%	11.27%	12.47%	13.68%	14.89%	16.09%	17.30%	18.50%	19.71%	20.91%
Calhoun	**-1.51%**	**-0.40%**	0.72%	1.83%	2.94%	4.06%	5.17%	6.29%	7.40%	8.52%	9.63%	10.75%	11.86%	12.98%	14.09%	15.21%	16.32%	17.44%	18.55%	19.67%
Decatur	**-5.54%**	**-4.47%**	**-3.39%**	**-2.31%**	**-1.24%**	**-0.16%**	0.91%	1.99%	3.06%	4.14%	5.22%	6.29%	7.37%	8.44%	9.52%	10.59%	11.67%	12.75%	13.82%	14.90%
Dougherty	**-7.04%**	**-6.30%**	**-5.56%**	**-4.82%**	**-4.08%**	**-3.35%**	**-2.61%**	**-1.87%**	**-1.13%**	**-0.39%**	0.35%	1.09%	1.83%	2.57%	3.31%	4.05%	4.79%	5.53%	6.27%	7.01%
Early	**-0.70%**	0.34%	1.39%	2.43%	3.48%	4.52%	5.57%	6.61%	7.66%	8.70%	9.75%	10.80%	11.84%	12.89%	13.93%	14.98%	16.02%	17.07%	18.11%	19.16%
Lee	**-0.74%**	0.40%	1.54%	2.68%	3.82%	4.96%	6.10%	7.25%	8.39%	9.53%	10.67%	11.81%	12.95%	14.09%	15.23%	16.37%	17.51%	18.65%	19.79%	20.94%
Miller	**-2.00%**	**-0.83%**	0.34%	1.51%	2.69%	3.86%	5.03%	6.20%	7.37%	8.55%	9.72%	10.89%	12.06%	13.23%	14.41%	15.58%	16.75%	17.92%	19.09%	20.27%
Mitchell	**-3.86%**	**-2.73%**	**-1.60%**	**-0.48%**	0.65%	1.78%	2.90%	4.03%	5.16%	6.29%	7.41%	8.54%	9.67%	10.79%	11.92%	13.05%	14.17%	15.30%	16.43%	17.56%
Randolph	0.35%	1.47%	2.58%	3.70%	4.81%	5.93%	7.04%	8.16%	9.27%	10.39%	11.50%	12.62%	13.73%	14.85%	15.96%	17.08%	18.20%	19.31%	20.43%	21.54%
Terrell	**-0.37%**	0.72%	1.81%	2.89%	3.98%	5.07%	6.16%	7.25%	8.34%	9.42%	10.51%	11.60%	12.69%	13.78%	14.87%	15.96%	17.04%	18.13%	19.22%	20.31%
Worth	**-1.07%**	0.03%	1.13%	2.23%	3.33%	4.43%	5.54%	6.64%	7.74%	8.84%	9.94%	11.04%	12.14%	13.25%	14.35%	15.45%	16.55%	17.65%	18.75%	19.85%

Table 4.2 Amount of Irrigated Water Derived from Floridan Aquifer

County	Total Irrigated Acres	90%ile Water rate (Ai/Yr)	Water Applied (Ai/Yr)	Surface Water	Ground water	Other Sources	Irrigated Ground Water (Ai/Yr)	Surface Water (Ai/Yr)	Withdrawal from Floridan (80%)	Surface and Floridan(Ai/Yr)
Baker	30,495	14.5	442,016	11.00%	83.00%	6.00%	366,873	48,622	293,499	342,121
Calhoun	27,522	14.2	390,700	56.00%	33.00%	11.00%	128,931	218,792	103,145	321,937
Decatur	58,539	11.8	690,494	4.00%	91.00%	5.00%	628,350	27,620	502,680	530,300
Dougherty	12,971	12.2	158,135	2.00%	98.00%	0.00%	154,973	3,163	123,978	127,141
Early	34,432	11.8	407,735	23.00%	68.00%	9.00%	277,260	93,779	221,808	315,587
Lee	16,877	11.8	199,795	22.00%	70.00%	8.00%	139,857	43,955	111,885	155,840
Miller	31,721	13	411,373	1.00%	96.00%	3.00%	394,918	4,114	315,935	320,049
Mitchell	67,179	13.8	926,577	7.00%	84.00%	9.00%	778,325	64,860	622,660	687,520
Randolph	22,516	12.7	285,359	15.80%	77.90%	6.40%	222,223	45,087	177,778	222,865
Terrell	27,292	13.6	372,396	44.00%	42.00%	14.00%	156,406	163,854	125,125	288,979
Worth	47,180	10.3	484,547	25.00%	47.00%	28.00%	227,737	121,137	182,190	303,327
Total								**834,982**	**2,780,682**	**3,615,665**

4.3 Irrigation Withdrawals by County During Drought

Hook et al. (2010) produced county-level irrigation application rates for each crop under different weather conditions: very wet, wet, median, dry, and very dry. These correspond to the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles, respectively, of applied water. To get an estimate of the total irrigation withdrawals per county under drought conditions we use equation 2.14 with the 90^{th} percentile applied water rate for the county and multiply by the total irrigated acres in the county reported in the 2012 Census of Agriculture (USDA: County Summary, 2012). In addition to the water application rates, Hook et al. (2010) disaggregated these withdrawals by groundwater and surface water. In the lower FRB, the principal aquifer is the Floridan aquifer; 65–80% of groundwater withdrawal is from the Floridan aquifer (Lawrence, 2016). The upper bound 80% is used to estimate the amount of groundwater withdrawal from the Floridan aquifer for each county. Table 4.2 shows the components used to estimate the amount of irrigation water pumped from surface water sources and the Floridan aquifer. The total amount of withdrawals considered for source switching is the sum of the surface water withdrawals and withdrawals from the Floridan aquifer. We can see from Table 4.2 that Mitchell county has by far the largest total irrigation withdrawals during drought from those two sources (687,520 acre-inches/year), followed by Decatur county (530,300 acre-inches/year). Six other counties withdraw around 320,000 acre-inches/year, and the other three withdraw less than 200,000 acre-inches/year.

4.4 Claiborne Aquifer Capacity

The other critical factor for evaluating the potential for source switching is the capacity of the alternative aquifer to meet future demand. The Claiborne aquifer underlies the Floridan aquifer and is a viable alternative water source for agricultural irrigation to meet some future water demand

(Gordon and Gonthier, 2017). In the lower FRB, fewer wells have been completed in the Claiborne aquifer than in the shallower Floridan aquifer, and there is less information about those wells' depths, water quality, and water-bearing characteristics (Gordon and Gonthier, 2017). The actual county-level capacity of the Claiborne aquifer is difficult to estimate. To examine the possibility of using the Claiborne aquifer as an alternative water source, we compare the amount of irrigation groundwater pumped from surface water sources and the Floridan aquifer with the available sustainable yield of the Claiborne aquifer as a whole.

The Synopsis Report (2010) performed sustainable yield modeling for the Claiborne aquifer in southwest Georgia. Sustainable yields were estimated using a numerical model simulation with multiple combinations of withdrawals from existing wells and hypothetical new wells (Synopsis Report, 2010). The results of the simulation indicated a range of sustainable yields for the Claiborne aquifer. Baseline withdrawals were calculated using actual withdrawals. Municipal and industrial withdrawals were determined from data reported to the Georgia EPD. Domestic and commercial withdrawals were evaluated using USGS data and county records. Agricultural withdrawals were estimated using a combination of USGS data and Georgia EPD data (Synopsis Report, 2010). The groundwater withdrawal baseline for the Claiborne aquifer was 67 MGD, and the modeled sustainable yield was from 100 to 250 MGD (Synopsis Report, 2010). After we convert the million gallons per day value to acre-inches per day, the current actual groundwater withdrawal for the Claiborne aquifer is 2,467 acre-inches/day, and the sustainable yield is from 3,682 to 9,206 acre-inches/day (Convert Units, 2021). The available yield for source switching is the difference between the baseline and the sustainable yield, resulting from 1,215 to 6,739 acre-inches/day (3,682.66 – 2,467.4 = 1,215.3; 9,206.7 – 2,467.4 = 6,739.3). The available sustainable yield of the Claiborne aquifer for one year ranges from 443,570 to 2,459,834 acre-inches (443,570 × 365 = 443,569.9; 6,739.3 × 365 = 2,459,833.6).

Referring to Table 4.2 we see the surface water withdrawals across the entire study area are 834,982 acre-inches per year. This is about twice the lower bound for the maximum sustainable yield for the Claiborne, but only one third the upper bound.

4.5 Prioritizing Counties for Source Switching

Climate change is a departure from the average state climate, which persists for an extended period. The warming of the climate is unequivocal, as is now evident from the observation of increases in global average temperature (IPCC 2007). Extreme weather events have changed in intensity over the last 50 years. The heat waves have become more frequent over most land areas, and the frequency of areas affected by drought has increased since 1970 (IPCC 2007). The temperature increase has been widespread in the U.S. The average temperature has increased by 1.1° C in the Southeast United States since the 1970s (Melillo et al., 2014). Such changes are characterized by a notable decrease in the number of frost days per year. With the acceleration of climate warming (IPCC 2007), scientific studies focus on long-term projects of temperature and precipitation to predict future climate change.

RCP scenarios 4.5 and 8.5 were used by Binita (2014) to project climate change vulnerability for the 2030s in Georgia. The average temperature and precipitation in the 2030s were compared to the historic baseline climate (1971-2000) to identify future climate anomalies. In the 2030s, the anomalies in average temperature are expected to rise in southwest Georgia, and conditions are expected to be drier in that region as well.

The need for an irrigation buyout auction is dependent on weather conditions in a given season or over a series of consecutive seasons. Table 4.1 covers a range of climate scenarios as represented by the probability of holding an auction, from once every century (exceptionally rare water shortages) to once every five years (frequent, acute water shortages). The threshold probability of well failure over this range is pretty consistent across the counties in the study area, with the exception of Dougherty county. As mentioned above, even if an auction was required every 10 years, the buyout auction would still be the strictly dominant policy for Dougherty county. To understand why, refer to Table 4.3 and Table 4.4.

Table 4.3 presents the economic impacts estimated in IMPLAN for the loss of agricultural production, the countervailing auction payments, and the difference between the two. Dougherty county has the lowest difference ($47,722) among all counties in the study area. Dougherty county has the higher drilling costs for a well tapping into the Claiborne aquifer ($77,757) (see Table 4.3). So, in Dougherty county, the actual cost to switch sources is high while the economic impact of an irrigation buyout auction is low. Clearly, if the state were to adopt source switching as a water management policy in the lower FRB, Dougherty county should be the last place to institute it. All of the other counties have more ambiguous tradeoffs between the costs of source switching and the economic impact of an auction. To prioritize the other counties we could use either the economic impact of the auction or the cost of drilling a new well plus the extra pumping costs.

Table 4.3 Economic Impacts of Lost Production and Auction Payments (150-acre field)

County	Lost Production Impacts	Auction Payment Impacts	Difference
Worth	$161,267	$14,123	$147,144
Calhoun	$128,784	$15,147	$113,637
Terrell	$127,753	$16,864	$110,889
Lee	$112,767	$9,793	$102,974
Early	$110,079	$13,270	$96,809
Decatur	$101,733	$9,334	$92,399
Mitchell	$82,173	$6,311	$75,862
Randolph	$81,744	$7,274	$74,470
Miller	$88,553	$19,576	$68,977
Baker	$88,643	$39,146	$49,497
Dougherty	$55,942	$8,220	$47,722

Table 4.4 Well Drilling and Expected Extra Pumping Costs (150-acre field)

County	Drilling Cost	Expected Extra Pumping Cost	Combined Costs
Randolph	$12,225	$60	$12,285
Terrell	$30,920	$379	$31,299
Lee	$35,963	$403	$36,366
Early	$37,630	$189	$37,819
Calhoun	$44,670	$1,095	$45,765
Baker	$51,624	$417	$52,041
Miller	$52,800	$352	$53,152
Worth	$64,080	$502	$64,582
Dougherty	$77,044	$713	$77,757
Mitchell	$82,728	$308	$83,036
Decatur	$98,600	$1,831	$100,431

4.6 Limitations of the Study

The costs of well drilling were developed through an email survey of well drillers in the study area. Those costs did not include the possibility of needing to seal off the Floridan aquifer when drilling a well into the Claiborne, which could be quite expensive. Appendix Table E1 presents the threshold probabilities of well failure when drilling costs are double the amount reported in Table 4.1. The general conclusions, i.e., that Dougherty county should be the last county to undertake source switching still hold, but the threshold probabilities are higher for all counties. The uncertainty of drilling costs by county is a limitation of the study. Ideally, we would like to have better numbers by county on the actual costs of drilling and whether or not wells into the Claiborne would need to seal off the Floridan aquifer.

Another limitation of the study is the use of 2012 data. 2011 was a drought year in Georgia and cotton and peanut yields were relatively low while prices were quite high. It would best to update the field-level revenue estimates based on more recent price and yield information.

The reliance on 2012 IMPLAN data for the economic impact analysis is potentially the most significant limitation. The county-level multipliers are updated periodically by IMPLAN, although these are typically marginal changes. The considerable economic disruptions of COVID-19, however, could lead to more significant changes in the multipliers. It is important to revisit this analysis using post-COVID-19 multipliers to fully understand the impacts and cost-effectiveness of source switching versus irrigation reduction auctions.

4.7 Conclusions

The study introduces an innovative method to compare two water management policies. The simulated results indicate that neither irrigation reduction auction nor source switching is a dominant strategy across all counties and weather conditions. If Georgia becomes warmer in future years with more frequent and severe droughts, source switching will become the more dominant strategy.

It is clear from Table 4.1 that if source switching were adopted as a water management policy for the lower FRB, Dougherty county should be last to switch. Decatur and Mitchell counties would also be low priorities for source switching. To prioritize the other counties, either the economic impacts of taking land out of production or the drilling costs for wells into the Claiborne aquifer could be used.

To ensure the greatest impact of source switching on instream flows, it is advised to switch surface water permits before switching Floridan aquifer wells. The amount of surface water withdrawals in the study area lie between the upper and lower bound of estimated maximum sustainable yields for the Claiborne aquifer. As such, it is possible the Claiborne could handle new withdrawals equal to the amount currently associated with surface water permits in the study area. It is vitally important, however, to ascertain if new withdrawals would create localized aquifer impacts that would elevate the probability of well failure. In the absence of that information, it is recommended that source switching efforts be spatially dispersed across the study area.

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APPENDIX

Appendix A: lists the details of components used in the simulation. It has 11 tables that represent 11 counties selected in the simulation.

Appendix B: lists tables for water used, TDH estimation, and electricity price (average, minimum, and maximum conditions).

Appendix C: lists the analyzed result by IMPLAN model.

Appendix D: lists the average water level, well depth, and aquifer name of groundwater in lower FRB.

Appendix E: lists the Sensitivity Analysis

Appendix A

Table A.1 Each Component for Auction and Source Switching Cost: Baker County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$86,272	$2,371	$5,695	$616	$79,961	$106,898	$52,041	$88,643	$88,643
1	$24,329	$85,442	$2,348	$5,640	$610	$79,192	$105,870	$52,461	$87,791	$176,434
2	$24,095	$84,621	$2,326	$5,586	$604	$78,431	$104,852	$52,886	$86,947	$263,380
3	$23,864	$83,807	$2,303	$5,532	$598	$77,677	$103,843	$53,316	$86,110	$349,491
4	$23,634	$83,001	$2,281	$5,479	$593	$76,930	$102,845	$53,749	$85,283	$434,773
5	$23,407	$82,203	$2,259	$5,426	$587	$76,190	$101,856	$54,187	$84,462	$519,236
6	$23,182	$81,413	$2,237	$5,374	$581	$75,457	$100,877	$54,629	$83,650	$602,886
7	$22,959	$80,630	$2,216	$5,323	$576	$74,732	$99,907	$55,075	$82,846	$685,732
8	$22,738	$79,855	$2,195	$5,271	$570	$74,013	$98,946	$55,526	$82,049	$767,781
9	$22,520	$79,087	$2,174	$5,221	$565	$73,302	$97,995	$55,982	$81,260	$849,042
10	$22,303	$78,326	$2,153	$5,171	$559	$72,597	$97,052	$56,441	$80,479	$929,521
11	$22,089	$77,573	$2,132	$5,121	$554	$71,899	$96,119	$56,906	$79,705	$1,009,226
12	$21,876	$76,827	$2,111	$5,072	$549	$71,207	$95,195	$57,375	$78,939	$1,088,165
13	$21,666	$76,089	$2,091	$5,023	$543	$70,523	$94,280	$57,848	$78,180	$1,166,345
14	$21,458	$75,357	$2,071	$4,974	$538	$69,845	$93,373	$58,327	$77,428	$1,243,773
15	$21,251	$74,633	$2,051	$4,927	$533	$69,173	$92,475	$58,810	$76,684	$1,320,457
16	$21,047	$73,915	$2,031	$4,879	$528	$68,508	$91,586	$59,298	$75,946	$1,396,403
17	$20,845	$73,204	$2,012	$4,832	$523	$67,849	$90,705	$59,790	$75,216	$1,471,619
18	$20,644	$72,500	$1,993	$4,786	$518	$67,197	$89,833	$60,288	$74,493	$1,546,112
19	$20,446	$71,803	$1,973	$4,740	$513	$66,551	$88,970	$60,790	$73,777	$1,619,889
20	$20,249	$71,113	$1,954	$4,694	$508	$65,911	$88,114	$61,298	$73,067	$1,692,956
21	$20,054	$70,429	$1,936	$4,649	$503	$65,277	$87,267	$61,810	$72,365	$1,765,320
22	$19,861	$69,752	$1,917	$4,604	$498	$64,649	$86,428	$62,328	$71,669	$1,836,989
23	$19,670	$69,081	$1,899	$4,560	$493	$64,028	$85,597	$62,851	$70,980	$1,907,969
24	$19,481	$68,417	$1,880	$4,516	$489	$63,412	$84,774	$63,378	$70,297	$1,978,266
25	$19,294	$67,759	$1,862	$4,473	$484	$62,802	$83,959	$52,041	$69,621	$2,047,887

Table A.2 Each Component for Auction and Source Switching Cost: Calhoun County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$125,722	$3,062	$9,265	$528	$115,929	$143,557	$45,765	$128,784	$128,784
1	$24,329	$124,513	$3,033	$9,176	$523	$114,814	$142,176	$46,871	$127,546	$256,330
2	$24,095	$123,316	$3,003	$9,088	$518	$113,710	$140,809	$47,988	$126,319	$382,649
3	$23,864	$122,130	$2,975	$9,000	$513	$112,617	$139,455	$49,115	$125,105	$507,754
4	$23,634	$120,956	$2,946	$8,914	$508	$111,534	$138,114	$50,254	$123,902	$631,655
5	$23,407	$119,793	$2,918	$8,828	$503	$110,462	$136,786	$51,405	$122,710	$754,366
6	$23,182	$118,641	$2,890	$8,743	$498	$109,400	$135,471	$52,566	$121,530	$875,896
7	$22,959	$117,500	$2,862	$8,659	$493	$108,348	$134,168	$53,740	$120,362	$996,258
8	$22,738	$116,370	$2,834	$8,576	$489	$107,306	$132,878	$54,924	$119,205	$1,115,463
9	$22,520	$115,251	$2,807	$8,493	$484	$106,274	$131,601	$56,121	$118,058	$1,233,521
10	$22,303	$114,143	$2,780	$8,412	$479	$105,252	$130,335	$57,329	$116,923	$1,350,444
11	$22,089	$113,046	$2,753	$8,331	$475	$104,240	$129,082	$58,550	$115,799	$1,466,243
12	$21,876	$111,959	$2,727	$8,251	$470	$103,238	$127,841	$59,782	$114,686	$1,580,929
13	$21,666	$110,882	$2,701	$8,171	$466	$102,245	$126,612	$61,027	$113,583	$1,694,512
14	$21,458	$109,816	$2,675	$8,093	$461	$101,262	$125,394	$62,284	$112,491	$1,807,002
15	$21,251	$108,760	$2,649	$8,015	$457	$100,288	$124,188	$63,553	$111,409	$1,918,411
16	$21,047	$107,714	$2,623	$7,938	$452	$99,324	$122,994	$64,835	$110,338	$2,028,749
17	$20,845	$106,679	$2,598	$7,862	$448	$98,369	$121,812	$66,130	$109,277	$2,138,026
18	$20,644	$105,653	$2,573	$7,786	$444	$97,423	$120,640	$67,438	$108,226	$2,246,252
19	$20,446	$104,637	$2,548	$7,711	$439	$96,486	$119,480	$68,758	$107,185	$2,353,437
20	$20,249	$103,631	$2,524	$7,637	$435	$95,559	$118,332	$70,092	$106,155	$2,459,592
21	$20,054	$102,634	$2,500	$7,564	$431	$94,640	$117,194	$71,438	$105,134	$2,564,726
22	$19,861	$101,648	$2,476	$7,491	$427	$93,730	$116,067	$72,799	$104,123	$2,668,849
23	$19,670	$100,670	$2,452	$7,419	$423	$92,829	$114,951	$74,172	$103,122	$2,771,971
24	$19,481	$99,702	$2,428	$7,347	$419	$91,936	$113,846	$75,559	$102,130	$2,874,102
25	$19,294	$98,743	$2,405	$7,277	$415	$91,052	$112,751	$45,765	$101,148	$2,975,250

Table A.3 Each Component for Auction and Source Switching Cost: Decatur County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$99,068	$2,665	$16,094	$770	$82,204	$109,435	$100,431	$101,733	$101,733
1	$24,329	$98,115	$2,639	$15,939	$763	$81,414	$108,382	$102,280	$100,755	$202,488
2	$24,095	$97,172	$2,614	$15,786	$755	$80,631	$107,340	$104,147	$99,786	$302,274
3	$23,864	$96,238	$2,589	$15,634	$748	$79,855	$106,308	$106,033	$98,827	$401,100
4	$23,634	$95,312	$2,564	$15,484	$741	$79,088	$105,286	$107,937	$97,876	$498,977
5	$23,407	$94,396	$2,539	$15,335	$734	$78,327	$104,273	$109,861	$96,935	$595,912
6	$23,182	$93,488	$2,515	$15,188	$727	$77,574	$103,271	$111,803	$96,003	$691,915
7	$22,959	$92,589	$2,491	$15,042	$720	$76,828	$102,278	$113,764	$95,080	$786,995
8	$22,738	$91,699	$2,467	$14,897	$713	$76,089	$101,294	$115,745	$94,166	$881,161
9	$22,520	$90,817	$2,443	$14,754	$706	$75,358	$100,320	$117,746	$93,260	$974,421
10	$22,303	$89,944	$2,420	$14,612	$699	$74,633	$99,356	$119,767	$92,364	$1,066,784
11	$22,089	$89,079	$2,396	$14,471	$692	$73,916	$98,400	$121,807	$91,475	$1,158,260
12	$21,876	$88,223	$2,373	$14,332	$686	$73,205	$97,454	$123,868	$90,596	$1,248,856
13	$21,666	$87,374	$2,350	$14,194	$679	$72,501	$96,517	$125,949	$89,725	$1,338,581
14	$21,458	$86,534	$2,328	$14,058	$673	$71,804	$95,589	$128,050	$88,862	$1,427,443
15	$21,251	$85,702	$2,305	$13,923	$666	$71,113	$94,670	$130,173	$88,008	$1,515,450
16	$21,047	$84,878	$2,283	$13,789	$660	$70,430	$93,760	$132,316	$87,161	$1,602,612
17	$20,845	$84,062	$2,261	$13,656	$653	$69,752	$92,858	$134,481	$86,323	$1,688,935
18	$20,644	$83,254	$2,240	$13,525	$647	$69,082	$91,965	$136,667	$85,493	$1,774,428
19	$20,446	$82,453	$2,218	$13,395	$641	$68,417	$91,081	$138,875	$84,671	$1,859,099
20	$20,249	$81,660	$2,197	$13,266	$635	$67,760	$90,205	$141,105	$83,857	$1,942,956
21	$20,054	$80,875	$2,176	$13,138	$629	$67,108	$89,338	$143,357	$83,051	$2,026,007
22	$19,861	$80,097	$2,155	$13,012	$623	$66,463	$88,479	$145,631	$82,252	$2,108,259
23	$19,670	$79,327	$2,134	$12,887	$617	$65,824	$87,628	$147,927	$81,461	$2,189,720
24	$19,481	$78,565	$2,113	$12,763	$611	$65,191	$86,786	$150,247	$80,678	$2,270,398
25	$19,294	$77,809	$2,093	$12,640	$605	$64,564	$85,951	$100,431	$79,902	$2,350,301

Table A.4 Each Component for Auction and Source Switching Cost: Dougherty County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$54,996	$946	$38,039	$1,107	$15,850	$41,362	$77,757	$55,942	$55,942
1	$24,329	$54,467	$937	$37,673	$1,096	$15,698	$40,964	$78,476	$55,404	$111,346
2	$24,095	$53,943	$928	$37,311	$1,086	$15,547	$40,570	$79,203	$54,871	$166,217
3	$23,864	$53,425	$919	$36,952	$1,075	$15,397	$40,180	$79,938	$54,344	$220,561
4	$23,634	$52,911	$910	$36,597	$1,065	$15,249	$39,793	$80,679	$53,821	$274,382
5	$23,407	$52,402	$901	$36,245	$1,055	$15,102	$39,411	$81,428	$53,304	$327,686
6	$23,182	$51,898	$893	$35,897	$1,045	$14,957	$39,032	$82,184	$52,791	$380,477
7	$22,959	$51,399	$884	$35,551	$1,035	$14,813	$38,657	$82,948	$52,284	$432,761
8	$22,738	$50,905	$876	$35,210	$1,025	$14,671	$38,285	$83,719	$51,781	$484,542
9	$22,520	$50,416	$867	$34,871	$1,015	$14,530	$37,917	$84,498	$51,283	$535,825
10	$22,303	$49,931	$859	$34,536	$1,005	$14,390	$37,552	$85,285	$50,790	$586,615
11	$22,089	$49,451	$851	$34,204	$995	$14,252	$37,191	$86,079	$50,301	$636,916
12	$21,876	$48,975	$842	$33,875	$986	$14,115	$36,833	$86,881	$49,818	$686,734
13	$21,666	$48,504	$834	$33,549	$976	$13,979	$36,479	$87,691	$49,339	$736,073
14	$21,458	$48,038	$826	$33,226	$967	$13,845	$36,129	$88,510	$48,864	$784,937
15	$21,251	$47,576	$818	$32,907	$958	$13,712	$35,781	$89,336	$48,395	$833,331
16	$21,047	$47,119	$811	$32,591	$948	$13,580	$35,437	$90,170	$47,929	$881,261
17	$20,845	$46,666	$803	$32,277	$939	$13,449	$35,096	$91,013	$47,468	$928,729
18	$20,644	$46,217	$795	$31,967	$930	$13,320	$34,759	$91,864	$47,012	$975,741
19	$20,446	$45,773	$787	$31,659	$921	$13,192	$34,425	$92,724	$46,560	$1,022,301
20	$20,249	$45,332	$780	$31,355	$912	$13,065	$34,094	$93,592	$46,112	$1,068,413
21	$20,054	$44,897	$772	$31,054	$904	$12,939	$33,766	$94,469	$45,669	$1,114,082
22	$19,861	$44,465	$765	$30,755	$895	$12,815	$33,441	$95,354	$45,230	$1,159,311
23	$19,670	$44,037	$757	$30,459	$886	$12,692	$33,120	$96,248	$44,795	$1,204,106
24	$19,481	$43,614	$750	$30,166	$878	$12,570	$32,801	$97,151	$44,364	$1,248,470
25	$19,294	$43,194	$743	$29,876	$869	$12,449	$32,486	$77,757	$43,937	$1,292,408

Table A.5 Each Component for Auction and Source Switching Cost: Early County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$104,850	$5,229	$18,783	$793	$85,274	$115,069	$37,819	$110,079	$110,079
1	$24,329	$103,842	$5,179	$18,602	$785	$84,454	$113,962	$38,009	$109,021	$219,100
2	$24,095	$102,843	$5,129	$18,424	$778	$83,642	$112,866	$38,202	$107,972	$327,072
3	$23,864	$101,854	$5,080	$18,246	$770	$82,838	$111,781	$38,397	$106,934	$434,006
4	$23,634	$100,875	$5,031	$18,071	$763	$82,041	$110,706	$38,593	$105,906	$539,912
5	$23,407	$99,905	$4,982	$17,897	$756	$81,252	$109,642	$38,791	$104,888	$644,799
6	$23,182	$98,945	$4,934	$17,725	$748	$80,471	$108,587	$38,992	$103,879	$748,678
7	$22,959	$97,993	$4,887	$17,555	$741	$79,697	$107,543	$39,194	$102,880	$851,558
8	$22,738	$97,051	$4,840	$17,386	$734	$78,931	$106,509	$39,398	$101,891	$953,449
9	$22,520	$96,118	$4,794	$17,219	$727	$78,172	$105,485	$39,604	$100,911	$1,054,361
10	$22,303	$95,193	$4,747	$17,053	$720	$77,420	$104,471	$39,813	$99,941	$1,154,302
11	$22,089	$94,278	$4,702	$16,889	$713	$76,676	$103,466	$40,023	$98,980	$1,253,282
12	$21,876	$93,372	$4,657	$16,727	$706	$75,939	$102,471	$40,236	$98,028	$1,351,310
13	$21,666	$92,474	$4,612	$16,566	$699	$75,209	$101,486	$40,450	$97,086	$1,448,395
14	$21,458	$91,585	$4,567	$16,407	$693	$74,485	$100,510	$40,667	$96,152	$1,544,547
15	$21,251	$90,704	$4,524	$16,249	$686	$73,769	$99,544	$40,886	$95,228	$1,639,775
16	$21,047	$89,832	$4,480	$16,093	$679	$73,060	$98,587	$41,107	$94,312	$1,734,087
17	$20,845	$88,968	$4,437	$15,938	$673	$72,357	$97,639	$41,330	$93,405	$1,827,492
18	$20,644	$88,113	$4,394	$15,785	$666	$71,662	$96,700	$41,556	$92,507	$1,919,999
19	$20,446	$87,265	$4,352	$15,633	$660	$70,973	$95,770	$41,783	$91,617	$2,011,617
20	$20,249	$86,426	$4,310	$15,483	$654	$70,290	$94,849	$42,013	$90,737	$2,102,353
21	$20,054	$85,595	$4,269	$15,334	$647	$69,614	$93,937	$42,246	$89,864	$2,192,217
22	$19,861	$84,772	$4,228	$15,186	$641	$68,945	$93,034	$42,480	$89,000	$2,281,217
23	$19,670	$83,957	$4,187	$15,040	$635	$68,282	$92,139	$42,717	$88,144	$2,369,361
24	$19,481	$83,150	$4,147	$14,896	$629	$67,625	$91,254	$42,956	$87,297	$2,456,658
25	$19,294	$82,350	$4,107	$14,752	$623	$66,975	$90,376	$37,819	$86,457	$2,543,115

Table A.6 Each Component for Auction and Source Switching Cost: Lee County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$110,157	$2,610	$8,224	$462	$101,471	$128,647	$36,366	$112,767	$112,767
1	$24,329	$109,098	$2,585	8144.9231	$457.56	$100,495	$127,410	$36,773	$111,683	$224,450
2	$24,095	$108,049	$2,560	8066.6065	$453.16	$99,529	$126,184	$37,184	$110,609	$335,059
3	$23,864	$107,010	$2,535	7989.043	$448.80	$98,572	$124,971	$37,600	$109,545	$444,604
4	$23,634	$105,981	$2,511	7912.2253	$444.49	$97,624	$123,769	$38,019	$108,492	$553,096
5	$23,407	$104,962	$2,487	7836.1462	$440.21	$96,686	$122,579	$38,442	$107,449	$660,545
6	$23,182	$103,953	$2,463	7760.7986	$435.98	$95,756	$121,401	$38,870	$106,416	$766,960
7	$22,959	$102,953	$2,439	7686.1756	$431.79	$94,835	$120,233	$39,302	$105,392	$872,353
8	$22,738	$101,963	$2,416	7612.27	$427.63	$93,923	$119,077	$39,738	$104,379	$976,732
9	$22,520	$100,983	$2,393	7539.0751	$423.52	$93,020	$117,932	$40,179	$103,375	$1,080,107
10	$22,303	$100,012	$2,370	7466.584	$419.45	$92,126	$116,798	$40,624	$102,381	$1,182,488
11	$22,089	$99,050	$2,347	7394.7899	$415.42	$91,240	$115,675	$41,073	$101,397	$1,283,885
12	$21,876	$98,098	$2,324	7323.6862	$411.42	$90,363	$114,563	$41,527	$100,422	$1,384,307
13	$21,666	$97,154	$2,302	7253.2661	$407.47	$89,494	$113,461	$41,985	$99,456	$1,483,763
14	$21,458	$96,220	$2,280	7183.5232	$403.55	$88,633	$112,371	$42,448	$98,500	$1,582,264
15	$21,251	$95,295	$2,258	7114.4508	$399.67	$87,781	$111,290	$42,915	$97,553	$1,679,816
16	$21,047	$94,379	$2,236	7046.0427	$395.83	$86,937	$110,220	$43,387	$96,615	$1,776,431
17	$20,845	$93,471	$2,215	6978.2922	$392.02	$86,101	$109,160	$43,863	$95,686	$1,872,117
18	$20,644	$92,573	$2,193	6911.1933	$388.25	$85,273	$108,111	$44,345	$94,766	$1,966,883
19	$20,446	$91,682	$2,172	6844.7395	$384.52	$84,453	$107,071	$44,831	$93,855	$2,060,738
20	$20,249	$90,801	$2,151	6778.9247	$380.82	$83,641	$106,041	$45,322	$92,952	$2,153,690
21	$20,054	$89,928	$2,131	6713.7427	$377.16	$82,837	$105,022	$45,818	$92,058	$2,245,748
22	$19,861	$89,063	$2,110	6649.1875	$373.53	$82,040	$104,012	$46,318	$91,173	$2,336,922
23	$19,670	$88,207	$2,090	6585.253	$369.94	$81,251	$103,012	$46,824	$90,297	$2,427,218
24	$19,481	$87,359	$2,070	6521.9333	$366.38	$80,470	$102,021	$47,335	$89,428	$2,516,647
25	$19,294	$86,519	$2,050	6459.2224	$362.86	$79,696	$101,040	$36,366	$88,568	$2,605,215

Table A.7 Each Component for Auction and Source Switching Cost: Miller County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$85,664	$2,889	$8,797	$537	$76,330	$103,785	$53,152	$88,553	$88,553
1	$24,329	$84,840	$2,861	$8,712	$532	$75,596	$102,787	$53,508	$87,702	$176,255
2	$24,095	$84,025	$2,834	$8,629	$527	$74,869	$101,798	$53,868	$86,858	$263,113
3	$23,864	$83,217	$2,806	$8,546	$522	$74,149	$100,819	$54,231	$86,023	$349,136
4	$23,634	$82,416	$2,779	$8,464	$517	$73,436	$99,850	$54,597	$85,196	$434,332
5	$23,407	$81,624	$2,753	$8,382	$512	$72,730	$98,890	$54,968	$84,377	$518,709
6	$23,182	$80,839	$2,726	$8,302	$507	$72,031	$97,939	$55,341	$83,565	$602,274
7	$22,959	$80,062	$2,700	$8,222	$502	$71,338	$96,997	$55,719	$82,762	$685,036
8	$22,738	$79,292	$2,674	$8,143	$497	$70,652	$96,065	$56,100	$81,966	$767,002
9	$22,520	$78,530	$2,648	$8,064	$492	$69,973	$95,141	$56,485	$81,178	$848,180
10	$22,303	$77,774	$2,623	$7,987	$488	$69,300	$94,226	$56,874	$80,397	$928,577
11	$22,089	$77,027	$2,598	$7,910	$483	$68,634	$93,320	$57,267	$79,624	$1,008,202
12	$21,876	$76,286	$2,573	$7,834	$478	$67,974	$92,423	$57,664	$78,859	$1,087,060
13	$21,666	$75,553	$2,548	$7,759	$474	$67,320	$91,534	$58,064	$78,100	$1,165,161
14	$21,458	$74,826	$2,523	$7,684	$469	$66,673	$90,654	$58,469	$77,350	$1,242,510
15	$21,251	$74,107	$2,499	$7,610	$465	$66,032	$89,782	$58,878	$76,606	$1,319,116
16	$21,047	$73,394	$2,475	$7,537	$460	$65,397	$88,919	$59,290	$75,869	$1,394,985
17	$20,845	$72,688	$2,451	$7,464	$456	$64,768	$88,064	$59,707	$75,140	$1,470,125
18	$20,644	$71,989	$2,428	$7,393	$451	$64,145	$87,217	$60,128	$74,417	$1,544,542
19	$20,446	$71,297	$2,404	$7,322	$447	$63,529	$86,379	$60,553	$73,702	$1,618,244
20	$20,249	$70,612	$2,381	$7,251	$443	$62,918	$85,548	$60,982	$72,993	$1,691,237
21	$20,054	$69,933	$2,358	$7,182	$438	$62,313	$84,725	$61,415	$72,291	$1,763,528
22	$19,861	$69,260	$2,336	$7,112	$434	$61,714	$83,911	$61,853	$71,596	$1,835,124
23	$19,670	$68,594	$2,313	$7,044	$430	$61,120	$83,104	$62,295	$70,908	$1,906,032
24	$19,481	$67,935	$2,291	$6,976	$426	$60,532	$82,305	$62,742	$70,226	$1,976,257
25	$19,294	$67,281	$2,269	$6,909	$422	$59,950	$81,514	$53,152	$69,551	$2,045,808

Table A.8 Each Component for Auction and Source Switching Cost: Mitchell County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$79,949	$2,224	$13,454	$669	$65,826	$92,616	$83,036	$82,173	$82,173
1	$24,329	$79,180	$2,203	$13,325	$663	$65,193	$91,725	$83,348	$81,383	$163,556
2	$24,095	$78,419	$2,181	$13,197	$656	$64,566	$90,843	$83,662	$80,600	$244,156
3	$23,864	$77,665	$2,160	$13,070	$650	$63,945	$89,970	$83,980	$79,825	$323,982
4	$23,634	$76,918	$2,140	$12,944	$644	$63,331	$89,104	$84,301	$79,058	$403,039
5	$23,407	$76,179	$2,119	$12,819	$637	$62,722	$88,248	$84,625	$78,298	$481,337
6	$23,182	$75,446	$2,099	$12,696	$631	$62,118	$87,399	$84,952	$77,545	$558,882
7	$22,959	$74,721	$2,079	$12,574	$625	$61,521	$86,559	$85,283	$76,799	$635,681
8	$22,738	$74,002	$2,059	$12,453	$619	$60,930	$85,726	$85,616	$76,061	$711,742
9	$22,520	$73,291	$2,039	$12,334	$613	$60,344	$84,902	$85,953	$75,329	$787,071
10	$22,303	$72,586	$2,019	$12,215	$607	$59,764	$84,086	$86,294	$74,605	$861,676
11	$22,089	$71,888	$2,000	$12,097	$602	$59,189	$83,277	$86,638	$73,888	$935,564
12	$21,876	$71,197	$1,981	$11,981	$596	$58,620	$82,477	$86,985	$73,177	$1,008,741
13	$21,666	$70,512	$1,961	$11,866	$590	$58,056	$81,683	$87,335	$72,474	$1,081,214
14	$21,458	$69,834	$1,943	$11,752	$584	$57,498	$80,898	$87,689	$71,777	$1,152,991
15	$21,251	$69,163	$1,924	$11,639	$579	$56,945	$80,120	$88,047	$71,087	$1,224,078
16	$21,047	$68,498	$1,905	$11,527	$573	$56,397	$79,350	$88,408	$70,403	$1,294,481
17	$20,845	$67,839	$1,887	$11,416	$568	$55,855	$78,587	$88,773	$69,726	$1,364,207
18	$20,644	$67,187	$1,869	$11,306	$562	$55,318	$77,831	$89,141	$69,056	$1,433,262
19	$20,446	$66,541	$1,851	$11,198	$557	$54,786	$77,083	$89,513	$68,392	$1,501,654
20	$20,249	$65,901	$1,833	$11,090	$551	$54,259	$76,342	$89,889	$67,734	$1,569,388
21	$20,054	$65,267	$1,816	$10,983	$546	$53,738	$75,608	$90,268	$67,083	$1,636,471
22	$19,861	$64,640	$1,798	$10,878	$541	$53,221	$74,881	$90,651	$66,438	$1,702,908
23	$19,670	$64,018	$1,781	$10,773	$536	$52,709	$74,161	$91,038	$65,799	$1,768,707
24	$19,481	$63,402	$1,764	$10,670	$531	$52,202	$73,447	$91,429	$65,166	$1,833,873
25	$19,294	$62,793	$1,747	$10,567	$525	$51,700	$72,741	$83,036	$64,540	$1,898,413

Table A.9 Each Component for Auction and Source Switching Cost: Randolph County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$79,434	$2,310	$14,465	$682	$64,287	$91,163	$12,285	$81,744	$81,744
1	$24,329	$78,670	$2,288	$14,326	$675	$63,669	$90,286	$12,347	$80,958	$162,702
2	$24,095	$77,914	$2,266	$14,188	$669	$63,057	$89,418	$12,408	$80,180	$242,882
3	$23,864	$77,165	$2,244	$14,052	$663	$62,450	$88,558	$12,471	$79,409	$322,290
4	$23,634	$76,423	$2,222	$13,917	$656	$61,850	$87,706	$12,533	$78,645	$400,935
5	$23,407	$75,688	$2,201	$13,783	$650	$61,255	$86,863	$12,597	$77,889	$478,824
6	$23,182	$74,960	$2,180	$13,650	$644	$60,666	$86,028	$12,661	$77,140	$555,964
7	$22,959	$74,239	$2,159	$13,519	$637	$60,083	$85,201	$12,726	$76,398	$632,362
8	$22,738	$73,525	$2,138	$13,389	$631	$59,505	$84,382	$12,791	$75,664	$708,026
9	$22,520	$72,818	$2,118	$13,260	$625	$58,933	$83,570	$12,857	$74,936	$782,962
10	$22,303	$72,118	$2,097	$13,133	$619	$58,366	$82,767	$12,924	$74,216	$857,177
11	$22,089	$71,425	$2,077	$13,007	$613	$57,805	$81,971	$12,992	$73,502	$930,679
12	$21,876	$70,738	$2,057	$12,881	$607	$57,249	$81,183	$13,060	$72,795	$1,003,474
13	$21,666	$70,058	$2,037	$12,758	$601	$56,699	$80,402	$13,128	$72,095	$1,075,570
14	$21,458	$69,384	$2,018	$12,635	$596	$56,154	$79,629	$13,198	$71,402	$1,146,972
15	$21,251	$68,717	$1,998	$12,513	$590	$55,614	$78,863	$13,268	$70,715	$1,217,687
16	$21,047	$68,056	$1,979	$12,393	$584	$55,079	$78,105	$13,339	$70,035	$1,287,723
17	$20,845	$67,402	$1,960	$12,274	$579	$54,549	$77,354	$13,410	$69,362	$1,357,085
18	$20,644	$66,754	$1,941	$12,156	$573	$54,025	$76,610	$13,482	$68,695	$1,425,780
19	$20,446	$66,112	$1,923	$12,039	$568	$53,505	$75,873	$13,555	$68,035	$1,493,814
20	$20,249	$65,476	$1,904	$11,923	$562	$52,991	$75,144	$13,629	$67,380	$1,561,195
21	$20,054	$64,847	$1,886	$11,809	$557	$52,481	$74,421	$13,703	$66,733	$1,627,927
22	$19,861	$64,223	$1,868	$11,695	$551	$51,977	$73,706	$13,778	$66,091	$1,694,018
23	$19,670	$63,606	$1,850	$11,583	$546	$51,477	$72,997	$13,854	$65,455	$1,759,473
24	$19,481	$62,994	$1,832	$11,471	$541	$50,982	$72,295	$13,931	$64,826	$1,824,299
25	$19,294	$62,388	$1,814	$11,361	$536	$50,492	$71,600	$12,285	$64,203	$1,888,502

Table A.10 Each Component for Auction and Source Switching Cost: Terrell County

Year \ PV	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$125,051	$2,702	$12,634	$636	$111,781	$139,049	$31,299	$127,753	$127,753
1	$24,329	$123,849	$2,676	$12,513	$630	$110,706	$137,711	$31,682	$126,525	$254,278
2	$24,095	$122,658	$2,650	$12,392	$624	$109,642	$136,387	$32,068	$125,308	$379,586
3	$23,864	$121,478	$2,625	$12,273	$618	$108,587	$135,076	$32,459	$124,103	$503,689
4	$23,634	$120,310	$2,600	$12,155	$612	$107,543	$133,777	$32,853	$122,910	$626,599
5	$23,407	$119,153	$2,575	$12,038	$606	$106,509	$132,491	$33,251	$121,728	$748,327
6	$23,182	$118,008	$2,550	$11,922	$600	$105,485	$131,217	$33,653	$120,558	$868,884
7	$22,959	$116,873	$2,525	$11,808	$594	$104,471	$129,955	$34,059	$119,398	$988,283
8	$22,738	$115,749	$2,501	$11,694	$589	$103,466	$128,706	$34,469	$118,250	$1,106,533
9	$22,520	$114,636	$2,477	$11,582	$583	$102,471	$127,468	$34,883	$117,113	$1,223,646
10	$22,303	$113,534	$2,453	$11,470	$577	$101,486	$126,242	$35,301	$115,987	$1,339,633
11	$22,089	$112,442	$2,430	$11,360	$572	$100,510	$125,029	$35,724	$114,872	$1,454,505
12	$21,876	$111,361	$2,406	$11,251	$566	$99,544	$123,826	$36,150	$113,767	$1,568,273
13	$21,666	$110,290	$2,383	$11,143	$561	$98,587	$122,636	$36,581	$112,673	$1,680,946
14	$21,458	$109,230	$2,360	$11,036	$556	$97,639	$121,456	$37,016	$111,590	$1,792,536
15	$21,251	$108,180	$2,337	$10,929	$550	$96,700	$120,289	$37,456	$110,517	$1,903,053
16	$21,047	$107,139	$2,315	$10,824	$545	$95,770	$119,132	$37,899	$109,454	$2,012,508
17	$20,845	$106,109	$2,293	$10,720	$540	$94,849	$117,987	$38,347	$108,402	$2,120,909
18	$20,644	$105,089	$2,271	$10,617	$534	$93,937	$116,852	$38,800	$107,360	$2,228,269
19	$20,446	$104,078	$2,249	$10,515	$529	$93,034	$115,728	$39,257	$106,327	$2,334,596
20	$20,249	$103,078	$2,227	$10,414	$524	$92,139	$114,616	$39,718	$105,305	$2,439,901
21	$20,054	$102,087	$2,206	$10,314	$519	$91,254	$113,514	$40,185	$104,292	$2,544,194
22	$19,861	$101,105	$2,185	$10,215	$514	$90,376	$112,422	$40,655	$103,290	$2,647,483
23	$19,670	$100,133	$2,164	$10,116	$509	$89,507	$111,341	$41,131	$102,296	$2,749,780
24	$19,481	$99,170	$2,143	$10,019	$504	$88,646	$110,271	$41,611	$101,313	$2,851,093
25	$19,294	$98,216	$2,122	$9,923	$500	$87,794	$109,210	$31,299	$100,339	$2,951,431

Table A.11 Each Component for Auction and Source Switching Cost: Worth County

PV / Year	Auction Payment	Industry Impacts	State Local Tax Loss	Household Payment Impact	State Local Tax Revenue	Economy Impacts	Total Auction Cost	Drilling Costs with Cumulative Extra Pumping Cost	Cost of Well Failure	Cumulative Value of Failure
0	$24,566	$156,135	$5,132	$7,744	$476	$147,915	$177,613	$64,582	$161,267	$161,267
1	$24,329	$154,634	$5,083	$7,670	$471	$146,493	$175,905	$65,089	$159,716	$320,983
2	$24,095	$153,147	$5,034	$7,596	$467	$145,084	$174,213	$65,601	$158,181	$479,164
3	$23,864	$151,674	$4,985	$7,523	$462	$143,689	$172,538	$66,118	$156,660	$635,824
4	$23,634	$150,216	$4,937	$7,450	$458	$142,307	$170,879	$66,640	$155,153	$790,977
5	$23,407	$148,771	$4,890	$7,379	$454	$140,939	$169,236	$67,167	$153,661	$944,638
6	$23,182	$147,341	$4,843	$7,308	$449	$139,584	$167,609	$67,700	$152,184	$1,096,822
7	$22,959	$145,924	$4,796	$7,238	$445	$138,242	$165,997	$68,238	$150,721	$1,247,543
8	$22,738	$144,521	$4,750	$7,168	$441	$136,913	$164,401	$68,781	$149,271	$1,396,814
9	$22,520	$143,132	$4,705	$7,099	$436	$135,596	$162,820	$69,329	$147,836	$1,544,650
10	$22,303	$141,755	$4,659	$7,031	$432	$134,292	$161,255	$69,883	$146,415	$1,691,065
11	$22,089	$140,392	$4,615	$6,963	$428	$133,001	$159,704	$70,443	$145,007	$1,836,072
12	$21,876	$139,042	$4,570	$6,896	$424	$131,722	$158,169	$71,008	$143,612	$1,979,684
13	$21,666	$137,705	$4,526	$6,830	$420	$130,456	$156,648	$71,578	$142,232	$2,121,916
14	$21,458	$136,381	$4,483	$6,764	$416	$129,201	$155,141	$72,154	$140,864	$2,262,780
15	$21,251	$135,070	$4,440	$6,699	$412	$127,959	$153,650	$72,736	$139,510	$2,402,289
16	$21,047	$133,771	$4,397	$6,635	$408	$126,729	$152,172	$73,324	$138,168	$2,540,457
17	$20,845	$132,485	$4,355	$6,571	$404	$125,510	$150,709	$73,917	$136,840	$2,677,297
18	$20,644	$131,211	$4,313	$6,508	$400	$124,303	$149,260	$74,517	$135,524	$2,812,821
19	$20,446	$129,949	$4,271	$6,445	$396	$123,108	$147,825	$75,122	$134,221	$2,947,041
20	$20,249	$128,700	$4,230	$6,383	$392	$121,924	$146,403	$75,733	$132,930	$3,079,971
21	$20,054	$127,462	$4,190	$6,322	$389	$120,752	$144,996	$76,351	$131,652	$3,211,623
22	$19,861	$126,237	$4,149	$6,261	$385	$119,591	$143,602	$76,974	$130,386	$3,342,009
23	$19,670	$125,023	$4,109	$6,201	$381	$118,441	$142,221	$77,604	$129,132	$3,471,142
24	$19,481	$123,821	$4,070	$6,141	$377	$117,302	$140,853	$78,240	$127,891	$3,599,032
25	$19,294	$122,630	$4,031	$6,082	$374	$116,174	$139,499	$64,582	$126,661	$3,725,693

Appendix B

Table B.1 Water Use for One Field in Lower Flint Region (Acre - ft)

County	Crop	Very Wet	Wet	Median	Dry	Very Dry
Colquitt	Corn	3.9	5.9	9.4	13.2	17.1
	Cotton	17.1	34.1	58.1	93.6	125.6
	Peanut	3.8	7.2	12.5	22.1	28.9
	Soybean	0.2	0.4	1	1.5	2.2
	Total	**25**	**47.6**	**80.9**	**130.5**	**173.8**
Grady	Corn	38.5	51.1	65.3	81.6	97.3
	Cotton	15.5	21.8	33.3	46.1	54.6
	Peanut	5.4	6.9	10.8	14.5	18
	Soybean	1	1.5	2.4	3.3	4.1
	Total	**60.3**	**81.3**	**111.9**	**145.5**	**173.9**
Seminole	Corn	15.4	19.6	25.6	31.9	37.7
	Cotton	29.6	39.5	59.5	75.6	93.4
	Peanut	12.6	17.5	24.2	31.5	37.8
	Soybean	0.4	0.8	1.1	1.4	1.8
	Total	**58**	**77.4**	**110.4**	**140.4**	**170.7**
Baker	Corn	13.3	17.8	22.5	29.5	35.6
	Cotton	28.3	37.8	57	73.7	92.6
	Peanut	15.6	22.6	32.5	41.2	50.4
	Soybean	0.7	1	1.6	2.2	2.6
	Total	**57.9**	**79.3**	**113.6**	**146.6**	**181.2**
Clay	Corn	8.8	13.2	19.8	25.2	30.7
	Cotton	14.8	29.5	43.3	60.1	77.1
	Peanut	9.4	17.3	26.7	38.1	47.8
	Soybean	0.9	2.1	3.5	5.1	6.3
	Total	**33.9**	**62.1**	**93.4**	**128.5**	**162**
Decatur	Corn	5.1	9.6	13.8	18.7	25.5
	Cotton	7.1	15.4	29.8	48.8	62.8
	Peanut	6.5	12.9	27.6	39.1	51.3
	Soybean	1	2.5	4.6	6.3	7.8
	Total	**19.7**	**40.4**	**75.8**	**112.9**	**147.4**
Dougherty	Corn	8.3	12.5	17.3	23	27.2
	Cotton	12.6	26.1	43.5	60	72.5
	Peanut	9.2	16.9	29.2	40.8	50.9
	Soybean	0.2	0.6	1.1	1.5	1.9
	Total	**30.3**	**56.1**	**91**	**125.3**	**152.4**

County	Crop	Very Wet	Wet	Median	Dry	Very Dry
Lee	Corn	16.8	25.8	38.8	50.1	61.3
	Cotton	4.3	11.4	18.6	27	34.8
	Peanut	5.2	12.4	20.6	30.3	38.1
	Soybean	0.9	3.4	7.6	11.5	13.7
	Total	**27.2**	**53.1**	**85.6**	**118.9**	**148**
Miller	Corn	16.1	20.7	28.5	34.8	41.1
	Cotton	9	23.7	40.2	60.2	79.5
	Peanut	6.8	14.9	22.3	30.7	38.8
	Soybean	0.4	1	1.4	2	2.6
	Total	**32.3**	**60.2**	**92.5**	**127.7**	**162.1**
Worth	Corn	5.4	7.7	11.8	16.4	19.9
	Cotton	9.8	19.5	34.6	55.1	69.7
	Peanut	4.4	8.7	16.3	26.3	35.1
	Soybean	0.2	0.6	1.7	2.7	3.8
	Total	**19.7**	**36.6**	**64.4**	**100.5**	**128.4**
Calhoun	Corn	11.3	16.5	24.7	30.7	37.5
	Cotton	18.6	31.9	43.5	58.2	74.3
	Peanut	15.4	24.8	36.3	50.7	63.4
	Soybean	0.4	0.8	1.3	1.8	2.2
	Total	**45.7**	**74**	**105.7**	**141.4**	**177.4**
Early	Corn	7.9	12.2	18.3	23.6	28.9
	Cotton	8.6	22.7	37	53.5	69.1
	Peanut	6	14.2	23.6	34.6	43.6
	Soybean	0.4	1.6	3.5	5.3	6.3
	Total	**22.9**	**50.7**	**82.4**	**117.1**	**148**
Mitchell	Corn	14.5	21.7	28.5	35.5	44.2
	Cotton	17.3	27.8	40.8	56.6	71.3
	Peanut	14.2	20.9	32.1	42.1	53.2
	Soybean	0.8	1.5	2.3	3	3.6
	Total	**46.8**	**71.9**	**103.7**	**137.1**	**172.4**
Randolph	Corn	8.7	13.4	21	27.1	33.5
	Cotton	0	3.6	28.5	55.7	85.5
	Peanut	0	3.6	12.7	26.3	39.4
	Soybean	0	0	0	0	0
	Total	**8.7**	**20.5**	**62.2**	**109.1**	**158.4**
Terrell	Corn	12.1	18.6	29.2	37.6	46.5
	Cotton	13.3	30	49.6	71.1	90.9
	Peanut	3.9	7.8	13.2	18.4	24
	Soybean	1.2	2.6	5.1	6.9	9.1
	Total	**30.5**	**59**	**97.1**	**134.1**	**170.6**

Table B.2 TDH Estimation

County	Aquifer	Average Water level (ft)	TDH
Baker	Floridan	34.1	138.1
	Claiborne	57.8	161.7
Calhoun	Floridan	21.0	125.0
	Claiborne	87.6	191.6
Decatur	Floridan	88.2	192.1
	Claiborne	243.5	347.5
Dougherty	Floridan	34.0	137.9
	Claiborne	84.3	188.3
Early	Floridan	29.5	133.4
	Claiborne	44.2	148.2
Lee	Floridan	28.8	132.7
	Claiborne	59.1	163.0
Miller	Floridan	36.5	140.4
	Claiborne	61.0	165.0
Mitchell	Floridan	86.2	190.1
	Claiborne	105.3	209.3
Randolph	Floridan	37.3	141.2
	Claiborne	43.5	147.5
Terrell	Floridan	24.3	128.2
	Claiborne	49.4	153.4
Worth	Floridan	113.4	217.3
	Claiborne	163.5	267.5

Table B.3 Pumping Cost at Ave Electricity Price ($/150 acres)

County	Aquifer	Very Wet	Wet	Median	Dry	Very Dry
Baker	Floridan	$1,243	$1,702	$2,437	$3,147	$3,889
	Claiborne	$1,456	$1,993	$2,854	$3,684	$4,554
Calhoun	Floridan	$888	$1,438	$2,054	$2,746	$3,446
	Claiborne	$1,362	$2,205	$3,149	$4,210	$5,284
Decatur	Floridan	$588	$1,207	$2,264	$3,373	$4,403
	Claiborne	$1,063	$2,183	$4,095	$6,099	$7,963
Dougherty	Floridan	$650	$1,203	$1,952	$2,687	$3,267
	Claiborne	$888	$1,642	$2,665	$3,668	$4,460
Early	Floridan	$475	$1,051	$1,708	$2,429	$3,070
	Claiborne	$527	$1,168	$1,897	$2,698	$3,409
Lee	Floridan	$561	$1,096	$1,766	$2,452	$3,053
	Claiborne	$689	$1,346	$2,169	$3,012	$3,750
Miller	Floridan	$704	$1,313	$2,018	$2,787	$3,539
	Claiborne	$827	$1,543	$2,371	$3,274	$4,156
Mitchell	Floridan	$1,383	$2,125	$3,064	$4,053	$5,095
	Claiborne	$1,522	$2,339	$3,372	$4,461	$5,608
Randolph	Floridan	$191	$450	$1,366	$2,395	$3,477
	Claiborne	$200	$470	$1,427	$2,501	$3,631
Terrell	Floridan	$608	$1,176	$1,936	$2,673	$3,400
	Claiborne	$727	$1,406	$2,315	$3,196	$4,066
Worth	Floridan	$667	$1,236	$2,176	$3,396	$4,337
	Claiborne	$821	$1,521	$2,678	$4,180	$5,337

Appendix C

Table C.1 IMPLAN Impact Result for 150 Acres Field Out of Production

County	Industry Loss	Employment Loss	State &Local Tax Loss
Colquitt	$179,571	1.31	$3,136
Grady	$245,497	3.31	$3,705
Seminole	$78,299	0.61	$3,118
Baker	$86,272	0.42	$2,371
Clay	$108,136	0.85	$3,385
Decatur	$99,068	0.69	$2,665
Dougherty	$54,996	0.72	$946
Lee	$110,157	0.74	$2,610
Miller	$85,664	0.49	$2,889
Worth	$156,135	0.89	$5,132
Calhoun	$125,722	0.96	$3,062
Early	$104,850	1.21	$5,229
Mitchell	$79,949	0.8	$2,224
Randolph	$79,434	0.66	$2,310
Terrell	$125,051	0.75	$2,702

Table C.2 IMPLAN Impact Result for the Standard Field Auction Payment

County	Industry Rev	Employment Rev	State &Local Tax Rev
Colquitt	$5,695	0.02	$616
Grady	$6,421	0.02	$853
Seminole	$16,094	0.08	$770
Baker	$38,039	0.17	$1,107
Clay	$8,224	0.02	$462
Decatur	$8,797	0.03	$537
Dougherty	$7,744	0.02	$476
Lee	$9,265	0.04	$528
Miller	$18,783	0.09	$793
Worth	$13,454	0.06	$669
Calhoun	$14,465	0.06	$682
Early	$12,634	0.05	$636
Mitchell	$5,695	0.02	$616
Randolph	$6,421	0.02	$853
Terrell	$16,094	0.08	$770

Appendix D

Table D.1 Average Water Level, Well Depth, and Aquifer Name of Groundwater in Lower FRB

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
Baker*	Lower	Floridan	12K014*	1989 - 2019	137	40	43	42	34.1	153.3
			09J008*	1977 - 2000	157	25	37	31		
			10H009*	1998 - 2021	200	15	50	33		
			09H014	1983 - 1999	200	49	67	58		
			10H007	1995 - 2015	169	56	64	60		
			09H004	1979 - 1982	180	36	38	37		
			09J007	1964	158	10	15	13		
			09J011	1969	165	32	35	34		
			09J016	1969	120	-	-	-		
			08J018	1977 - 2010	170	35	65	50		
			09J004	1977 - 2010	245	36	66	51		
			09J018	1977	250	-	-	-		
			10J004	1977 - 1998	140	26	45	36		
			10J009	1995 - 2019	100	25	33	29		
			09J003	1977 - 1998	120	25	55	40		
			10J010	2010	80	21	23	22		
			09J015	2010	102	-	-	-		
			09J001	1979 -1981	115	20	25	23		
			11J020	1985 - 1999	196	10	27	19		
			10K010	1985	160	-	-	-		
			10K008	2002	120	20	22	21		
			12K008	1977 - 1999	195	20	52	36		
			12K009	1977 - 2011	160	34	45	40		
			10K006	1990 - 1999	100	10	13	12		
			12K130	1987 - 1999	94	26	43	35		
		Claiborne	11J023	1995 - 2015	560	40	50	45	57.8	430.2
			11J024	1995	560	-	-	-		
			09J014	1974	401	-	-	-		
			10J012	1987	390	-	-	-		
			11J014	1977 - 1999	240	67	74	71		
Calhoun*	Lower	Floridan	10K005*	1987 - 2021	138	20	35	28	21.0	150.1
			08K023	2010	135	11	13	12		
			08K021	-	130	-	-	-		
			08K019	2009	130	-	-	-		
			10K005	1983 - 2021	138			-		
			09K012	2010 - 2011	225	27	30	29		
			09L031	2010	250	-	-	-		
			09L029	2010 - 2011	107	10	15	13		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			08L019	-	170	-	-	-		
			09L030	2010 - 2011	143	5	10	8		
			07L005	1979 - 2011	140	52	57	55		
			09L006	1979 - 1994	140	11	18	15		
			10L002	1959 -1998	105	8	14	11		
		Claiborne	09K003	1969 - 2012	545	50	60	55	87.6	372.3
			07L004	1979 - 2009	140	67	75	71		
			07L005	1979 - 2011	157	53	72	63		
			07L001	1979 - 2011	647	146	178	162		
Decatur*	Lower	Floridan	08E038*	2004 - 2021	148	21	24	23	88.2	204.8
			09E009*	1999 -2021	360	210	225	218		
			08E039*	2002 -2021	65	10	17	14		
			09E005*	1999 - 2021	80	35	55	45		
			09F520*	1982 - 2021	251	35	53	44		
			10G001*	1982 - 2021	160	30	50	40		
			09G001*	1982 - 2021	255	35	56	46		
			08D006	2000 - 2016	380	200	210	205		
			07D006	1991 - 2006	340	190	200	195		
			07D004	1999 - 2010	120	54	66	60		
			08D003	1999 - 2011	300	150	180	165		
			08D002	2000 - 2012	340	190	200	195		
			08D090	2000 - 2016	340	210	220	215		
			08D007	2000 - 2012	300	210	225	218		
			08E023	1999 -2000	280	170	175	173		
			07E009	1999 - 2011	320	82	86	84		
			07E062	1999 - 2011	300	74	77	76		
			08E024	1999 - 2011	216	75	76	76		
			07E001	1999 - 2011	154	100	104	102		
			07E008	1999 - 2011	145	31	32	32		
			08E040	2002 - 2004	285	200	210	205		
			09E521	2000 - 2011	294	181	186	184		
			08E019	1999 - 2011	147	10	20	15		
			08E022	1999 - 2011	85	17	20	19		
			08E021	1999- 2011	125	16	20	18		
			08E020	1999 - 2000	88	5	10	8		
			09E383	1954	244	100	110	105		
			09E003	1999 - 2011	75	30	36	33		
			08E031	2000 - 2001	240	109	110	110		
			09E008	1999 - 2000	320	125	145	135		
			08E035	2000	115	15	18	17		
			10G229	1962	160	40	46	43		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			10G184	1962	142	50	56	53		
			10G002	1977	116	-	-	-		
			10G005	1979 - 1986	190	48	53	51		
			08G009	2002	100	42	45	44		
			08G002	1978	170	-	-	-		
			09F006	1979	250	46	50	48		
			10F004	1979 - 2011	120	35	50	43		
			08F513	2010 - 2011	195	40	45	43		
			08F004	1961	83	45	50	48		
		Claiborne	08F515	2015	800	-	-	-	243.5	821.7
			09G020	2010	760	-	-	-		
			10D002	1960	905	240	247	244		
Dougherty*	Lower	Floridan	11K027	1972 - 1998	100	5	23	14	34.0	147.2
			12K132*	1966 - 2021	110	42	48	45		
			12K037*	1996 - 2021	200	50	53	52		
			13K014*	1982 - 2021	131	21	29	25		
			11K015*	1982 - 2021	177	9	13	11		
			12K124*	1987 - 2021	182	45	49	47		
			12K117*	1987 - 2021	190	41	42	42		
			12K173*	1998 - 2021	180	40	43	42		
			11K003	2007 - 2021	150	16	20	18		
			12K168*	1997 - 2021	180	38	41	40		
			12K175*	1998 - 2021	187	49	51	50		
			12K063*	1998 - 2021	-	47	51	49		
			12K180*	2007 - 2021	170	13	20	17		
			12K170*	1997 - 2021	180	34	37	36		
			12L373*	2002 - 2021	170	22	35	29		
			12L348*	1997 - 2021	180	44	44	44		
			12L340*	1997 - 2021	178	39	45	42		
			12L405	2015 - 2021	180	35	35	35		
			12L277*	2007 - 2021	203	11	22	17		
			12L356*	1998 - 2021	160	36	41	39		
			12L346*	1989 -2021	160	40	46	43		
			12L273*	1987 - 2021	120	36	44	40		
			12L344*	1997 - 2021	160	37	39	38		
			12L375*	2001 - 2021	105	26	28	27		
			12L268*	1987 - 2021	-	28	29	29		
			13L180*	2007 - 2021	310	34	46	40		
			12L269*	1987 - 2021	164	39	44	42		
			12L028*	1982 - 2021	100	10	12	11		
			12L029*	1982 - 2021	178	25	38	32		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			13L049*	2007 - 2021	170	13	25	19		
			13K017	1984 - 2011	132	75	90	83		
			12K136	1993 - 1995	215	30	55	43		
			12K137	1993 - 1994	85	28	47	38		
			11K033	1982 - 2011	77	11	23	17		
			12K126	1988 - 1989	224	39	54	47		
			12K016	1982 - 2012	131	13	48	31		
			12K053	1970 - 2007	85	26	46	36		
			13K011	1977 - 2008	430	65	80	73		
			12K101	1985 - 2018	120	26	56	41		
			12K171	1998 - 2016	140	19	46	33		
			11K004	1979 - 1998	150	21	36	29		
			11K043	1992 - 2011	170	15	27	21		
			12K129	1988 - 2016	211	23	55	39		
			11K003	1979 - 2021	150	16	45	31		
			12K169	1977	180	26	26	26		
			11K046	1995 - 1997	115	-	-	-		
			12K167	1996 - 1998	57	31	42	37		
			12K151	1995	200	19	20	20		
			12K152	1995	80	19	20	20		
			12K154	1995	200	19	19	19		
			12K155	1995	80	20	21	21		
			12K123	1988 - 2019	242	15	46	31		
			12K148	1995 - 2000	200	14	26	20		
			12K150	1995	30	17	18	18		
			12K147	1995 - 2003	185	15	40	28		
			11K044	1992 - 1998	200	19	28	24		
			11K028	1975 - 2008	155	15	31	23		
			12K166	1996 - 1998	93	29	41	35		
			12K144	1995 - 1998	200	11	32	22		
			12K145	1995 - 1998	80	11	32	22		
			12K146	1995 - 1998	30	11	31	21		
			12K122	1988 - 2001	98	14	35	25		
			12K172	1998 - 2018	125	16	46	31		
			12K162	1965	247	33	34	34		
			12K141	1996 - 2016	200	14	47	31		
			12K142	1995 - 2011	80	27	34	31		
			12K143	1995 -2014	30	13	30	22		
			12K160	-	233	-	-	-		
			12K163	1966	245	46	47	47		
			12K015	1984 - 1985	114	30	33	32		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			12K161	1961	207	43	45	44		
			12K094	1979 - 2003	115	20	45	33		
			12K165	1969	265	40	48	44		
			12K007	1951 - 1953	79	41	51	46		
			12K164	1969	260	52	52	52		
			13K092	1996 - 1997	144	56	66	61		
			12K174	-	180	-	-	-		
			12K006	1951 - 1961	247	-	-	-		
			12K182	-	200	-	-	-		
			12L338	1996 - 1998	57	34	42	38		
			12L349	1997	165	28	29	29		
			12L339	1997 - 2017	187	30	63	47		
			12L347	1997 - 2021	160	9	32	21		
			11L078	1974 - 1994	100	4	20	12		
			12L377	1997	170	38	38	38		
			12L370	2000 - 2017	172	25	49	37		
			12L372	2000 - 2017	58	10	54	32		
			12L380	2000	158	32	32	32		
			12L381	1999	165	32	32	32		
			12L352	1998 - 2015	100	4	49	27		
			12L378	2000	179	52	54	53		
			12L061	1971 - 2013	195	14	37	26		
			12L405	2015 - 2021	195	24	35	30		
			12L350	2012 - 2013	92	11	43	27		
			13L048	1982 - 2005	345	51	76	64		
			12L341	1997 - 2000	153	16	32	24		
			12L363	-	59	-	-	0		
			12L382	1999	168	27	27	27		
			12L342	1997 - 2018	100	9	40	25		
			12L357	1998 - 2008	160	11	36	24		
			12L343	1997 - 2016	200	20	44	32		
			12L368	-	59	-	-	-		
			13L012	1978 - 2019	218	20	46	33		
			12L351	1998 - 2018	165	14	42	28		
			12L367	-	39	-	-	-		
			12L030	1982 - 2017	180	4	32	18		
			12L050	1983 - 2011	22	13	22	18		
			12L310	1991 - 2018	250	14	46	30		
			13L031	1978 - 1998	290	42	89	66		
			12L345	1997 - 2021	160	16	42	29		
			12L312	1991 - 1998	110	20	36	28		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			12L311	1991 - 2010	100	5	17	11		
			13L032	1978 - 1998	285	46	72	59		
			12L326	1994 - 2015	115	12	37	25		
			13L202	1994 - 1997	98	86	87	87		
			12L328	-	43	-	-	-		
			12L309	1991 - 2011	29	11	18	15		
			11L114	1992 - 1998	180	29	38	34		
			12L305	1994 - 2011	22	8	10	9		
			13L182	1996 - 1998	270	41	62	52		
			13L179	1996 - 1998	120	35	53	44		
			13L191	1996 - 1997	130	45	49	47		
			11L113	1992 - 2012	98	11	22	17		
			12L048	1987 - 1998	85	21	44	33		
			11L120	1993	50	19	20	20		
			11L020	1984 - 2011	150	16	26	21		
			13L209	1996 - 1997	110	50	58	54		
			12L047	1987 - 1991	169	24	45	35		
			13L205	1996 - 1997	70	54	57	56		
			13L190	1996 - 1997	100	44	46	45		
			13L204	1996 - 1997	78	50	52	51		
			13L206	1996 - 1997	79	48	52	50		
			13L208	1996 - 1997	108	55	61	58		
			11L023	1985 - 1994	109	18	35	27		
			13L207	1996 - 1997	110	52	55	54		
			13L189	1996 - 1997	125	39	46	43		
			13L186	1994 - 1997	195	60	62	61		
			13L185	1996 - 1997	173	72	82	77		
			13L184	1996 - 1997	192	61	72	67		
			13L184	1996 - 1997	201	61	73	67		
			13L056	1984 - 1994	199	45	60	53		
			14L048	1996 - 2008	135	25	45	35		
			13L188	1996 - 1997	192	61	69	65		
			13L187	-	190	-	-	-		
			13L181	1996 - 1998	225	23	41	32		
			11L111	1992 - 2011	125	11	32	22		
			13L057	1982 - 2008	150	46	72	59		
			11L077	1974 - 2008	130	9	22	16		
			11L070	1973 - 1998	135	18	24	21		
			11L116	1993 - 2008	150	3	25	14		
			11L117	1993 - 2019	64	2	23	13		
			12L298	1991	34	23	23	23		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			12L297	1990 - 1991	68	34	39	37		
			12L300	1991	52	21	46	34		
			12L267	1989 - 1994	187	-	-	-		
			12L299	1991	38	19	30	25		
			11L092	1980 - 2011	125	21	34	28		
			11L022	1982 - 1987	110	13	37	25		
			12L292	1990 - 1994	74	5	36	21		
			12L293	1990 - 1991	69	4	31	18		
			12L294	1990 - 2011	30	5	25	15		
			12L307	1991 - 1992	130	28	30	29		
			11L003	1977 - 2008	86	7	20	14		
			13L014	1979 -1994	99	11	31	21		
			11L115	1992 - 2008	150	10	28	19		
			13L058	1985 - 1998	173	44	66	55		
			12L044	1982 - 1988	91	20	28	24		
			11L021	1982 - 1998	82	29	41	35		
			11L017	1983 - 1988	144	26	38	32		
			13L052	1982 - 2008	105	6	29	18		
			11L110	1991	280	-	-	-		
			11L112	1992 - 2011	180	21	37	29		
			11L103	1986	140	55	55	55		
			13L047	1977 - 2011	256	28	63	46		
			13L003	1963 - 2000	243	21	43	32		
		Claiborne	11L001*	1978 - 2021	251	12	17	15	84.3	642.0
			12L019*	2007 - 2021	257	50	59	55		
			13L015*	1979 - 2021	351	62	73	68		
			11K002	1979 - 2005	320	22	35	29		
			13K002	1979 - 1992	340	65	70	68		
			12L402	-	452	-	-	-		
			13L011	1977 - 2014	418	60	100	80		
			13L018	1957	900	-	-	-		
			13L240	-	614	-	-	-		
			12L013	1975	900	53	70	62		
			11L109	1989	370	173	173	173		
			12L008	1952	800	123	123	123		
			12L003	1939 - 1957	768	-	-	-		
			12L005	1975	868	97	97	97		
			12L398	-	850	-	-	-		
			11L107	1989	360	52	52	52		
			13L026	1978	942	86	86	86		
			13L027	1978 - 1980	942	56	88	72		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			12L007	1953	725	192	195	194		
			13L016	1979 - 1980	560	60	123	92		
			12L399	-	475	-	-	-		
			13L021	1979	560	79	79	79		
			13L004	1954	700	45	45	45		
			13L244	-	830	-	-	-		
			12L010	1955 - 1976	895	31	97	64		
			13L017	1979 - 1980	550	60	122	91		
			13L002	1979	550	68	68	68		
			12L017	1975	820	65	65	65		
			12L012	1975	855	114	155	135		
			11L024	-	840	-	-	-		
			12L015	1975	840	130	132	131		
Early*	Lower	Floridan	06G006*	1982 - 2021	123	31	65	48	29.5	158.9
			08K001*	1981 - 2021	125	1	35	18		
			06H007	1977 - 1990	165	12	51	32		
			06H013	1977 - 2011	150	18	63	41		
			06H019	-	140	-	-	-		
			06H017	2002 - 2019	245	42	64	53		
			06H005	1977 - 1998	140	23	58	41		
			06H009	1977 - 2011	160	18	59	39		
			06H012	1977 - 2008	205	11	41	26		
			05H002	-	200	-	-	-		
			05H008	1977 - 2011	145	13	45	29		
			05H021	2010 - 2011	110	26	42	34		
			06H011	1980 - 1990	120	8	22	15		
			05J007	1980 - 2011	100	23	43	33		
			05J002	1962	276	-	-	-		
			05J006	1971 - 1985	93	12	34	23		
			06J010	2010 - 2012	275	6	8	7		
			06J007	-	130	-	-	-		
			06J004	2002	75	8		8		
			06J002	1971 - 1990	145	12	41	27		
			08J016	-	132	-	-	-		
			08J015	1978 - 2008	160	19	36	28		
			08J001	1953 - 1976	131	50	54	52		
			08J019	-	140	-	-	-		
			06J009	2010 - 2011	160	35	43	39		
			06J011	-	200	-	-	-		
			05J009	-	165	-	-	-		
			08J020	-	131	-	-	-		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			08J005	1977 - 2000	100	7	35	21		
			08J013	1977 - 1982	243	21	32	27		
			07K015	2010 - 2011	200	3	4	4		
			06K020	2010	72	44	44	44		
			08K024	-	103	-	-	-		
			08K016	1969 - 1999	260	17	41	29		
			08K013	1977 - 2008	155	21	34	28		
			07K016	-	160	-	-	-		
			08K015	1977 - 1998	244	15	35	25		
		Claiborne	08K025*	2017 - 2021	290	22	37	30	44.2	313.6
			06K010*	1981 - 2021	140	73	80	77		
			06G011	1977 - 1994	200	24	62	43		
			05H006	1965 - 1994	494	32	63	48		
			05H007	1975 - 2011	455	47	70	59		
			05H015	1982 - 1992	380	21	41	31		
			05H001	1961 - 1979	380	20	23	22		
			05H009	1979 - 1986	460	72	95	84		
			05H010	1977 - 2011	326	28	61	45		
			07K009	1973 - 2011	198	19	35	27		
			08K026	-	295	-	-	-		
			06K004	1951	145	24	24	24		
Lee**	Lower	Floridan	12M017*	1985 - 2021	181	17	73	45	28.8	165.7
			12M026	1985 - 1998	220	28	52	40		
			13P016	-	130	-	-	-		
			11M039	-	175	-	-	-		
			12M057	-	159	-	-	-		
			11M018	1984	160	-	-	-		
			12M021	1982 - 1998	180	35	44	40		
			12M059	-	190	-	-	-		
			13M081	1983 - 1998	150	30	41	36		
			12M022	1982 - 2000	164	7	25	16		
			13M013	1985 - 1999	170	31	41	36		
			13M064	1983 - 1998	250	8	19	14		
			13M003	1983 - 1990	163	11	13	12		
			12M003	1979 - 1998	140	29	48	39		
			11M010	1977 - 2008	120	18	56	37		
			12M015	1976 - 1985	105	20	38	29		
			13M083	1983 - 1994	165	15	31	23		
			13M088	207		-	-	-		
			12M035	1996	165	35	35	35		
			13M063	1983 - 1994	160	17	35	26		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			13M008	1983 - 1998	143	11	28	20		
			12M060	2010	125	44	44	44		
			13M082	1983 - 1998	160	19	34	27		
			12M013	1967 - 2000	158	20	49	35		
			13M055	1983 - 1990	150	6	14	10		
			13M057	1983 - 1998	163	1	6	4		
			12M010	1978 - 1999	185	15	54	35		
			13M072	-	125	-	-	-		
			13M069	1985	135	3	3	3		
			13M048	1985 - 1998	135	3	7	5		
			13M073	-	100	-	-	-		
			13M043	-	420	-	-	-		
			13M010	1982 - 1994	215	5	98	52		
			13M011	1983 - 2000	160	2	35	19		
			13M049	1985 - 2000	110	22	39	31		
			11M015	1979 - 2011	213	23	57	40		
			13M014	1983 - 1993	185	9	27	18		
			13M019	1984 - 1988	20	1	19	10		
			13M012	1983 - 1994	46	1	23	12		
			13M080	1983 - 2000	160	17	32	25		
			13M046	1983 - 2017	105	2	19	11		
			12M034	1993 - 2002	43	16	19	18		
			13M058	1983 - 1994	175	19	34	27		
			13M004	1977 - 1998	140	13	34	24		
			13M056	1983 - 2011	173	16	40	28		
			13M065	1983 - 2008	140	6	27	17		
			12M012	1978 - 2000	135	5	37	21		
			13M059	1983 - 1998	160	3	17	10		
			12M020	1980 - 1984	156	121	156	139		
			13M074	1986 - 1986	150	38	38	38		
			12M004	1979 - 1990	190	2	37	20		
			12M011	1958 - 2010	197	7	37	22		
			13M079	1983 - 1998	155	16	34	25		
			13M075	1981	173	22	22	22		
			13M077	1983 - 1994	140	5	21	13		
			13M078	1983 - 1994	155	29	51	40		
			13M071	1985	160	30	30	30		
			13M066	1983 - 2011	120	21	47	34		
			13M060	1983 - 2000	165	25	42	34		
			13M084	1987 - 2000	110	1	10	6		
			13M009	1977 - 1986	160	23	46	35		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			13M067	1983	115	28	28	28		
			13M085	1987 - 1994	120	3	4	4		
			13M086	1987 - 2011	160	36	67	52		
			12N006	-	280	-	-	-		
			12N003	1978 - 1990	240	22	43	33		
			12N005	1985 - 1990	98	3	18	11		
			13N003	1977 - 2011	160	32	53	43		
			13N014	2010 - 2011	165	31	165	98		
			13N004	1978 - 1987	300	31	62	47		
			13N009	1980 - 2010	115	4	37	21		
			13N007	1978 - 2011	160	19	61	40		
			12N004	1978 - 2012	200	11	35	23		
			13P005	1982 - 2008	240	28	57	43		
			13P012	-	200	-	-	-		
			11P006	1978 - 2008	319	9	24	17		
			12P012	1978 - 1998	175	14	27	21		
			12N007	-	343	-	-	-		
			13P004	1978 - 1990	140	2	15	9		
			13P014	-	113	-	-	-		
			13P015	1999	300	60	60	60		
			12P011	1978 - 1998	105	11	37	24		
			12P010	1978 - 2008	185	15	34	25		
		Claiborne	11P015*	1984 - 2021	151	33	43	38	59.1	299.7
			06K010*	1981 - 2021	140	73	79	76		
			12M001*	1978 - 2021	385	75	149	112		
			12M058	-	420	-	-	-		
			11M038	-	360	-	-	-		
			13M087	-	445	-	-	-		
			12M056	-	395	-	-	-		
			12M019	1979 - 2010	300	24	55	40		
			12M014	1965	380	73	73	73		
			11P003	1969 - 2011	195	31	40	36		
			11P020	-	185	-	-	-		
			11P001	1950	180	33	33	33		
			13P018	2010	360	63	68	66		
Miller*	Lower	Floridan	08G001*	2007 - 2021	225	13	46	29.5	36.5	160.9
			07H002	1980 - 2015	75	1	33	17		
			08G014	-	210	-	-	-		
			07G027	2010 - 2011	145	1	40	20.5		
			07G029	-	120	-	-	-		
			07G022	-	290	-	-	-		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			07G020	1993	55	21	28	24.5		
			08G008	1993 - 2019	69	23	39	31		
			09G011	1993 - 2019	36	31	36	33.5		
			09G006	1977 - 2008	220	33	67	50		
			07H027	2010	140	33	33	33		
			09H013	1978 - 1986	165	22	59	40.5		
			07H018	1992 - 2019	75	32	52	42		
			06H003	1977 - 2000	180	20	64	42		
			09H012	1979 - 2011	205	27	59	43		
			08H011	1979 - 1990	121	29	40	34.5		
			08H010	1981 - 2011	210	38	59	48.5		
			08H001	1963	234	25	25	25		
			08H002	1963	135	27	28	27.5		
			08H015	-	210	-	-	-		
			06H001	1964	135	47	47	47		
			08H012	1990 - 2000	80	41	60	50.5		
			08H018	-	180	-	-	-		
			06H022	2010 - 2011	180	30	54	42		
			09H011	1977 - 2008	195	44	89	66.5		
			08H017	-	200	-	-	-		
			06H016	1993 - 2001	38	18	34	26		
			07H001	1964	390	-	-	-		
			07H026	2010 - 2011	150	33	33	33		
			08H007	1977 - 2008	200	23	56	39.5		
			07H025	2007 - 2011	120	18	40	29		
		Claiborne	08H016	-	740	-	-	-	61.0	440.0
			07H024	1993 - 2019	140	43	79	61		
Mitchell*	Lower	Floridan	10G313*	1976 - 2021	206	37	63	50	86.2	351.9
			11J030*	2018 - 2021	236	29	50	39.5		
			13J004*	1978 - 2021	208	36	61	48.5		
			12K001*	1976 - 2021	270	14	37	25.5		
			13K013	1976 - 1986	2010	164	177	170.5		
			13K008	1976	295	34	34	34		
			12J003	1979 - 1994	82	13	29	21		
			12G046	2004	740	246	246	246		
			10G317	2007 - 2010	175	39	43	41		
			13G009	-	387	-	-	-		
			10G314	2002 - 2019	370	41	48	44.5		
			12G039	1972	822	121	121	121		
			12G041	-	577	-	-	-		
			12G001	1942	720	215	215	215		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			10H012	2010	225	64	64	64		
			12H015	-	351	-	-	-		
			10H006	1979 - 2011	200	45	67	56		
			11H005	1977 - 1990	185	38	44	41		
			13H011	-	700	-	-	-		
			11H001	1966	110	38	38	38		
			12H023	-	200	-	-	-		
			13H006	1960	305	-	-	-		
			13H004	-	316	-	-	-		
			13H009	1967	345	200	200	200		
			12H012	-	221	-	-	-		
			10H003	1980 - 2000	84	24	59	41.5		
			12H011	1960	287	-	-	-		
			13H012	2010	455	197	199	198		
			12H019	2009	98	45	45	45		
			12H020	2009	133	47	47	47		
			12H014	-	350	-	-	-		
			12H008	1976 - 2019	341	24	45	34.5		
			12H024	-	320	-	-	-		
			12H004	1941	396	63	63	63		
			12H003	1989	207	60	60	60		
			13H005	-	380	-	-	-		
			13H007	1976 - 1990	320	169	175	172		
			12J004	-	220	-	-	-		
			11J001	1979 - 2013	190	13	41	27		
			11J018	1977 - 2008	200	21	43	32		
			12J005	-	300	-	-	-		
			11J019	1977 - 1999	225	24	39	31.5		
			13J015	2010	560	193	193	193		
			13J001	1976 - 2011	431	209	225	217		
			11J012	1982 - 2018	225	32	51	41.5		
			11J016	1979 - 2008	206	19	38	28.5		
			13J007	1990 - 1991	150	124	125	124.5		
			12J002	1979 - 2010	200	25	44	34.5		
			13J009	-	497	-	-	-		
			12J001	1942	460	70	70	70		
			13J014	2010 - 2012	500	83	96	89.5		
			13K023	1985 - 2008	386	149	175	162		
			13K007	1978 - 1978	285	43	43	43		
			13K001	1963 - 1989	382	89	108	98.5		
			13K021	1985 - 2006	310	127	148	137.5		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
		Claiborne	11J011*	1981 - 2021	417	31	52	41.5	105.3	689.4
			11J025*	2018 - 2021	710	32	45	38.5		
			10H013	-	820	142	157	149.5		
			11J029	-	700	104	132	118		
			11H016	-	800	172	186	179		
Randolph*	Lower	Floridan	07M004	1992	75	35	38	36.5	37.25	65.00
			07M003	1979 - 2011	60	41	50	45.5		
			08M004	1992	70	36	36	36		
			08P003	1992	55	31	31	31		
		Claiborne	09M009*	2007 - 2021	94	23	31	27	43.5	101.9
			07L014	1984 - 2011	124	41	48	44.5		
			07M003	1972 - 2011	50	40	43	41.5		
			09N003	1949	135	33	35	34		
			09N002	1978 - 1994	134	39	52	45.5		
			07N007	1979 - 2011	68	34	42	38		
			09N006	1979 - 2011	90	63	85	74		
			08P001	-	120	-	-	-		
Terrell	Lower	Floridan	10M003	1980 - 2008	176	4	31	17.5	24.3	158.1
			10M020	-	200	-	-	-		
			11M025	1992 - 2012	120	9	26	17.5		
			11M006	1980 - 1991	120	13	29	21		
			10M016	-	95	-	-	-		
			11M007	1980 - 2008	95	7	27	17		
			11M031	-	150	-	-	-		
			11M032	-	160	-	-	-		
			11M034	2002	90	23	23	23		
			10M019	2010	190	15	15	15		
			11M041	2010 - 2011	165	11	21	16		
			10M021	-	250	-	-	-		
			10N013	1980 - 1990	140	33	48	40.5		
			10N012	1980 - 2000	103	20	41	30.5		
			10N024	2010 - 2012	90	21	26	23.5		
			11N011	2010	150	32	32	32		
			11N013	-	300	-	-	-		
			10N025	-	350	-	-	-		
			09P005	1979 - 1992	60	35	41	38		
		Claiborne	11M011	1978 - 2011	320	34	57	45.5	49.4	257.7
			11M024	-	320	-	-	-		
			10M009	1979 - 1989	430	28	175	101.5		
			11M013	1978 - 2011	320	34	57	45.5		
			11M003	1953 - 1994	115	32	92	62		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			11M001	1953 - 2011	202	33	51	42		
			11M042	2010 - 2011	240	23	34	28.5		
			09N011	2008 - 2011	210	45	49	47		
			10N017	1978 - 2011	180	30	41	35.5		
			11N006	1979 - 2011	135	32	47	39.5		
			11N007	1979 - 2011	120	41	53	47		
			11N012	-	500	-	-	-		
Worth*	Lower	Floridan	13M006*	1982 - 2021	123	5	45	25	113.4	350.3
			15L020*	1977 - 2021	450	190	220	205		
			16K034	2004 - 2008	354	188	190	189		
			16J037	2008	520	160	165	162.5		
			16J042	2005	490	194	200	197		
			15J018	1990 - 2008	460	215	225	220		
			14J003	1990	280	-	-	-		
			16J036	1998 - 2008	290	170	175	172.5		
			16J041	2008	440	188	120	154		
			16J011	1970 - 2006	570	120	165	142.5		
			16J047	1970	440	-	-	-		
			14J028	-	540	-	-	-		
			16J043	2008	640	-	-	-		
			14J027	1996 - 2008	460	150	160	155		
			14J006	-	250	-	-	-		
			15K014	2008	552	189	191	190		
			15J006	-	305	-	-	-		
			15K006	1976	305	190	217	203.5		
			16K038	-	420	-	-	-		
			16K050	2008	620	155	160	157.5		
			14K060	-	460	-	-	-		
			15K019	2000	400	140	140	140		
			16K016	1968 - 2019	610	150	200	175		
			16K025	-	540	-	-	-		
			15K017	1995 - 2007	440	90	90	90		
			14N012	2008 - 2010	200	15	18	16.5		
			14N001	1943 - 1967	325	13	13	13		
			14N004	1980 - 2019	250	10	32	21		
			15N005	2003	260	118	118	118		
			15N006	2002	210	27	27	27		
			15N007	-	250	-	-	-		
			14N013	1997 - 2008	270	29	36	32.5		
			14M008	1982 - 1999	102	28	40	34		
			14M020	1996	300	28	28	28		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			13M051	1985 - 1999	245	16	24	20		
			14M021	1996	210	28	28	28		
			15M008	1998 - 2008	260	50	55	52.5		
			15M021	2008	170	64	64	64		
			14M019	1998	250	20	20	20		
			15M007	1998 - 2008	260	50	70	60		
			15M009	1996 - 2008	220	72	74	73		
			15M019	2008	82	61	61	61		
			14M018	1996 - 2008	205	14	16	15		
			15M011	1997	220	42	42	42		
			14M017	1995 - 2008	220	20	32	26		
			15M012	1997	300	90	91	90.5		
			14M001	1964 - 1965	215	32	32	32		
			15M022	2008	122	76	76	76		
			15M023	2008	170	74	76	75		
			16L032	2008	575	180	180	180		
			14L056	2007 - 2008	320	57	60	58.5		
			14L046	1992 - 2009	162	70	105	87.5		
			14L009	1985 - 1991	238	53	58	55.5		
			16L023	1996 - 2007	500	170	170	170		
			16L025	2007	490	186	191	188.5		
			15L053	1993 - 2008	480	60	180	120		
			14L006	1977 - 2011	235	110	150	130		
			16L024	2008	400	176	176	176		
			16L026	2007	460	164	169	166.5		
			16L011	1969	210	106	108	107		
			14L002	1965	460	183	185	184		
			16L030	2006	460	140	145	142.5		
			15L042	-	196	-	-	-		
			16K024	2008	420	161	163	162		
			14J600	1966	250	201	202	201.5		
			16K035	1997	580	196	200	198		
			14K003	165	370	-	-	-		
			16K055	2008	340	185	185	185		
			16K031	1998 - 2007	450	160	178	169		
			16K029	2008	400	140	142	141		
			15K018	1997	460	127	130	128.5		
			14L057	1998 - 2008	480	85	90	87.5		
			16L027	2007	380	173	175	174		
			16L001	1965	410	160	165	162.5		
			15L042	-	196	-	-	-		

County	FRB	Aquifer	Site Code	Interval (Year)	Well depth (ft)	Lowest water level	Highest water level	Average water Level	Water Level Average in County(ft)	Average Well Depth
			16L011	1969	210	100	106	103		
			16L031	2006	460	140	145	142.5		
			16L028	2006 - 2007	460	140	150	145		
		Claiborne	15K016	1998 - 2008	740	-	-	-	163.5	534.0
			14K059	1997 - 2008	600	205	220	212.5		
			16K052	2008	725	150	170	160		
			13M005*	2007 - 2021	345	20	40	30		
			14N016	2009 - 2017	460	159	240	199.5		
			15N008	1990 - 2010	334	170	261	215.5		

* Data from active sites

Appendix E: Sensitivity Analysis

Table E.1 Threshold Probability of Well Failure (PrF*) - Doubled Drilling Cost

County \ Pr(Auction)	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%
Baker	-4.61%	-3.40%	-2.20%	-0.99%	0.22%	1.42%	2.63%	3.83%	5.04%	6.25%	7.45%	8.66%	9.86%	11.07%	12.28%	13.48%	14.69%	15.89%	17.10%	18.31%
Calhoun	-3.07%	-1.95%	-0.84%	0.28%	1.39%	2.51%	3.62%	4.73%	5.85%	6.96%	8.08%	9.19%	10.31%	11.42%	12.54%	13.65%	14.77%	15.88%	17.00%	18.11%
Decatur	-9.88%	-8.81%	-7.73%	-6.66%	-5.58%	-4.51%	-3.43%	-2.35%	-1.28%	-0.20%	0.87%	1.95%	3.02%	4.10%	5.18%	6.25%	7.33%	8.40%	9.48%	10.55%
Dougherty	-13.21%	-12.47%	-11.73%	-11.00%	-10.26%	-9.52%	-8.78%	-8.04%	-7.30%	-6.56%	-5.82%	-5.08%	-4.34%	-3.60%	-2.86%	-2.12%	-1.38%	-0.64%	0.10%	0.83%
Early	-2.23%	-1.19%	-0.14%	0.90%	1.95%	2.99%	4.04%	5.08%	6.13%	7.17%	8.22%	9.26%	10.31%	11.35%	12.40%	13.44%	14.49%	15.54%	16.58%	17.63%
Lee	-2.17%	-1.03%	0.11%	1.25%	2.39%	3.54%	4.68%	5.82%	6.96%	8.10%	9.24%	10.38%	11.52%	12.66%	13.80%	14.94%	16.08%	17.22%	18.37%	19.51%
Miller	-4.67%	-3.50%	-2.33%	-1.16%	0.01%	1.19%	2.36%	3.53%	4.70%	5.87%	7.05%	8.22%	9.39%	10.56%	11.73%	12.91%	14.08%	15.25%	16.42%	17.59%
Mitchell	-8.37%	-7.24%	-6.12%	-4.99%	-3.86%	-2.73%	-1.61%	-0.48%	0.65%	1.77%	2.90%	4.03%	5.16%	6.28%	7.41%	8.54%	9.66%	10.79%	11.92%	13.04%
Randolph	-0.32%	0.80%	1.91%	3.03%	4.14%	5.26%	6.37%	7.49%	8.60%	9.72%	10.83%	11.95%	13.06%	14.18%	15.29%	16.41%	17.52%	18.64%	19.76%	20.87%
Terrell	-1.46%	-0.37%	0.72%	1.81%	2.90%	3.99%	5.07%	6.16%	7.25%	8.34%	9.43%	10.52%	11.61%	12.69%	13.78%	14.87%	15.96%	17.05%	18.14%	19.22%
Worth	-2.85%	-1.75%	-0.65%	0.45%	1.55%	2.65%	3.76%	4.86%	5.96%	7.06%	8.16%	9.26%	10.36%	11.46%	12.57%	13.67%	14.77%	15.87%	16.97%	18.07%