AN EXAMINATION OF THE DISTRIBUTION OF GEORGIA’S AGRICULTURAL WATER USE PERMITS AND POSSIBLE ERRORS RESULTING FROM THE USE OF COUNTY LEVEL PERMIT DATA FOR WATERSHED OR RIVER BASIN MANAGEMENT PRACTICES

by

PETER JOSEPH FOSTER

(Under the Direction of Jeff Mullen)

ABSTRACT

Georgia uses the administrative permitting system to manage surface water and groundwater throughout the state. Under the existing system, permits and associated water-use data are all referenced to one of Georgia’s 159 counties. If the state of Georgia decided to switch its water management approach from a county system to a watershed or river basin system, problems could arise from the utilization of water-use data collected at the county level. The objectives of this study are as follows: First, organize and reference water-use data from the Georgia Agriculture Permitting Database into corresponding watershed and river basin segments. Second, calculate theoretical quantity estimates of county permitted withdrawals using county land area percentages inside each Georgia watershed/river basin and compare these estimates to actual quantities. The results of this study demonstrate that discrepancies between estimates and actual quantities may signal errors resulting from the reorganization of county level water-use data.

INDEX WORDS: Georgia, Agriculture, Water, Permits, Watersheds, River Basins
AN EXAMINATION OF THE DISTRIBUTION OF GEORGIA’S AGRICULTURAL WATER USE PERMITS AND POSSIBLE ERRORS RESULTING FROM THE USE OF COUNTY LEVEL PERMIT DATA FOR WATERSHED OR RIVER BASIN MANAGEMENT PRACTICES

by

PETER JOSEPH FOSTER

B.S., The University of Arizona, 2003

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2005
AN EXAMINATION OF THE DISTRIBUTION OF GEORGIA’S AGRICULTURAL WATER
USE PERMITS AND POSSIBLE ERRORS RESULTING FROM THE USE OF COUNTY
LEVEL PERMIT DATA FOR WATERSHED OR RIVER BASIN MANAGEMENT
PRACTICES

by

PETER JOSEPH FOSTER

Major Professor: Jeff Mullen
Committee: Warren Kriesel
Jack Houston

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
December 2005
DEDICATION

This work is dedicated to Dad, Mom, Alison, and Andrew. Thank you for supporting me in all of my endeavors, both academic and otherwise. You inspire me to pursue my dreams and I love you all very much.
ACKNOWLEDGEMENTS

This thesis is the culmination of my graduate work at the University of Georgia. I would like to acknowledge some of the many people that helped me along the way. Thank you to Dr. Jeff Mullen, my major professor. Dr. Mullen graciously stepped in to guide me after my original plans were unexpectedly altered. His patience and knowledge were critical to my success. I would also like to thank the other members of my committee, Dr. Warren Kriesel and Dr. Jack Houston.

In the course of my research, I received incredible support from a handful of graduate students at the UGA Department of Geography. Thank you to Bo Xu. Bo was always willing to answer my ArcView questions and I could not have completed this work without her. Thank you also to Fuyuan Liang and Mario Giraldo.

I would like to thank my good friends Mark, Katy, and Joe. Thank you for making my time in Georgia truly enjoyable. You are great people and I am proud to call you my friends.

Finally, I would like to thank my family for their endless support. Dad, thank you for all the great advice over these last few years. You are my role model and I love you very much. Mom, thank you! Your efforts were truly amazing and I absolutely could not have done this without you. You are incredible and I love you very much. Alison and Andrew, you are both fantastic influences on me and I am so proud of the things you have each accomplished. I am remarkably blessed to be supported by such an extraordinary family. Thank you!
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Acknowledgements</th>
<th>v</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Tables</td>
<td>viii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>ix</td>
</tr>
<tr>
<td>Chapter</td>
<td></td>
</tr>
<tr>
<td>1      INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2.1. Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2. Problem Statement</td>
<td>2</td>
</tr>
<tr>
<td>1.3. Objectives</td>
<td>4</td>
</tr>
<tr>
<td>1.4 Procedure</td>
<td>4</td>
</tr>
<tr>
<td>1.5 Organization of the Thesis</td>
<td>5</td>
</tr>
<tr>
<td>2      GEORGIA WATER</td>
<td>6</td>
</tr>
<tr>
<td>2.1. Georgia Water Background</td>
<td>6</td>
</tr>
<tr>
<td>2.2. Groundwater Supplies</td>
<td>7</td>
</tr>
<tr>
<td>2.3. Surface Water Supplies</td>
<td>7</td>
</tr>
<tr>
<td>2.4. Total Water Demand</td>
<td>8</td>
</tr>
<tr>
<td>2.5. Joint Comprehensive Water Plan Study Committee</td>
<td>9</td>
</tr>
<tr>
<td>2.6. Georgia Agriculture</td>
<td>11</td>
</tr>
<tr>
<td>2.7. Irrigation Water-use</td>
<td>11</td>
</tr>
<tr>
<td>2.8. Water-use Data Collection</td>
<td>12</td>
</tr>
</tbody>
</table>
2.9. Brief History of United States Water Law .......................................................12
2.10. Georgia Water Law ........................................................................................14

3 WATERSHED MANAGEMENT ...............................................................................18
3.1. Georgia’s River Basins and Watersheds .........................................................18
3.2. Watershed Management ..................................................................................18
3.3. Watershed Management Benefits.....................................................................19
3.4. Watershed Management in Practice .................................................................21

4 METHODOLOGY ......................................................................................................24
4.1. Geographic Information Systems .....................................................................24
4.2. Data Set ............................................................................................................25
4.3. Data Analysis ...................................................................................................26
4.4. Data Organization and Website Creation.........................................................28

5 RESULTS ....................................................................................................................33
5.1. Overview of Results .........................................................................................33
5.2. Watershed Results ............................................................................................33
5.3. Individual Watershed Summaries ....................................................................35
5.4. River Basin Results ..........................................................................................64
5.5. Individual River Basin Summaries ...................................................................65

6 POLICY IMPLICATIONS, CONCLUSIONS, AND RECOMMENDATIONS........92
6.1. Policy Implications...........................................................................................92
6.2. Conclusions ......................................................................................................96
6.3. Recommendations ............................................................................................98

REFERENCES ............................................................................................................................100
LIST OF TABLES

Table 2.1: Georgia Groundwater Withdrawals by Aquifer in Year 2000 ........................................15

Table 2.2: Georgia Water Withdrawals by Source in Year 2000 ..................................................15

Table 2.3: Comprehensive vs. Selective Permit Programs in Administrative Permitting

States..............................................................................................................................................16

Table 5.1: Watershed % Differences Across Source Categories for Estimated vs. Actual

Permitting Figures.........................................................................................................................73

Table 5.2: Groundwater + Surface Water Permitted Withdrawals Ranking at Watershed

Level.............................................................................................................................................76

Table 5.3: River Basin % Differences Across Source Categories for Estimated vs. Actual

Permitting Figures.........................................................................................................................78

Table 5.4: Groundwater + Surface Water Permitted Withdrawals Ranking at River Basin

Level.............................................................................................................................................79
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Trends in U.S. Population and Freshwater Withdrawals, 1950-2000</td>
<td>2</td>
</tr>
<tr>
<td>2.1</td>
<td>Georgia Aquifer Systems</td>
<td>17</td>
</tr>
<tr>
<td>3.1</td>
<td>Georgia’s 14 River Basins</td>
<td>22</td>
</tr>
<tr>
<td>3.2</td>
<td>Georgia’s 52 Watersheds</td>
<td>23</td>
</tr>
<tr>
<td>4.1</td>
<td>Georgia Agriculture Groundwater Permits</td>
<td>31</td>
</tr>
<tr>
<td>4.2</td>
<td>Georgia Agriculture Surface Water Permits</td>
<td>32</td>
</tr>
<tr>
<td>5.1</td>
<td>Overestimated and Underestimated Watersheds: Agricultural Groundwater Permits</td>
<td>80</td>
</tr>
<tr>
<td>5.2</td>
<td>Overestimated and Underestimated Watersheds: Agricultural Groundwater Permitted Withdrawals (GPM)</td>
<td>81</td>
</tr>
<tr>
<td>5.3</td>
<td>Overestimated and Underestimated Watersheds: Agricultural Surface Water Permits</td>
<td>82</td>
</tr>
<tr>
<td>5.4</td>
<td>Overestimated and Underestimated Watersheds: Agricultural Surface Water Permitted Withdrawals (GPM)</td>
<td>83</td>
</tr>
<tr>
<td>5.5</td>
<td>Overestimated and Underestimated Watersheds: Agricultural Groundwater + Surface Water Permits</td>
<td>84</td>
</tr>
<tr>
<td>5.6</td>
<td>Overestimated and Underestimated Watersheds: Agricultural Groundwater + Surface Water Permitted Withdrawals (GPM)</td>
<td>85</td>
</tr>
</tbody>
</table>
Figure 5.7: Overestimated and Underestimated River Basins: Agricultural Groundwater Permits.................................................................86

Figure 5.8: Overestimated and Underestimated River Basins: Agricultural Groundwater Permitted Withdrawals (GPM)..........................87

Figure 5.9: Overestimated and Underestimated River Basins: Agricultural Surface Water Permits..........................................................88

Figure 5.10: Overestimated and Underestimated River Basins: Agricultural Surface Water Permitted Withdrawals (GPM)..................89

Figure 5.11: Overestimated and Underestimated River Basins: Agricultural Groundwater + Surface Water Permits............................90

Figure 5.12: Overestimated and Underestimated River Basins: Agricultural Groundwater + Surface Water Permitted Withdrawals (GPM)........................................91
CHAPTER 1
INTRODUCTION

1.1. Background

In the most basic sense, water is one of the most valuable resources on Earth. Without water, humans can live for merely a few days. While water is vital for our physical health, it is equally as critical to the health of our economies. Virtually every industry on the planet relies on some amount of freshwater resources. Industries such as manufacturing and agriculture use water as a direct input of production. Conversely, businesses such as those that provide financial services may use water simply for plumbing and drinking purposes. Either way, water is needed to keep economies running smoothly. In general, water is a renewable resource and the fundamental quantity of freshwater on Earth has remained fairly constant throughout time. That being said, the increasing world population is placing great stress on our water supplies. As the strains on our freshwater resources increase, the job of managing those resources becomes progressively more difficult.

Typically, the task of allocating water resources falls on the government. In the United States, federal and state laws govern the use of water resources. In the 1830s, water law was first recognized as a distinct legal category in the United States (Tarlock, 1988). Laws and regulations regarding water-use are imperative because at the fundamental level, water is an own-price inelastic good on the demand side. Since it is absolutely vital to human existence, individuals will pay virtually any price to obtain enough water to satisfy their physiological needs.
Regulatory measures are necessary to ensure all citizens receive their basic water requirements at a reasonable price.

In the United States, low water prices and increasing populations have led to high levels of freshwater consumption (Figure 1.1). As surface and groundwater consumption increases throughout the country, policy makers are becoming increasingly aware of the water scarcity issues facing their states.

1.2. Problem Statement

Georgia has always been one of the “wettest” states in the country (Kundell and Tetens, 1998). As such, it would seem that water management would be a simple endeavor. In reality, water allocation in Georgia is a complex undertaking that is often a hotly debated topic. Currently, Georgia uses the administrative permitting system to manage surface water and groundwater throughout the state. Under the existing system, permits and associated water-use
data are all referenced to one of Georgia’s 159 counties. An example of this system is the database from which the dataset used in this study was derived. The Georgia Ag Permitting Database is an agricultural water-use permit database referenced by withdrawal point and encompassing county. Since rivers, lakes, aquifers, watersheds, and river basins do not yield to county boundaries, this current system may be ineffective. A better method may be to manage Georgia’s water at the watershed or river basin level.

The administrative permitting system employed in Georgia requires all water-use above a threshold of 100,000 gallons per day to be permitted. The task of issuing water-use permits is important. Administrators must consider the needs of Georgia water-users as well as the environmental impacts of their consumption. Allocating scarce freshwater resources amongst competing users across and within sectors is a difficult task, compounded by the state’s 159 counties and corresponding political agendas. When ecological concerns are factored into the equation, the task becomes all the more daunting.

In response to these problems, the watershed management theory has been developed. The concept of switching from the county level water management system to a more streamlined watershed management approach is gaining attention throughout the country. Unfortunately, most water-use data is collected and compiled with respect to political boundaries such as counties. If a watershed management policy were implemented in Georgia, what would be the consequences of managing water at the watershed level with data collected at the county level? How would such a shift impact specific water-use sectors throughout the state? Specifically, how would policy decisions regarding one of Georgia’s largest consumers of freshwater resources, the agricultural sector, be affected by such a change in management techniques?
This study will examine the consequences of using agricultural water-use data referenced by county for watershed or river basin management practices. To do this, existing agricultural water-use permit data will be converted from the county level to the watershed and river basin level. By assuming that water withdrawals are evenly distributed across a given county, land area based quantity estimates of county permitted withdrawals within a particular watershed or river basin can be calculated. For example, if 25% of the land area of a county lies within a given watershed, it is estimated that 25% of the county’s total permitted withdrawals are attributed to that watershed. These land area based estimates can be compared to actual figures to uncover errors that may indicate mistakes in the allocation of permitted agricultural water withdrawals.

1.3. Objectives

The objectives of this study are as follows:

- Organize and reference data from the Georgia Ag Permitting Database into corresponding watershed and river basin segments.
- Calculate theoretical quantity estimates of county permitted withdrawals using county land area percentages inside each Georgia watershed/river basin and compare these estimates to actual quantities. Discrepancies between estimates and actual quantities may signal errors resulting from the reorganization of county level water-use data.
- Present information in a website that can serve as a reference for policy makers considering a switch to the watershed or river basin water management system.

1.4 Procedure

The data set used for this study is the Georgia Department of Natural Resources Ag Permitting Database. Spatial analysis of the data set was conducted using Geographic Information Systems (GIS) techniques via the ArcView GIS 3.3 software package. This method
allowed water-use permits at the county level to be referenced to one of 52 watersheds located inside the state.

1.5 Organization of the Thesis

Chapter 2 discusses water supplies and aggregate water demand in Georgia. Additionally, the chapter briefly outlines state water-use data acquisition procedures as well as state and national water laws. Chapter 3 defines the watersheds and river basins found in Georgia and provides details regarding watershed management policy. Chapter 4 outlines the procedures used to meet the objectives of the study. Chapter 5 discusses the results of the study and Chapter 6 provides policy implications, conclusions, and recommendations drawn from the analysis.
CHAPTER 2

GEORGIA WATER

2.1. Georgia Water Background

Georgia, the largest state east of the Mississippi River, has always been considered a water-rich state. Georgia has a climate that traditionally receives rainfall at levels far above the national average. Each year the state receives approximately 50 inches of precipitation compared to a national average of 30 inches (Georgia Fact Sheet, 2005). Additionally, the state is home to 70,150 miles of rivers and streams, 425,382 acres of lakes, 854 square miles of estuaries, 100 miles of coastline, 4,500,000 acres of freshwater wetlands, and 384,000 acres of tidal wetlands (Georgia Board of Natural Resources, 2001). Clearly, Georgia has a wealth of freshwater resources. That being said, the state is not immune to water scarcity issues.

According to the Georgia Board of Natural Resources (2001), there are 7 major stresses on Georgia’s water supply. The first is growth in north Georgia. The ever increasing population of Atlanta and surrounding communities requires substantial quantities of water. Moreover, the water needs of this region must be satisfied via limited groundwater reserves. Consequently, the vast majority of north Georgia’s water withdrawals come from surface water sources plagued by low flow rates. The second major stress on Georgia’s water supply is growth in Coastal Georgia. Saltwater intrusion into the Floridan Aquifer is the chief concern here. The third issue designated as problematic by the Georgia Board of Natural Resources is agricultural water-use in the Flint River Basin. Farmers in Southwest Georgia rely heavily on irrigation. In drought years, the Flint
River is greatly taxed by these practices. The fourth stress on Georgia’s water supply is interstate conflicts between Georgia, Alabama, and Florida over management practices in the Coosa, Tallapoosa, Flint, and Chattahoochee river basins. The drought of 1998 through 2001 is listed by the Georgia Board of Natural Resources as the fifth major stress on state water resources. Outdated infrastructure and degenerating aquatic habitats are the sixth and seventh major stresses on Georgia’s water.

2.2. Groundwater Supplies

Georgia relies on 6 major aquifer systems for its groundwater supply (Figure 2.1). The Floridan aquifer, the Claiborne aquifer, and the Clayton aquifer constitute the major sources of groundwater in south Georgia. The Cretaceous aquifer lies under parts of central Georgia, while the Crystalline and Paleozoic rock aquifers are located in north Georgia. Approximately one quarter of Georgia’s total water withdrawals come from the groundwater located in these aquifers (Table 2.1). 1985 was the first year that total groundwater withdrawals in Georgia exceeded one billion gallons per day (Tyson, 1993). In the year 2000, groundwater withdrawals in Georgia totaled nearly 1.5 billion gallons per day (Fanning, 2003). For the purposes of this study, the term withdrawal refers to water being removed from a surface water or groundwater source for consumptive use or non-consumptive use. The term consumptive use is defined by the USGS (2005) as the quantity of water that is not available for immediate reuse because it has been evaporated, transpired, or incorporated into products, plant tissue, or animal tissue.

2.3. Surface Water Supplies

As noted earlier, there are more than 70 thousand miles of rivers and streams connecting nearly one half of a million acres of lakes and reservoirs in the state of Georgia. In the year 2000, surface water withdrawals from these sources exceeded 5 billion gallons per day. Today, over
half of Georgia’s approximately 8.5 million residents rely on surface water for drinking purposes. North Georgia is heavily dependent on surface water resources. Fortunately, Georgia’s surface water resources are usually replenished by the above average annual levels of rainfall that the state typically receives.

2.4. Total Water Demand

Per capita water-use in Georgia reached an all-time high in the year 1980. That year, total water withdrawals equaled approximately 6,725,000,000 gallons per day. In 1980, the population of Georgia was 5,463,105. In 2000, Georgia had a population of 8,186,450 (U.S. Census Bureau). That year, estimated total water withdrawals equaled approximately 6,487,000,000 gallons per day. This decrease in per capita water-use may be a result of permitting regulations enacted into Georgia state law in the 1970’s. These regulations will be discussed in section 2.10 Georgia Water Law. Additionally, changes in water pricing may have affected per capita water-use in Georgia over the last 25 years. Price structures such as the increasing block system (price increases as consumption increases), and the flat rate system (price remains constant regardless of consumption) have been implemented in Georgia with varying results. As water becomes increasingly scarce in Georgia, talks of rate increases will be heavily debated (Shirek, 2004).

In the year 2000, approximately 22.35% of total water withdrawals in Georgia came from groundwater sources. Surface water sources provided the remaining 77.65% (Fanning, 2003). The U.S. Geological Survey predicts that in the future, public water-use will increase as the population of Georgia increases. In addition, it is thought that industrial water-use will decrease as technologies improve and more emphasis is placed on conservation. Water-use for irrigation purposes in Georgia is expected to continue to fluctuate as yearly weather trends vary (Fanning, 2003).
2.5. Joint Comprehensive Water Plan Study Committee

In 2001, state officials decided to undertake a broad ranging investigation of Georgia’s water situation. That year, the Joint Comprehensive Water Plan Study Committee (Study Committee) was created when Senate Resolution 142 was adopted by the Georgia General Assembly. The Study Committee met from May 2001 through August 2002. According to its Final Report (2002), the 5 objectives for which the Study Committee was created are as follows:

- undertake a study of the water resources issues facing Georgia, including water quality and quantity
- consider existing policy, laws, rules and programs to manage water resources
- develop principles for a comprehensive water plan
- recommend a process and schedule to prepare the details of a comprehensive water plan
- recommend any other action or legislation the study committee deems appropriate

In addition to the Study Committee, Senate Resolution 142 created a Georgia Water Plan Advisory Committee (Advisory Committee). The Advisory Committee included members from Georgia’s scientific community, business community, environmental community, agriculture community, outdoor recreation community, academic community, commercial fisheries community, and various river basin groups. The Advisory Committee was established to gather information, prepare briefs, provide recommendations, and evaluate proposals.
After fifteen months of meetings and deliberations, the Study Committee made 35 recommendations in its Final Report to the Governor and General Assembly (2002). Of particular note are the following recommendations:

- Enact enabling legislation to provide for the development and implementation of a comprehensive state water management plan
- Amend the Ground Water-use Act to require every person withdrawing water from a system of wells in a total amount exceeding 100,000 gallons per day to obtain a permit from the Environmental Protection Division
- Amend the Ground Water-use Act and the Water Quality Control Act to require persons holding farm use permits to measure and periodically report water-use from all agricultural irrigation wells and pumps
- Amend the Water Quality Control Act to require persons withdrawing water from ponds, impoundments, and sinkholes for farm uses in amounts in excess of 100,000 gallons per day for irrigation to obtain a permit from the Environmental Protection Division

With the Joint Comprehensive Water Plan Study Committee’s recommendations in mind, House Bill 237 was introduced in the 2003 session of the Georgia General Assembly. One of the major points of the bill was agricultural water-use. The bill called for new regulations on agricultural water-use measurements. Essentially, the bill would have helped policy makers gain valuable information about how much water is used by the state’s agricultural sector, one of the largest water-users in Georgia. Ultimately, House Bill 237 was not enacted into Georgia law.

As the Joint Comprehensive Water Plan Study Committee was being formulated in 2001, the Georgia Board of Natural Resources (2001) drafted a paper about the state’s major water
issues. Titled *Water Issues White Paper*, the document provides a hierarchy of water-uses facing Georgia. It lists human needs as the chief priority. Farm irrigation is second, followed by industrial and recreational uses.

2.6. Georgia Agriculture

Farming is a major industry in Georgia. Agriculture accounts for 16 percent of the state’s gross domestic product and employs 15 percent of the state’s labor force (Doherty and McKissick, 2000). The state of Georgia ranks first in the country in the production of three major crops: peanuts, pecans, and rye. Approximately 45 percent of all peanuts grown in the United States come from Georgia. Likewise, Georgia is the nation’s second leading producer of peaches and third leading producer of tomatoes and cotton (Georgia Farm Bureau, 1997).

In 2002, the number of farms in Georgia totaled 49,311. That year, the average size of a Georgia farm was 218 acres. In total, 3,076,482 acres of 10,744,239 total acres (28.63%) of Georgia farmland were irrigated in 2002. This is approximately a 3.84% increase from the 1997 irrigated farm acres/total farm acres ratio of 24.79% (USDA, 2002).

2.7. Irrigation Water-use

An absolutely necessary element of agricultural production in the western states, crop irrigation has become increasingly common in eastern states such as Georgia. Farmers make decisions about irrigation based on factors such as weather, crop type, growth rate, and soil conditions. Irrigation in Georgia is seasonal and generally occurs from April through October (Hook et al., 1999). While no measures exist to precisely gauge total agricultural water-use, it is estimated that irrigation is responsible for over one billion gallons of freshwater withdrawals per day in Georgia. That figure ranks 3rd largest of the 6 major sectors of water-use in the state:
Thermoelectric, Public Supply, Irrigation, Industrial/Mining, Domestic/Commercial, and Livestock (Table 2.2) (Fanning, 2003).

2.8. Water-use Data Collection

In 1979, the Georgia Water-Use Program was established when several state agencies, including the U.S. Geological Survey (USGS), Environmental Protection Division, and the Department of Natural Resources, agreed to jointly collect comprehensive water-use data for the state of Georgia (Fanning, 1985). As a result, the USGS now publishes extensive state water-use reports every five years. At the time of this study, the most recent report was from the year 2000. Titled, Water-use in Georgia by County for 2000 and Water-Use Trends for 1980-2000, the report provides water-use data for each county in Georgia by source and sector (Fanning, 2003).

Water-use data found in the 2000 report were obtained from files belonging to the Georgia Environmental Protection Division (EPD), as well as various Federal, State, and local sources. According to the author, both permitted and non-permitted water-use is represented in the report. Permitted use was obtained from records kept by the EPD, while non-permitted use was estimated by a variety of entities. For example, the University of Georgia Cooperative Extension Service provided irrigation estimates for the report.

2.9. Brief History of United States Water Law

Laws governing water allocation in the United States can be divided into two distinct doctrines: riparian rights and prior appropriations. Historically, eastern states have followed the former and western states the latter. Eastern water law is the primary focus of this section. The riparian rights doctrine has roots in English common law and was implemented in the eastern United States by the original colonists. Individuals acquired riparian rights by owning land
adjacent to a waterway. Owners were entitled to water from the waterway provided their use was reasonable and did not interfere with the rights of downstream users.

As settlers headed west, it became evident that the dry climate they encountered would not be conducive to riparian law. Consequently, the doctrine of prior appropriations was developed. Under this doctrine, whomever first established use of a water source was granted a vested right to continue using the source. Unlike riparian rights, prior appropriations had no rules ensuring secondary claims (Kundell and Tetens, 1998).

In the 1830s, water law was first recognized as a distinct legal category. It was during this time when groundwater and surface water developed separate legal doctrines (Tarlock, 1988). Initially, groundwater in eastern states was subject to absolute ownership. As such, landowners could withdraw as much or as little water as they desired. Eventually, the absolute ownership doctrine for groundwater gave way to the reasonable-use doctrine. This new doctrine limited the ability of individuals to export groundwater to outside locations (Kundell and Tetens, 1998).

In the eastern United States, riparian law based on reasonable-use was the status-quo for generations. That being said, some eastern states eventually shifted to a regulated riparianism doctrine. Regulated riparianism is also known as administrative permitting. Under the administrative permitting doctrine, water-use above a certain threshold must be permitted. Two approaches exist for administrative permitting: comprehensive permitting and selective permitting. The comprehensive permitting scheme requires all withdrawals over the predetermined limit to be permitted. Conversely, the selective permitting system only requires withdrawal permits for specific circumstances or geographic locations. Table 2.3 shows the states that comply with the comprehensive permitting scheme as well as those that use the selective permitting scheme (Kundell and Tetens, 1998).
2.10. Georgia Water Law

Today, Georgia allocates water resources via the administrative permitting doctrine. Like many states in the east, Georgia was originally a strict riparian state. That changed in 1972 when two important pieces of legislation were enacted. The first, titled the Executive Reorganization Act, granted the Georgia Board of Natural Resources responsibility for the state’s water resources (Kundell and Tetens, 1998). Today, through its various divisions, the Board of Natural Resources manages all of Georgia’s water. The Environmental Protection Division, Coastal Resources Division, Wildlife Resources Division, and Pollution Prevention Assistance Division are all subsets of the Georgia Board of Natural Resources (Georgia Board of Natural Resources, 2001).

The second significant piece of legislation from 1972 was the Ground Water-use Act. This act created the basic permitting system that is used today in Georgia. When it was passed, the law stated that withdrawals of groundwater over 100,000 gallons per day must be permitted. A division of the Georgia Department of Natural Resources, the Environmental Protection Division was responsible for issuing permits. Surface water in Georgia became regulated via permitting in 1977. Similar to the Ground Water-use Act of 1972, individuals making surface water withdrawals in excess of 100,000 gallons per day were required to obtain a permit. Originally, withdrawals of both surface water and groundwater for agricultural use were excused from the permit requirements. This changed in 1988, when legislation was passed that established a permitting scheme for agricultural water-use (Kundell and Tetens, 1998). Today, Georgia water law is still heavily influenced by the legislation discussed above.
Table 2.1. Georgia Groundwater Withdrawals by Aquifer in Year 2000 (Millions of Gallons Per Day)

<table>
<thead>
<tr>
<th>Aquifer Name</th>
<th>Public Supply</th>
<th>Domestic &amp; Commercial</th>
<th>Industrial &amp; Mining</th>
<th>Irrigation</th>
<th>Livestock</th>
<th>Thermo-electric</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floridan</td>
<td>141.50</td>
<td>44.58</td>
<td>204.57</td>
<td>425.01</td>
<td>0.93</td>
<td>2.71</td>
<td>819.31</td>
</tr>
<tr>
<td>Claiborne</td>
<td>22.94</td>
<td>6.19</td>
<td>2.43</td>
<td>119.58</td>
<td>0.16</td>
<td>0.78</td>
<td>152.08</td>
</tr>
<tr>
<td>Clayton</td>
<td>10.57</td>
<td>0.75</td>
<td>8.19</td>
<td>92.42</td>
<td>0.07</td>
<td>0.18</td>
<td>113.18</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>58.04</td>
<td>10.76</td>
<td>67.55</td>
<td>88.46</td>
<td>1.85</td>
<td>0.00</td>
<td>226.66</td>
</tr>
<tr>
<td>Crystalline-rock</td>
<td>20.18</td>
<td>58.62</td>
<td>2.76</td>
<td>3.87</td>
<td>6.21</td>
<td>0.02</td>
<td>91.66</td>
</tr>
<tr>
<td>Paleozoic-rock</td>
<td>24.45</td>
<td>7.24</td>
<td>11.90</td>
<td>3.35</td>
<td>0.10</td>
<td>0.00</td>
<td>47.04</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>277.68</td>
<td>129.14</td>
<td>297.40</td>
<td>732.70</td>
<td>9.32</td>
<td>3.69</td>
<td>1,449.9</td>
</tr>
</tbody>
</table>

Source: Fanning, 2003

Table 2.2. Georgia Water Withdrawals by Source in Year 2000 (Millions of Gallons Per Day)

<table>
<thead>
<tr>
<th>Source</th>
<th>Public Supply</th>
<th>Domestic &amp; Commercial</th>
<th>Industrial &amp; Mining</th>
<th>Irrigation</th>
<th>Livestock</th>
<th>Thermo-electric</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater</td>
<td>277.68</td>
<td>129.14</td>
<td>297.40</td>
<td>732.70</td>
<td>9.32</td>
<td>3.69</td>
<td>1449.93</td>
</tr>
<tr>
<td>Surface water</td>
<td>968.28</td>
<td>12.63</td>
<td>364.66</td>
<td>359.46</td>
<td>25.35</td>
<td>3306.27</td>
<td>5036.65</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1245.9</td>
<td>141.77</td>
<td>662.06</td>
<td>1092.16</td>
<td>34.67</td>
<td>3309.96</td>
<td>6486.58</td>
</tr>
</tbody>
</table>

Source: Fanning, 2003
Table 2.3. Comprehensive vs. Selective Permit Programs in Administrative Permitting States

<table>
<thead>
<tr>
<th>States with Comprehensive Permit Programs</th>
<th>States with Selective Permit Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>Alabama</td>
</tr>
<tr>
<td>Delaware</td>
<td>Arkansas</td>
</tr>
<tr>
<td>Florida</td>
<td>Illinois</td>
</tr>
<tr>
<td>Georgia</td>
<td>South Carolina</td>
</tr>
<tr>
<td>Iowa</td>
<td>Maine</td>
</tr>
<tr>
<td>Kentucky</td>
<td>Mississippi</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>New York</td>
</tr>
<tr>
<td>Minnesota</td>
<td>North Carolina</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Pennsylvania</td>
</tr>
<tr>
<td>New Jersey</td>
<td>Indiana</td>
</tr>
<tr>
<td>Maryland</td>
<td>Virginia</td>
</tr>
</tbody>
</table>

Source: Kundell and Tetens, 1998
1: Floridan aquifer
2: Floridan, Claiborne, Clayton, and Providence aquifers
3: Floridan and Cretaceous aquifers
4: Claiborne, Clayton, and Providence aquifers
5: Cretaceous aquifer
6: Crystalline-rock aquifer
7: Paleozoic-rock aquifer

Figure 2.1. Georgia Aquifer Systems (Map by Cressler, 2000)
CHAPTER 3
WATERSHED MANAGEMENT

3.1. Georgia’s River Basins and Watersheds

Paul DeBarry (2004) defines a river basin as the drainage area of a river and its tributaries. The United States is home to 350 river basins. A watershed is defined as the area of land where precipitation drains to a single stream, river, or lake. Watersheds are essentially natural drainage basins. The state of Georgia has 14 major river basins (Figure 3.1) and 52 subsequent watersheds (Figure 3.2). River basins and watersheds are functions of topography and do not correspond to political boundaries.

3.2. Watershed Management

According to Isobel Heathcote (1998), an effective water management strategy meets three criteria. First, it facilitates a sufficient supply of water that is sustainable into the future. Next, it maintains water quality at satisfactory levels. Such levels are those that meet government regulations and other societal water quality measures. Last, an effective water management strategy supports sustainable economic development over the short and long term.

The traditional approach to water resource management has been on a jurisdiction or ownership specified basis (DeMeo and Kundell, 2001). Examples of this approach include Georgia’s current system of issuing water-use permits referenced at the county level. This fragmented method often leads to ineffective political quarreling and redundancies in management practices. In general, the traditional approach relies on separate agencies to administer laws at federal, state, and local levels. Also, public and private lands are treated
differently under the conventional method. In the end, coordination efforts under the traditional approach to water resources management are difficult at best (Environmental Protection Agency, 2001). In contrast, the watershed management approach serves as an integrated method of managing water resources. DeMeo and Kundell (2001) define watershed management as “…the process of intentionally applying technical, political, and economic tools for the use, protection, and/or restoration of all the water resources within the entire land area of a watershed.”

Watershed management policies are becoming increasingly popular as strategies to administer water-use. Kundell and Tetens (1998) note that watershed management approaches can also be referred to as ecosystem, river basin, and holistic approaches. They go on to say that as water demands increase and interstate water transfers become more common, the need to account for hydrologic boundaries, watershed protection, and the fragile relationship between surface water and groundwater will become paramount. Failure to consider these issues could have negative effects on critical water supplies.

DeBarry (2004) defines the watershed management approach as a coordinating framework for environmental management. He states that the scheme should focus on both public-sector and private-sector efforts to address problems in hydrologically defined geographic areas. DeBarry goes on to stress the importance of a proactive approach to water resource management. Administering water policy at the watershed level can prevent flooding, maintain groundwater quality and quantity, maintain stream flows, prevent stream bank erosion, and preserve environmentally sensitive areas.

3.3. Watershed Management Benefits

Watershed management schemes offer several benefits over traditional management practices. First, managing water at the watershed level produces greater environmental results.
Such practices assist in uncovering the various stressors that affect watershed ecology. These stressors are everything from pollution to over allocation. Often, watershed management systems result in managers who are better prepared to make the decisions needed to protect or restore valuable resources (Environmental Protection Agency, 1996).

The second major benefit of managing water at the watershed level is improved efficiency. Tasks such as monitoring water levels, modeling usage, and issuing permits can be streamlined via the watershed approach. According to the Environmental Protection Agency (1996), water monitoring productivity in North Carolina increased by nearly 40 percent when the coordinated watershed approach was employed. Data collection is an area of water resources management with significant room for improvement. Watershed management schemes can facilitate the coordination of permit holders via grouping and other practices. Such techniques can result in more accurate reporting of permitted water-use figures (Environmental Protection Agency, 1996).

Public support is the third benefit associated with the watershed management system. As people become aware of their watershed, they are more inclined to participate in protection and restoration efforts. Such awareness can reduce conflicts and foster a sense of community. Ultimately, this improves the chances of success for various environmental programs and policies.

A final advantage of managing water at the watershed level is improved federal grant access and looser federal regulations. The EPA actively encourages watershed protection by offering grants and other incentives to participants. For example, the EPA has supported legislation allowing states who employ watershed management schemes to issue National Pollutant Discharge Elimination System (NPDES) permits on a 10-year cycle instead of the
standard 5-year cycle. Such allowances benefit states in that they can curtail the red tape associated with permit allocation (Environmental Protection Agency, 1996).

3.4. Watershed Management in Practice

Water resources are increasingly being managed at the watershed and river basin level (DeBarry, 2004). Derivations of the watershed management approach can be observed throughout the eastern United States. In 1985, water-use permitting began in Massachusetts. From the onset, management has taken place at the river basin level. Outstanding permits in each river basin are reviewed every five years. By checking permits in this fashion, administrators gain valuable insight into the total water demand being placed on state river basins. Similarly, water is managed in Florida by five districts defined by the state’s river basins (Kundell and Tetens, 1998). It is expected that watershed and river basin approaches will become progressively more popular as states are faced with increasingly difficult water allocation decisions. The watershed or river basin approach seems to be especially suited for the state of Georgia. With 159 counties, Georgia is second only to Texas (254 counties) for most counties in one state. With so many counties to consider, a comprehensive watershed or river basin approach could streamline state water-use data acquisition and management practices.
Figure 3.1. Georgia’s 14 River Basins
(Map by University of Georgia School of Marine Programs Coastal GIS Lab)
Figure 3.2. Georgia’s 52 Watersheds
(Map by Georgia Department of Community Affairs)
CHAPTER 4

METHODOLOGY

4.1. Geographic Information Systems

A Geographic Information Systems (GIS) approach was used to meet two objectives of this study:

- Organize and reference data from the Georgia Ag Permitting Database into corresponding watershed and river basin segments.
- Calculate theoretical quantity estimates of county permitted withdrawals using county land area percentages inside each Georgia watershed/river basin and compare these estimates to actual quantities.

GIS merges traditional database technology with spatial elements. This results in maps that possess the ability to perform various evaluations for a range of data (Lyon 2003). First developed in the 1960s for academic and government use, GIS has become one of the key components of today’s information technology infrastructure (Lo and Yeung 2002).

GIS allows users to manage significant quantities of spatial and numerical data. Additionally, it facilitates spatial problem solving. The uses of GIS are far ranging. It can be applied to the fields of cartography, geography, urban planning, economics, anthropology, law enforcement, mathematics, and many others (Lo and Yeung 2002). The field of environmental policy relies heavily on GIS. Moreover, the discipline of water resources management possesses several characteristics that make it an ideal candidate for GIS analysis. Foremost, the spatial component of rivers, lakes, and aquifers can easily be captured in a GIS system. Additionally,
these spatial components can be merged with water-use data to efficiently produce maps and displays of various modeling results (Lyon 2003).

Technological innovations like Global Positioning Systems (GPS) have added to the overall effectiveness of GIS. Today, study parameters can be spatially referenced with GPS technology and subsequently plotted in maps with a high degree of accuracy (Lyon 2003). This study was based upon a data set with GPS generated latitude and longitude points for Georgia agricultural water permits.

4.2. Data Set

The data set used for this study was obtained from the Georgia Ag Permitting Database. Started in 1999, the Ag Permitting Database is a collection of agricultural permit data that is managed and updated by a small team of individuals at the Georgia Department of Natural Resources. Acting program manager, Cliff Lewis, indicated that his team attempts to go into the community every 60 days to acquire updated permit information (Lewis, 2005). The resulting database has separate data sets of groundwater and surface water permits. Groundwater permits have GPS generated latitude and longitude figures denoting the position of each well. Likewise, surface water permits have GPS generated latitude and longitude figures indicating the location of the withdrawal point from each water source. Additionally, both the groundwater and surface water data sets include individual permit numbers, total permitted gallons per minute, and the date each permit was established.

At the time of this study, the groundwater data set was composed of 10,193 permits. Of those 10,193 groundwater permits, 1,592 were missing latitude and longitude information. The surface water portion of the data set had information for 11,536 permits. Of those 11,536 permits, 540 observations contained no latitude and longitude reference points. Together, these
2,132 missing observations accounted for 9.81% of the combined groundwater and surface water data. While these missing observations contained no specific latitude and longitude reference points, each was associated with one of Georgia’s 159 counties. Accordingly, it was possible to plot the missing data by county to obtain statistical information about spatial disbursement.

A Wilcoxon two-sample test was preformed on each segment of the data: groundwater permits, surface water permits, and groundwater + surface water permits. The Wilcoxon two-sample test is used to determine whether two sets of observations come from the same distribution. The null hypothesis for our test was that the data containing latitude and longitude points was distributed the same as the original data set. In all three cases, we failed to reject the null hypothesis at an alpha level of 0.10. The results of this procedure support the assumption that our subset of data is spatially distributed across watersheds in the same manner as the original data set.

4.3. Data Analysis

ArcView GIS version 3.3 was the primary software package used to plot and analyze the data set. All required GIS procedures were facilitated by the ArcView software. The first true hurdle to overcome concerning this project was the acquisition of a serviceable map of Georgia’s 52 watersheds. The Georgia GIS Clearinghouse is a website containing various state maps that are compatible with GIS software such as ArcView. After a search of the website proved unsuccessful, the sole alternative was to digitize a basic jpg image of Georgia’s watersheds (Figure 3.2). For this, the digitizing feature of ArcView was used to capture spatial information regarding each polygon forming one of the state’s 52 watersheds. After digitizing the watershed map, it had to be rectified so that all points corresponded to the latitude and longitude system. This was imperative because our agriculture permit data was referenced via latitude and
longitude coordinates. Rectifying the initial map would insure that the data could be accurately plotted and analyzed.

In addition to the map of Georgia’s 52 watersheds, a map of the state’s 159 counties was obtained from the Georgia Department of Transportation through the Georgia GIS Clearinghouse website. Next, the watershed map and the county map were merged via the Union operation in the ArcView GeoProcessing tool. The resulting map facilitated the calculation of the percentage of each county’s land area inside each watershed. The resulting data table was used to determine all the counties, and corresponding county land area proportions, located inside each of Georgia’s 52 watersheds. The following calculations were used to facilitate this step:

\[
\begin{align*}
LA_{j,i} &= \text{land area of county } j \text{ within watershed } i \\
LA_j &= \text{land area of county } j \\
LA_{j,i}/LA_j &= \%LA_{j,i} = \text{proportion of county } j \text{ land area within watershed } i
\end{align*}
\]

After calculating the county land area proportions in each watershed, the map needed to be populated with our permit data. This required the groundwater and the surface water data sets to be placed in DBF 4 format. This format allowed the data to be imported by ArcView. To begin with, the data for groundwater permits was plotted onto the merged watershed and county map (Figure 4.1). Next, in a new project, the same procedure was followed for the surface water data set (Figure 4.2). In the end, two populated maps existed, one for groundwater and one for surface water. In addition to displaying the state’s agricultural water permits in a spatial fashion, the maps facilitated all further analysis.

In order to complete the objectives of this study, it was imperative to know two pieces of information regarding each permit: in what county it was located and in what watershed it was
located. For this, the GeoProcessing tool in ArcView was employed. The *Assign Data by Location* operation was used to join the features of our spatial map with the various permit data that shared the same location. The resulting table contained the necessary county and watershed information for each permit.

### 4.4. Data Organization and Website Creation

Using the tables created by ArcView, each watershed was critically analyzed. The county level data was placed into appropriate watersheds and, using the proportions obtained earlier (e.g. $\%LA_{j,i}$), the following calculations were performed.

\[
\%LA_{j,i} = \text{proportion of county } j \text{ land area within watershed } i
\]

\[
P_j = \text{total # of permits in county}
\]

\[
\%LA_{j,i} \times P_j = GW.WD_{i,j}
\]

$GW.WD_{i,j}$ = estimated groundwater withdrawals permitted from watershed $i$ in county $j$

The above calculations generated the estimated (land area based) withdrawal figure for each county in every Georgia watershed. The major assumption underlying this land area based estimate is that agricultural activities are evenly dispersed throughout the land area of a given county.

\[
GW.WD^*_{i,j} = \text{actual groundwater withdrawals permitted from watershed } i \text{ in county } j
\]

The above calculation was derived directly from the GIS procedure described in section 4.3. $GW.WD^*_{i,j}$ represents data from the Ag Permitting Database, now referenced to a specific watershed.

\[
GW.WD_i = \sum_j GW.WD_{i,j} = \text{estimated groundwater withdrawals permitted in watershed } i
\]

\[
GW.WD^*_{i} = \sum_j GW.WD^*_{i,j} = \text{actual groundwater withdrawals permitted in watershed } i
\]
The above calculations are simply a summation of the estimated and actual withdrawals by county for each Georgia watershed.

\[ GW.WD_j - GW.WD^*_j = \text{error due to data referenced at county level} \]

The above calculation generated the error figures upon which the analysis in this study is based. It should be noted that all of the above calculations were subsequently performed for surface water (SW.WD) and groundwater + surface water (GWSW.WD).

After performing this series of calculations, the results for each watershed were organized into tabular form. Tables include information regarding groundwater permits, surface water permits, groundwater plus surface water permits, groundwater permitted withdrawals, surface water permitted withdrawals, groundwater plus surface water permitted withdrawals, and a distribution of permits and permitted withdrawals across all counties in each watershed. Additionally, a set of bar graphs was produced for each watershed illustrating the difference between the estimated number of permits and permitted withdrawals (e.g. \( GW.WD_{i,j} \)) issued in each county and the actual number (e.g. \( GW.WD^*_{i,j} \)). Finally, a series of pie charts was produced for each watershed illustrating the distribution of permits and permitted withdrawals across all counties in each watershed. This process was then repeated for Georgia’s 14 river basins by aggregating watershed data to the larger river basin level.

In an effort to organize the large quantity of information generated for each watershed and river basin, a website was created to accommodate links to the various tables and graphs. The website serves not only as an organizational tool, but also as a device for water policy and academic research. Each watershed includes a table of contents allowing the user to browse relevant data. This initial page is linked to a clickable map of Georgia’s 52 watersheds. Upon accessing the site, the user can click on a watershed of interest and be directed to data.
specifically applicable to that watershed. Additionally, the user can access pertinent river basin information via the homepage or the various watershed pages.
Figure 4.1. Georgia Agriculture Groundwater Permits
Figure 4.2. Georgia Agriculture Surface Water Permits
CHAPTER 5
RESULTS

5.1. Overview of Results

The primary objective of this study was to look for possible errors resulting from the use of water permitting data collected at the county level for watershed or river basin based management practices. To meet this objective, permitting data from one of the state’s major water-use sectors, the agriculture sector, was analyzed. To accomplish this, all permits and subsequent permitted withdrawals had to be grouped into their respective watershed and river basin. A GIS approach was used to facilitate this step. After spatially plotting the permits, data was analyzed for intrinsic errors. This was done by comparing actual number of permits in a given watershed or river basin with a theoretical estimate derived from the county land area proportions making up the watershed or river basin.

5.2. Watershed Results

The easiest way to compare errors between estimated permits or permitted withdrawals and actual permits or permitted withdrawals is by using the percentage difference between them. Individual watershed percentage differences across source categories can be viewed in Table 5.1.

Groundwater

The results of this study show that 17 watersheds have actual numbers of groundwater permits that are higher than corresponding land area based estimates. Conversely, 27 watersheds have actual groundwater permit numbers lower than land area based estimates. The remaining 8 watersheds contain no groundwater permit data (Figure 5.1). The results of this study also show
that 20 watersheds have actual groundwater permitted withdrawal (gpm) numbers higher than land area based estimates. Conversely, 24 watersheds have actual groundwater permitted withdrawal (gpm) numbers lower than land area based estimates. The remaining 8 watersheds contain no groundwater permitted withdrawal data (Figure 5.2).

**Surface Water**

The results of this study show that 18 watersheds have actual numbers of surface water permits that are higher than corresponding land area based estimates. Conversely, 32 watersheds have actual surface water permit numbers lower than land area based estimates. The remaining 2 watersheds, Guntersville Lake and Upper Little Tennessee, contain no surface water permit data (Figure 5.3). The results of this study also show that 22 watersheds have actual surface water permitted withdrawal (gpm) numbers higher than land area based estimates and 28 watersheds have actual surface water permitted withdrawal (gpm) numbers lower than land area based estimates. The remaining 2 watersheds, Guntersville Lake and Upper Little Tennessee, contain no surface water permitted withdrawal data (Figure 5.4).

**Groundwater + Surface Water**

The results of this study show that 20 watersheds have actual numbers of groundwater + surface water permits that are higher than corresponding land area based estimates. Conversely, 30 watersheds have actual groundwater + surface water permit numbers lower than land area based estimates. The remaining 2 watersheds, Guntersville Lake and Upper Little Tennessee, contain no groundwater + surface water permit data (Figure 5.5). The results of this study also show that 19 watersheds have actual groundwater + surface water permitted withdrawal (gpm) numbers higher than land area based estimates. Conversely, 31 watersheds have actual groundwater + surface water permitted withdrawal (gpm) numbers lower than land area based
estimates. The remaining 2 watersheds, Guntersville Lake and Upper Little Tennessee, contain no groundwater + surface water permitted withdrawal data (Figure 5.6).

5.3. Individual Watershed Summaries

This section includes a brief summary of the data obtained for each watershed. Of the 6 categories analyzed in this study, only the percentage difference between actual and estimated groundwater + surface water permitted withdrawals is addressed. The groundwater + surface water permitted withdrawals category was selected because it provides a clear and concise picture of total agriculture water withdrawals in each watershed. For watersheds located in Georgia and one or more states, data is only relevant to the Georgia portion of the watershed.

Alapaha Watershed

Located in south Georgia, the Alapaha watershed encompasses segments of 14 Georgia counties. Like the majority of south Georgia, the counties making up the Alapaha watershed have a vast agricultural sector. The largest city positioned inside the Alapaha watershed is Valdosta. Currently, there are 482 groundwater permits issued for agricultural use in the Alapaha watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 261,255 gallons per minute. Similarly, 1,542 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 1,445,391 gallons per minute. Together, agricultural groundwater and surface water permits in the Alapaha watershed authorize total freshwater withdrawals at a rate of 1,706,646 gallons per minute. This figure ranks highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 1,706,646 gallons of water per minute authorized to be withdrawn from sources inside the Alapaha watershed is 3.22% higher than the corresponding land area based estimate.
Altamaha Watershed

Located in southeast Georgia, the Altamaha watershed encompasses segments of 12 Georgia counties. The largest city positioned inside the Altamaha watershed is Jesup. Currently, there are 102 groundwater permits issued for agricultural use in the Altamaha watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 36,666 gallons per minute. Similarly, 430 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 345,010 gallons per minute. Together, agricultural groundwater and surface water permits in the Altamaha watershed authorize total freshwater withdrawals at a rate of 381,676 gallons per minute. This figure ranks 15th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 381,676 gallons of water per minute authorized to be withdrawn from sources inside the Altamaha watershed is 4.17% lower than the corresponding land area based estimate.

Apalachee Bay-St. Marks Watershed

Located on the Georgia-Florida state line, the Apalachee Bay-St. Marks watershed encompasses segments of only 1 Georgia county. The largest city positioned inside the watershed is Tallahassee, FL. Currently, there are 6 groundwater permits issued in Georgia for agricultural use in the Apalachee Bay-St. Marks watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 1,958 gallons per minute. Similarly, 1 surface water permit is issued in the Georgia portion of the watershed. This permit allows surface water to be pumped at a rate of 450 gallons per minute. Together, Georgia agricultural groundwater and surface water permits in the Apalachee Bay-St. Marks watershed authorize total freshwater withdrawals at a rate of 2,408 gallons per minute. This figure ranks 49th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of
2,408 gallons of water per minute authorized to be withdrawn from sources inside the Apalachee Bay-St. Marks watershed is 1,048.26% lower than the corresponding land area based estimate.

**Apalachicola Watershed**

Located on the Georgia-Florida state line, the Apalachicola watershed encompasses segments of only 1 Georgia county. Currently, there are 11 groundwater permits issued in Georgia for agricultural use in the Apalachicola watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 11,300 gallons per minute. Similarly, 4 surface water permits are dispersed throughout the Georgia portion of the watershed. In total, these permits allow surface water to be pumped at a rate of 7,300 gallons per minute. Together, Georgia agricultural groundwater and surface water permits in the Apalachicola watershed authorize total freshwater withdrawals at a rate of 18,600 gallons per minute. This figure ranks 37\(^{th}\) highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 18,600 gallons of water per minute authorized to be withdrawn from sources inside the Apalachicola watershed is 97.53% lower than the corresponding land area based estimate.

**Aucilla Watershed**

Located on the Georgia-Florida state line, the Aucilla watershed encompasses segments of 2 Georgia counties. Currently, there are 79 groundwater permits issued in Georgia for agricultural use in the Aucilla watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 59,820 gallons per minute. Similarly, 24 surface water permits are dispersed throughout the Georgia portion of the watershed. In total, these permits allow surface water to be pumped at a rate of 23,980 gallons per minute. Together, agricultural groundwater and surface water permits in the Aucilla watershed authorize total freshwater withdrawals at a rate of 83,800 gallons per minute. This figure ranks 26\(^{th}\) highest out of the 51 watersheds for which data was
available at the time of this study (Table 5.2). The actual figure of 83,800 gallons of water per minute authorized to be withdrawn from sources inside the Aucilla watershed is 22.82% higher than the corresponding land area based estimate.

**Brier Watershed**

Located in east Georgia, the Brier watershed encompasses segments of 9 Georgia counties. The largest city positioned inside the Brier watershed is Waynesboro. Currently, there are 46 groundwater permits issued for agricultural use in the Brier watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 26,030 gallons per minute. Similarly, 66 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 108,594 gallons per minute. Together, agricultural groundwater and surface water permits in the Brier watershed authorize total freshwater withdrawals at a rate of 134,624 gallons per minute. This figure ranks 21st highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 134,624 gallons of water per minute authorized to be withdrawn from sources inside the Brier watershed is 3.01% higher than the corresponding land area based estimate.

**Broad Watershed**

Located in northeast Georgia, the Broad watershed encompasses segments of 14 Georgia counties. The largest city positioned inside the Broad watershed is Commerce. Currently, there are 6 groundwater permits issued for agricultural use in the Broad watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 286 gallons per minute. Similarly, 41 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 32,137 gallons per minute. Together, agricultural groundwater and surface water permits in the Broad watershed authorize total freshwater
withdrawals at a rate of 32,423 gallons per minute. This figure ranks 32\textsuperscript{nd} highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 32,423 gallons of water per minute authorized to be withdrawn from sources inside the Broad watershed is 8.62\% lower than the corresponding land area based estimate.

**Canoochee Watershed**

Located in east Georgia, the Canoochee watershed encompasses segments of 10 Georgia counties. The largest city positioned inside the Canoochee watershed is Swainsboro. Currently, there are 134 groundwater permits issued for agricultural use in the Canoochee watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 50,499 gallons per minute. Similarly, 531 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 457,709 gallons per minute. Together, agricultural groundwater and surface water permits in the Canoochee watershed authorize total freshwater withdrawals at a rate of 508,208 gallons per minute. This figure ranks 12\textsuperscript{th} highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 508,208 gallons of water per minute authorized to be withdrawn from sources inside the Canoochee watershed is 15.39\% higher than the corresponding land area based estimate.

**Conasauga Watershed**

Located on the Georgia-Tennessee state line, the Conasauga watershed encompasses segments of 6 Georgia counties. The largest city positioned inside the Conasauga watershed is Dalton. Currently, no groundwater permits are issued for agricultural use in the Conasauga watershed. At present, 17 agricultural surface water permits are dispersed throughout the Georgia portion of the watershed. In total, these permits allow surface water to be pumped at a rate of 17,925 gallons per minute. Together, Georgia agricultural groundwater and surface water permits
in the Conasauga watershed authorize total freshwater withdrawals at a rate of 17,925 gallons per minute. This figure ranks 38th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 17,925 gallons of water per minute authorized to be withdrawn from sources inside the Conasauga watershed is 35.52% lower than the corresponding land area based estimate.

**Coosawattee Watershed**

Located in north Georgia, the Coosawattee watershed encompasses segments of 8 Georgia counties. The largest city positioned inside the Coosawattee watershed is Fairmount. Currently, there is 1 groundwater permit issued for agricultural use in the Coosawattee watershed. This permit allows groundwater to be pumped at a rate of 150 gallons per minute. Similarly, only 12 agricultural surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 9,990 gallons per minute. Together, agricultural groundwater and surface water permits in the Coosawattee watershed authorize total freshwater withdrawals at a rate of 10,140 gallons per minute. This figure ranks 44th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 10,140 gallons of water per minute authorized to be withdrawn from sources inside the Coosawattee watershed is 66.64% lower than the corresponding land area based estimate.

**Cumberland-St. Simons Watershed**

Located in southeast Georgia, the Cumberland-St. Simons watershed encompasses segments of 5 Georgia counties. The largest city positioned inside the Cumberland-St. Simons watershed is Brunswick. Currently, there is 1 groundwater permit issued for agricultural use in the Cumberland-St. Simons watershed. This permit allows groundwater to be pumped at a rate of
160 gallons per minute. Similarly, 1 surface water permit is issued in the watershed. This permit allows surface water to be pumped at a rate of 1,000 gallons per minute. Together, agricultural groundwater and surface water permits in the Cumberland-St. Simons watershed authorize total freshwater withdrawals at a rate of 1,160 gallons per minute. This figure ranks 50th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 1,160 gallons of water per minute authorized to be withdrawn from sources inside the Cumberland-St. Simons watershed is 629.82% lower than the corresponding land area based estimate.

**Etowah Watershed**

Located in north Georgia, the Etowah watershed encompasses segments of 15 Georgia counties. The largest city positioned inside the Etowah watershed is Rome. Currently, there are 14 groundwater permits issued for agricultural use in the Etowah watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 842 gallons per minute. Similarly, 50 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 44,885 gallons per minute. Together, agricultural groundwater and surface water permits in the Etowah watershed authorize total freshwater withdrawals at a rate of 45,727 gallons per minute. This figure ranks 29th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 45,727 gallons of water per minute authorized to be withdrawn from sources inside the Etowah watershed is 3.71% higher than the corresponding land area based estimate.

**Guntersville Lake Watershed**

Located predominately in Alabama and Tennessee, the Guntersville Lake watershed encompasses only a small segment of one Georgia county. At present, there are no groundwater
or surface water permits issued for agricultural use in the Georgia sector of the Guntersville Lake watershed.

**Hiwassee Watershed**

Located on the Georgia-Tennessee-North Carolina state line, the Hiwassee watershed encompasses segments of 5 Georgia counties. Currently, no groundwater permits are issued for agricultural use in the Georgia sector of the Hiwassee watershed. However, 14 agricultural surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 6,075 gallons per minute. Together, Georgia agricultural groundwater and surface water permits in the Hiwassee watershed authorize total freshwater withdrawals at a rate of 6,075 gallons per minute. This figure ranks 47th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 6,075 gallons of water per minute authorized to be withdrawn from sources inside the Hiwassee watershed is 14.69% higher than the corresponding land area based estimate.

**Ichaway-Nochaway Watershed**

Located in southwest Georgia, the Ichaway-Nochaway watershed encompasses segments of 11 Georgia counties. Like the majority of southwest Georgia, the counties making up the Ichaway-Nochaway watershed have a vast agricultural sector. The largest city positioned inside the Ichaway-Nochaway watershed is Dawson. Currently, there are 624 groundwater permits issued for agricultural use in the Ichaway-Nochaway watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 463,295 gallons per minute. Similarly, 461 agricultural surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 571,320 gallons per minute. Together, agricultural groundwater and surface water permits in the Ichaway-Nochaway watershed authorize total
freshwater withdrawals at a rate of 1,034,615 gallons per minute. This figure ranks 7th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 1,034,615 gallons of water per minute authorized to be withdrawn from sources inside the Ichaway-Nochaway watershed is 8.46% higher than the corresponding land area based estimate.

**Kinchafoonee Muckalee Watershed**

Located in southwest Georgia, the Kinchafoonee Muckalee watershed encompasses segments of 9 Georgia counties. Like the majority of southwest Georgia, the counties making up the Kinchafoonee Muckalee watershed have a vast agricultural sector. The largest city positioned inside the Kinchafoonee Muckalee watershed is Americus. Currently, there are 356 groundwater permits issued for agricultural use in the Kinchafoonee Muckalee watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 256,068 gallons per minute. Similarly, 376 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 476,450 gallons per minute. Together, agricultural groundwater and surface water permits in the Kinchafoonee Muckalee watershed authorize total freshwater withdrawals at a rate of 732,518 gallons per minute. This figure ranks 10th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 732,518 gallons of water per minute authorized to be withdrawn from sources inside the Kinchafoonee Muckalee watershed is 0.78% lower than the corresponding land area based estimate.

**Little (GA & SC) Watershed**

Located in east Georgia, the Little watershed encompasses segments of 8 Georgia counties. The largest city positioned inside the Little watershed is Thomson. Currently, there are
2 groundwater permits issued for agricultural use in the Little watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 310 gallons per minute. Similarly, 15 agricultural surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 12,835 gallons per minute. Together, agricultural groundwater and surface water permits in the Little watershed authorize total freshwater withdrawals at a rate of 13,145 gallons per minute. This figure ranks 42nd highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 13,145 gallons of water per minute authorized to be withdrawn from sources inside the Little watershed is 13.49% lower than the corresponding land area based estimate.

**Little Watershed**

Located in south Georgia, the Little watershed encompasses segments of 7 Georgia counties. Like the majority of south Georgia, the counties making up the Little watershed have a vast agricultural sector. Currently, there are 503 groundwater permits issued for agricultural use in the Little watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 221,808 gallons per minute. Similarly, 932 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 889,905 gallons per minute. Together, agricultural groundwater and surface water permits in the Little watershed authorize total freshwater withdrawals at a rate of 1,111,713 gallons per minute. This figure ranks 6th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 1,111,713 gallons of water per minute authorized to be withdrawn from sources inside the Little watershed is 13.00% higher than the corresponding land area based estimate.
Little Ocmulgee Watershed

Located in central Georgia, the Little Ocmulgee watershed encompasses segments of 6 Georgia counties. The largest city positioned inside the Little Ocmulgee watershed is Eastman. Currently, there are 174 groundwater permits issued for agricultural use in the Little Ocmulgee watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 74,096 gallons per minute. Similarly, 314 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 250,910 gallons per minute. Together, agricultural groundwater and surface water permits in the Little Ocmulgee watershed authorize total freshwater withdrawals at a rate of 325,006 gallons per minute. This figure ranks 16th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 325,006 gallons of water per minute authorized to be withdrawn from sources inside the Little Ocmulgee watershed is 7.44% lower than the corresponding land area based estimate.

Little Satilla Watershed

Located in southeast Georgia, the Little Satilla watershed encompasses segments of 6 Georgia counties. The largest city positioned inside the Little Satilla watershed is Baxley. Currently, there are 112 groundwater permits issued for agricultural use in the Little Satilla watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 60,580 gallons per minute. Similarly, 136 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 93,604 gallons per minute. Together, agricultural groundwater and surface water permits in the Little Satilla watershed authorize total freshwater withdrawals at a rate of 154,184 gallons per minute. This figure ranks 20th highest out of the 51 watersheds for which data was available at the time of this study (Table
5.2). The actual figure of 154,184 gallons of water per minute authorized to be withdrawn from sources inside the Little Satilla watershed is 2.88% lower than the corresponding land area based estimate.

**Lower Chattahoochee Watershed**

Located on the Georgia-Florida-Alabama state line, the Lower Chattahoochee watershed encompasses segments of 6 Georgia counties. Currently, there are 326 groundwater permits issued for agricultural use in the Georgia portion of the Lower Chattahoochee watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 288,805 gallons per minute. Similarly, 126 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 129,450 gallons per minute. Together, agricultural groundwater and surface water permits in the Lower Chattahoochee watershed authorize total freshwater withdrawals at a rate of 418,255 gallons per minute. This figure ranks 13th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 418,255 gallons of water per minute authorized to be withdrawn from sources inside the Lower Chattahoochee watershed is 19.92% lower than the corresponding land area based estimate.

**Lower Flint Watershed**

Located in southwest Georgia, the Lower Flint watershed encompasses segments of 10 Georgia counties. Like the majority of southwest Georgia, the counties making up the Lower Flint watershed have a vast agricultural sector. The largest city positioned inside the Lower Flint watershed is Albany. Currently, there are 1,333 groundwater permits issued for agricultural use in the Lower Flint watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 1,282,133 gallons per minute. Similarly, 133 surface water permits are dispersed
throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 122,460 gallons per minute. Together, agricultural groundwater and surface water permits in the Lower Flint watershed authorize total freshwater withdrawals at a rate of 1,404,593 gallons per minute. This figure ranks 2\textsuperscript{nd} highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 1,404,593 gallons of water per minute authorized to be withdrawn from sources inside the Lower Flint watershed is 4.91% higher than the corresponding land area based estimate.

**Lower Ochlockonee Watershed**

Located on the Georgia-Florida state line, the Lower Ochlockonee watershed encompasses segments of 3 Georgia counties. Currently, there are 29 groundwater permits issued for agricultural use in the Georgia portion of the Lower Ochlockonee watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 17,655 gallons per minute. Similarly, 64 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 55,850 gallons per minute. Together, agricultural groundwater and surface water permits in the Lower Ochlockonee watershed authorize total freshwater withdrawals at a rate of 73,505 gallons per minute. This figure ranks 27\textsuperscript{th} highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 73,505 gallons of water per minute authorized to be withdrawn from sources inside the Lower Ochlockonee watershed is 124.22% lower than the corresponding land area based estimate.

**Lower Ocmulgee Watershed**

Located in south Georgia, the Lower Ocmulgee watershed encompasses segments of 14 Georgia counties. Like the majority of south Georgia, the counties making up the Lower
Ocmulgee watershed have a vast agricultural sector. The largest city positioned inside the Lower Ocmulgee watershed is Warner Robins. Currently, there are 730 groundwater permits issued for agricultural use in the Lower Ocmulgee watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 399,200 gallons per minute. Similarly, 779 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 747,155 gallons per minute. Together, agricultural groundwater and surface water permits in the Lower Ocmulgee watershed authorize total freshwater withdrawals at a rate of 1,146,355 gallons per minute. This figure ranks 5th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 1,146,355 gallons of water per minute authorized to be withdrawn from sources inside the Lower Ocmulgee watershed is 9.92% lower than the corresponding land area based estimate.

Lower Oconee Watershed

Located in central Georgia, the Lower Oconee watershed encompasses segments of 13 Georgia counties. The largest city positioned inside the Lower Oconee watershed is Milledgeville. Currently, there are 118 groundwater permits issued for agricultural use in the Lower Oconee watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 51,132 gallons per minute. Similarly, 264 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 199,823 gallons per minute. Together, agricultural groundwater and surface water permits in the Lower Oconee watershed authorize total freshwater withdrawals at a rate of 250,955 gallons per minute. This figure ranks 19th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 250,955 gallons of water per minute authorized to be
withdrawn from sources inside the Lower Oconee watershed is 16.40% lower than the corresponding land area based estimate.

**Lower Ogeechee Watershed**

Located in southeast Georgia, the Lower Ogeechee watershed encompasses segments of 7 Georgia counties. The largest city positioned inside the Lower Ogeechee watershed is Statesboro. Currently, there are 165 groundwater permits issued for agricultural use in the Lower Ogeechee watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 77,057 gallons per minute. Similarly, 236 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 206,570 gallons per minute. Together, agricultural groundwater and surface water permits in the Lower Ogeechee watershed authorize total freshwater withdrawals at a rate of 283,627 gallons per minute. This figure ranks 17th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 283,627 gallons of water per minute authorized to be withdrawn from sources inside the Lower Ogeechee watershed is 9.72% lower than the corresponding land area based estimate.

**Lower Savannah Watershed**

Located on the Georgia-South Carolina state line, the Lower Savannah watershed encompasses segments of 3 Georgia counties. Currently, there are 28 groundwater permits issued for agricultural use in the Georgia portion of the Lower Savannah watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 14,390 gallons per minute. Similarly, 15 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 12,325 gallons per minute. Together, agricultural groundwater and surface water permits in the Lower Savannah watershed authorize total
freshwater withdrawals at a rate of 26,715 gallons per minute. This figure ranks 34th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 26,715 gallons of water per minute authorized to be withdrawn from sources inside the Lower Savannah watershed is 20.44% lower than the corresponding land area based estimate.

**Middle Chattahoochee-Lake Harding Watershed**

Located in west Georgia and east Alabama, the Middle Chattahoochee-Lake Harding watershed encompasses segments of 12 Georgia counties. The largest city positioned inside the Middle Chattahoochee-Lake Harding watershed is Smyrna. Currently, there are 2 groundwater permits issued for agricultural use in the Georgia portion of the Middle Chattahoochee-Lake Harding watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 115 gallons per minute. Similarly, 60 Georgia surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 44,157 gallons per minute. Together, agricultural groundwater and surface water permits in the Middle Chattahoochee-Lake Harding watershed authorize total freshwater withdrawals at a rate of 44,272 gallons per minute. This figure ranks 30\(^{th}\) highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 44,272 gallons of water per minute authorized to be withdrawn from sources inside the Middle Chattahoochee-Lake Harding watershed is 2.10% lower than the corresponding land area based estimate.

**Middle Chattahoochee-Walter F. George Reservoir Watershed**

Located on the Georgia-Alabama state line, the Middle Chattahoochee-Walter F. George Reservoir watershed encompasses segments of 11 Georgia counties. Currently, there are 11 groundwater permits issued for agricultural use in the Georgia portion of the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 4,525 gallons per minute.
Similarly, 58 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 86,490 gallons per minute. Together, agricultural groundwater and surface water permits in the Middle Chattahoochee-Walter F. George Reservoir watershed authorize total freshwater withdrawals at a rate of 91,015 gallons per minute. This figure ranks 24th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 91,015 gallons of water per minute authorized to be withdrawn from sources inside the Middle Chattahoochee-Walter F. George Reservoir watershed is 97.55% lower than the corresponding land area based estimate.

**Middle Flint Watershed**

Located in southwest Georgia, the Middle Flint watershed encompasses segments of 12 Georgia counties. Like the majority of southwest Georgia, the counties making up the Middle Flint watershed have a vast agricultural sector. The largest city positioned inside the Middle Flint watershed is Cordele. Currently, there are 663 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 484,588 gallons per minute. Similarly, 401 surface water permits are dispersed throughout the Middle Flint. In total, these permits allow surface water to be pumped at a rate of 452,276 gallons per minute. Together, agricultural groundwater and surface water permits in the Middle Flint watershed authorize total freshwater withdrawals at a rate of 936,864 gallons per minute. This figure ranks 8th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 936,864 gallons of water per minute authorized to be withdrawn from sources inside the Middle Flint watershed is 7.65% lower than the corresponding land area based estimate.
**Middle Savannah Watershed**

Located on the Georgia-South Carolina state line, the Middle Savannah watershed encompasses segments of 5 Georgia counties. The largest city positioned inside the Middle Savannah watershed is Augusta. Currently, there are 12 groundwater permits issued for agricultural use in the Georgia portion of the Middle Savannah watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 8,640 gallons per minute. Similarly, 23 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 27,350 gallons per minute. Together, agricultural groundwater and surface water permits in the Middle Savannah watershed authorize total freshwater withdrawals at a rate of 35,990 gallons per minute. This figure ranks 31st highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 35,990 gallons of water per minute authorized to be withdrawn from sources inside the Middle Savannah watershed is 50.90% lower than the corresponding land area based estimate.

**Middle Tennessee Chickamauga Watershed**

Located on the Georgia-Tennessee-Alabama state line, the Middle Tennessee Chickamauga watershed encompasses segments of 4 Georgia counties. Currently, there are 2 groundwater permits issued for agricultural use in the Georgia portion of the Middle Tennessee Chickamauga watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 200 gallons per minute. Similarly, 16 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 13,060 gallons per minute. Together, agricultural groundwater and surface water permits in the Middle Tennessee Chickamauga watershed authorize total freshwater withdrawals at a rate of 13,260 gallons per minute. This figure ranks 41st highest out of the 51 watersheds for which data was
available at the time of this study (Table 5.2). The actual figure of 13,260 gallons of water per minute authorized to be withdrawn from sources inside the Middle Tennessee Chickamauga watershed is 30.11% higher than the corresponding land area based estimate.

**Ocoee Watershed**

Located on the Georgia-Tennessee-North Carolina state line, the Ocoee watershed encompasses segments of 4 Georgia counties. Currently, no groundwater permits are issued for agricultural use in the Georgia portion of the Ocoee watershed. At present, 21 agricultural surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 17,370 gallons per minute. Together, agricultural groundwater and surface water permits in the Ocoee watershed authorize total freshwater withdrawals at a rate of 17,370 gallons per minute. This figure ranks 39th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 17,370 gallons of water per minute authorized to be withdrawn from sources inside the Ocoee watershed is 7.71% higher than the corresponding land area based estimate.

**Ogeechee Coastal Watershed**

Located in southeast Georgia, the Ogeechee Coastal watershed encompasses segments of 6 Georgia counties. Currently, there are 13 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 3,570 gallons per minute. Similarly, 3 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 3,600 gallons per minute. Together, agricultural groundwater and surface water permits in the Ogeechee Coastal watershed authorize total freshwater withdrawals at a rate of 7,170 gallons per minute. This figure ranks 46th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The
actual figure of 7,170 gallons of water per minute authorized to be withdrawn from sources inside the Ogeechee Coastal watershed is 18.31% lower than the corresponding land area based estimate.

**Ohoopee Watershed**

Located in southeast Georgia, the Ohoopee watershed encompasses segments of 10 Georgia counties. The largest city positioned inside the Ohoopee watershed is Vidalia. Currently, there are 97 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 50,940 gallons per minute. Similarly, 422 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 349,012 gallons per minute. Together, agricultural groundwater and surface water permits in the Ohoopee watershed authorize total freshwater withdrawals at a rate of 399,952 gallons per minute. This figure ranks 14th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 399,952 gallons of water per minute authorized to be withdrawn from sources inside the Ohoopee watershed is 9.27% lower than the corresponding land area based estimate.

**Oostanaula Watershed**

Located in northwest Georgia, the Oostanaula watershed encompasses segments of 6 Georgia counties. The largest city positioned inside the Oostanaula watershed is Calhoun. Currently, no groundwater permits are issued for agricultural use in the watershed. However, 20 agricultural surface water permits are dispersed throughout the Oostanaula watershed. In total, these permits allow surface water to be pumped at a rate of 19,465 gallons per minute. Together, agricultural groundwater and surface water permits in the Oostanaula watershed authorize total freshwater withdrawals at a rate of 19,465 gallons per minute. This figure ranks 36th highest out
of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 19,465 gallons of water per minute authorized to be withdrawn from sources inside the Oostanaula watershed is 1.86% higher than the corresponding land area based estimate.

**Satilla Watershed**

Located in south Georgia, the Satilla watershed encompasses segments of 14 Georgia counties. Like the majority of south Georgia, the counties making up the Satilla watershed have a vast agricultural sector. The largest city positioned inside the Satilla watershed is Waycross. Currently, there are 358 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 166,274 gallons per minute. Similarly, 1,245 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 1,067,220 gallons per minute. Together, agricultural groundwater and surface water permits in the Satilla watershed authorize total freshwater withdrawals at a rate of 1,233,494 gallons per minute. This figure ranks 4th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 1,233,494 gallons of water per minute authorized to be withdrawn from sources inside the Satilla watershed is 11.20% higher than the corresponding land area based estimate.

**Spring Watershed**

Located in southwest Georgia, the Spring watershed encompasses segments of 6 Georgia counties. Like the majority of southwest Georgia, the counties making up the Spring watershed have a vast agricultural sector. The largest city positioned inside the Spring watershed is Blakely. Currently, there are 1,253 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 1,133,237 gallons per
minute. Similarly, 114 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 121,230 gallons per minute. Together, agricultural groundwater and surface water permits in the Spring watershed authorize total freshwater withdrawals at a rate of 1,254,467 gallons per minute. This figure ranks 3rd highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 1,254,467 gallons of water per minute authorized to be withdrawn from sources inside the Spring watershed is 12.00% higher than the corresponding land area based estimate.

**St. Marys Watershed**

Located on the Georgia-Florida state line, the St. Marys watershed encompasses segments of 3 Georgia counties. Currently, there are 3 groundwater permits issued for agricultural use in the Georgia portion of the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 1,175 gallons per minute. Similarly, 6 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 7,500 gallons per minute. Together, agricultural groundwater and surface water permits in the St. Marys watershed authorize total freshwater withdrawals at a rate of 8,675 gallons per minute. This figure ranks 45th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 8,675 gallons of water per minute authorized to be withdrawn from sources inside the St. Marys watershed is 52.40% lower than the corresponding land area based estimate.

**Tugaloo Watershed**

Located on the Georgia-South Carolina-North Carolina state line, the Tugaloo watershed encompasses segments of 6 Georgia counties. The largest city positioned inside the Tugaloo
watershed is Toccoa. Currently, no groundwater permits are issued for agricultural use in the watershed. However, 14 agricultural surface water permits are dispersed throughout the Tugaloo. In total, these permits allow surface water to be pumped at a rate of 12,598 gallons per minute. Together, agricultural groundwater and surface water permits in the Tugaloo watershed authorize total freshwater withdrawals at a rate of 12,598 gallons per minute. This figure ranks 43rd highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 12,598 gallons of water per minute authorized to be withdrawn from sources inside the Tugaloo watershed is 6.33% higher than the corresponding land area based estimate.

**Upper Chattahoochee Watershed**

Located in north Georgia, the Upper Chattahoochee watershed encompasses segments of 15 Georgia counties. The largest city positioned inside the Upper Chattahoochee watershed is Roswell. Currently, there are 14 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 3,305 gallons per minute. Similarly, 50 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 49,259 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Chattahoochee watershed authorize total freshwater withdrawals at a rate of 52,564 gallons per minute. This figure ranks 28th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 52,564 gallons of water per minute authorized to be withdrawn from sources inside the Upper Chattahoochee watershed is 12.09% higher than the corresponding land area based estimate.
**Upper Coosa Watershed**

Located on the Georgia-Alabama state line, the Upper Coosa watershed encompasses segments of 6 Georgia counties. Currently, there are 7 groundwater permits issued for agricultural use in the Georgia portion of the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 2,495 gallons per minute. Similarly, 32 Georgia surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 28,740 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Coosa watershed authorize total freshwater withdrawals at a rate of 31,235 gallons per minute. This figure ranks 33rd highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 31,235 gallons of water per minute authorized to be withdrawn from sources inside the Upper Coosa watershed is 34.41% higher than the corresponding land area based estimate.

**Upper Flint Watershed**

Located in central Georgia, the Upper Flint watershed encompasses segments of 18 Georgia counties. The largest city positioned inside the Upper Flint watershed is Griffin. Currently, there are 48 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 19,405 gallons per minute. Similarly, 128 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 92,434 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Flint watershed authorize total freshwater withdrawals at a rate of 111,839 gallons per minute. This figure ranks 22nd highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual
figure of 111,839 gallons of water per minute authorized to be withdrawn from sources inside the Upper Flint watershed is 19.75% lower than the corresponding land area based estimate.

**Upper Little Tennessee Watershed**

Located predominately in North Carolina, the Upper Little Tennessee watershed encompasses segments of only one Georgia county. No data was available regarding agricultural groundwater permits in the Georgia portion of the watershed. Similarly, no agricultural surface water permits have been issued in the Upper Little Tennessee. As such, groundwater and surface water withdrawals of 0 gallons per minute are authorized for agricultural uses in this sector of Georgia. This figure ranks lowest of the 51 watersheds for which data was available at the time of this study (Table 5.2).

**Upper Ochlockonee Watershed**

Located in southwest Georgia, the Upper Ochlockonee watershed encompasses segments of 5 Georgia counties. Like the majority of southwest Georgia, the counties making up the Upper Ochlockonee watershed have a vast agricultural sector. The largest city positioned inside the Upper Ochlockonee watershed is Cairo. Currently, there are 171 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 86,769 gallons per minute. Similarly, 527 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 495,650 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Ochlockonee watershed authorize total freshwater withdrawals at a rate of 582,419 gallons per minute. This figure ranks 11th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 582,419 gallons of water per
minute authorized to be withdrawn from sources inside the Upper Ochlockonee watershed is 5.57% lower than the corresponding land area based estimate.

**Upper Ocmulgee Watershed**

Located in central Georgia, the Upper Ocmulgee watershed encompasses segments of 20 Georgia counties. The largest cities positioned inside the Upper Ocmulgee watershed are Atlanta and Macon. Currently, there are 26 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 4,660 gallons per minute. Similarly, 111 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 89,477 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Ocmulgee watershed authorize total freshwater withdrawals at a rate of 94,137 gallons per minute. This figure ranks 24th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 94,137 gallons of water per minute authorized to be withdrawn from sources inside the Upper Ocmulgee watershed is 9.79% lower than the corresponding land area based estimate.

**Upper Oconee Watershed**

Located in north central Georgia, the Upper Oconee watershed encompasses segments of 19 Georgia counties. The largest city positioned inside the Upper Oconee watershed is Athens. Currently, there are 25 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 2,145 gallons per minute. Similarly, 124 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 86,322 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Oconee watershed authorize
total freshwater withdrawals at a rate of 88,467 gallons per minute. This figure ranks 25th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 88,467 gallons of water per minute authorized to be withdrawn from sources inside the Upper Oconee watershed is 0.75% lower than the corresponding land area based estimate.

**Upper Ogeechee Watershed**

Located in central Georgia, the Upper Ogeechee watershed encompasses segments of 11 Georgia counties. The largest city positioned inside the Upper Ogeechee watershed is Millen. Currently, there are 127 groundwater permits issued for agricultural use in the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 106,688 gallons per minute. Similarly, 133 surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 168,210 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Ogeechee watershed authorize total freshwater withdrawals at a rate of 274,898 gallons per minute. This figure ranks 18th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 274,898 gallons of water per minute authorized to be withdrawn from sources inside the Upper Ogeechee watershed is 4.80% higher than the corresponding land area based estimate.

**Upper Savannah Watershed**

Located on the Georgia-South Carolina state line, the Upper Savannah watershed encompasses segments of 6 Georgia counties. Currently, there is 1 groundwater permit issued for agricultural use in the Georgia portion of the watershed. This permit allows groundwater to be pumped at a rate of 100 gallons per minute. At present, 27 agricultural surface water permits are
dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 20,060 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Savannah watershed authorize total freshwater withdrawals at a rate of 20,160 gallons per minute. This figure ranks 35th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 20,160 gallons of water per minute authorized to be withdrawn from sources inside the Upper Savannah watershed is 1.23% higher than the corresponding land area based estimate.

**Upper Suwannee Watershed**

Located on the Georgia-Florida state line, the Upper Suwannee watershed encompasses segments of 6 Georgia counties. Currently, there are 9 groundwater permits issued for agricultural use in the Georgia portion of the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 1,400 gallons per minute. Similarly, 12 agricultural surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 11,880 gallons per minute. Together, Georgia agricultural groundwater and surface water permits in the Upper Suwannee watershed authorize total freshwater withdrawals at a rate of 13,280 gallons per minute. This figure ranks 40th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 13,280 gallons of water per minute authorized to be withdrawn from sources inside the Upper Suwannee watershed is 478.36% lower than the corresponding land area based estimate.

**Upper Tallapoosa Watershed**

Located on the Georgia-Alabama state line, the Upper Tallapoosa watershed encompasses segments of 6 Georgia counties. Currently, no groundwater permits are issued for agricultural use in the Georgia portion of the watershed. However, 14 surface water permits are
dispersed throughout the Georgia side of the Upper Tallapoosa. In total, these permits allow surface water to be pumped at a rate of 3,658 gallons per minute. Together, agricultural groundwater and surface water permits in the Upper Tallapoosa watershed authorize total freshwater withdrawals at a rate of 3,658 gallons per minute. This figure ranks 48th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 3,658 gallons of water per minute authorized to be withdrawn from sources inside the Upper Tallapoosa watershed is 66.97% lower than the corresponding land area based estimate.

**Withlacoochee Watershed**

Located on the Georgia-Florida state line, the Withlacoochee watershed encompasses segments of 9 Georgia counties. Like the majority of south Georgia, the counties making up the Withlacoochee watershed have a vast agricultural sector. The largest city positioned inside the Withlacoochee watershed is Tifton. Currently, there are 357 groundwater permits issued for agricultural use in the Georgia portion of the watershed. In aggregate, these permits allow groundwater to be pumped at a rate of 207,730 gallons per minute. Similarly, 799 agricultural surface water permits are dispersed throughout the watershed. In total, these permits allow surface water to be pumped at a rate of 728,968 gallons per minute. Together, agricultural groundwater and surface water permits in the Withlacoochee watershed authorize total freshwater withdrawals at a rate of 936,698 gallons per minute. This figure ranks 9th highest out of the 51 watersheds for which data was available at the time of this study (Table 5.2). The actual figure of 936,698 gallons of water per minute authorized to be withdrawn from sources inside the Withlacoochee watershed is 5.38% higher than the corresponding land area based estimate.
5.4. River Basin Results

As with the watershed data, the easiest way to compare river basin errors between estimated permits or permitted withdrawals and actual permits or permitted withdrawals is by using the percentage difference between them. Individual river basin percentage differences across source categories can be viewed in Table 5.3.

**Groundwater**

The results of this study show that 6 river basins have actual numbers of groundwater permits that are higher than corresponding land area based estimates. Conversely, 7 river basins have actual groundwater permit numbers lower than land area based estimates. The Tallapoosa river basin contains no groundwater permit data (Figure 5.7). The results of this study also show that 6 river basins have actual groundwater permitted withdrawal (gpm) numbers higher than land area based estimates. Conversely, 7 river basins have actual groundwater permitted withdrawal (gpm) numbers lower than land area based estimates. The Tallapoosa river basin contains no groundwater permitted withdrawal data (Figure 5.8).

**Surface Water**

The results of this study show that 6 river basins have actual numbers of surface water permits that are higher than corresponding land area based estimates. Conversely, 8 river basins have actual surface water permit numbers lower than land area based estimates (Figure 5.9). The results of this study also show that 6 river basins have actual surface water permitted withdrawal (gpm) numbers higher than land area based estimates and 8 river basins have actual surface water permitted withdrawal (gpm) numbers lower than land area based estimates (5.10).
Groundwater + Surface Water

The results of this study show that 6 river basins have actual numbers of groundwater + surface water permits that are higher than corresponding land area based estimates. Conversely, 8 river basins have actual groundwater + surface water permit numbers lower than land area based estimates (Figure 5.11). The results of this study also show that 5 river basins have actual groundwater + surface water permitted withdrawal (gpm) numbers higher than land area based estimates. Conversely, 9 river basins have actual groundwater + surface water permitted withdrawal (gpm) numbers lower than land area based estimates (Figure 5.12).

5.5. Individual River Basin Summaries

Altamaha River Basin

Located in southeast Georgia, the Altamaha river basin encompasses segments of 19 Georgia counties. Currently, there are 199 groundwater permits issued for agricultural use in the Altamaha river basin. In total, these permits allow groundwater to be pumped at a rate of 87,606 gallons per minute. Similarly, 852 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 694,022 gallons per minute. Together, agricultural groundwater and surface water permits in the Altamaha river basin authorize total freshwater withdrawals at a rate of 781,628 gallons per minute. This figure ranks 6th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 781,628 gallons of water per minute authorized to be withdrawn from sources inside the Altamaha river basin is 6.78% lower than the corresponding land area based estimate (Table 5.3).

Chattahoochee River Basin

Starting in north Georgia and encompassing most of the western border of the state, the Chattahoochee river basin includes segments of 37 Georgia counties. Currently, there are 353
groundwater permits issued for agricultural use in the Chattahoochee river basin. In total, these permits allow groundwater to be pumped at a rate of 296,750 gallons per minute. Similarly, 294 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 309,356 gallons per minute. Together, agricultural groundwater and surface water permits in the Chattahoochee river basin authorize total freshwater withdrawals at a rate of 606,106 gallons per minute. This figure ranks 8th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 606,106 gallons of water per minute authorized to be withdrawn from sources inside the Chattahoochee river basin is 27.50% lower than the corresponding land area based estimate (Table 5.3).

**Coosa River Basin**

Located in northwest Georgia, the Coosa river basin encompasses segments of 21 Georgia counties. Currently, there are 22 groundwater permits issued for agricultural use in the Coosa river basin. In total, these permits allow groundwater to be pumped at a rate of 3,487 gallons per minute. Similarly, 124 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 121,005 gallons per minute. Together, agricultural groundwater and surface water permits in the Coosa river basin authorize total freshwater withdrawals at a rate of 124,492 gallons per minute. This figure ranks 11th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 124,492 gallons of water per minute authorized to be withdrawn from sources inside the Coosa river basin is 0.26% lower than the corresponding land area based estimate (Table 5.3).

**Flint River Basin**

Spanning much of the western portion of Georgia, the Flint river basin encompasses segments of 41 Georgia counties. Currently, there are 4,277 groundwater permits issued for
agricultural use in the Flint river basin. In total, these permits allow groundwater to be pumped at a rate of 3,638,726 gallons per minute. Similarly, 1,613 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 1,833,170 gallons per minute. Together, agricultural groundwater and surface water permits in the Flint river basin authorize total freshwater withdrawals at a rate of 5,471,896 gallons per minute. This figure ranks highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 5,471,896 gallons of water per minute authorized to be withdrawn from sources inside the Flint river basin is 3.78% higher than the corresponding land area based estimate (Table 5.3).

**Ochlockonee River Basin**

Located in southwest Georgia, the Ochlockonee river basin encompasses segments of 7 Georgia counties. Currently, there are 296 groundwater permits issued for agricultural use in the Ochlockonee river basin. In total, these permits allow groundwater to be pumped at a rate of 177,502 gallons per minute. Similarly, 620 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 583,230 gallons per minute. Together, agricultural groundwater and surface water permits in the Ochlockonee river basin authorize total freshwater withdrawals at a rate of 760,732 gallons per minute. This figure ranks 7th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 760,732 gallons of water per minute authorized to be withdrawn from sources inside the Ochlockonee river basin is 19.46% lower than the corresponding land area based estimate (Table 5.3).

**Ocmulgee River Basin**

Centrally located in Georgia, the Ocmulgee river basin encompasses segments of 31 Georgia counties. Currently, there are 930 groundwater permits issued for agricultural use in the
Ocmulgee river basin. In total, these permits allow groundwater to be pumped at a rate of 477,956 gallons per minute. Similarly, 1,204 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 1,087,542 gallons per minute. Together, agricultural groundwater and surface water permits in the Ocmulgee river basin authorize total freshwater withdrawals at a rate of 1,565,498 gallons per minute. This figure ranks 3rd highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 1,565,498 gallons of water per minute authorized to be withdrawn from sources inside the Ocmulgee river basin is 10.32% lower than the corresponding land area based estimate (Table 5.3).

**Oconee River Basin**

Centrally located in Georgia, the Oconee river basin encompasses segments of 29 Georgia counties. Currently, there are 143 groundwater permits issued for agricultural use in the Oconee river basin. In total, these permits allow groundwater to be pumped at a rate of 53,277 gallons per minute. Similarly, 388 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 286,145 gallons per minute. Together, agricultural groundwater and surface water permits in the Oconee river basin authorize total freshwater withdrawals at a rate of 339,422 gallons per minute. This figure ranks 9th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 339,422 gallons of water per minute authorized to be withdrawn from sources inside the Oconee river basin is 12.32% lower than the corresponding land area based estimate (Table 5.3).

**Ogeechee River Basin**

Located in eastern Georgia, the Ogeechee river basin encompasses segments of 22 Georgia counties. Currently, there are 439 groundwater permits issued for agricultural use in the
Ogeechee river basin. In total, these permits allow groundwater to be pumped at a rate of 237,814 gallons per minute. Similarly, 903 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 836,089 gallons per minute. Together, agricultural groundwater and surface water permits in the Ogeechee river basin authorize total freshwater withdrawals at a rate of 1,073,903 gallons per minute. This figure ranks 5th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 1,073,903 gallons of water per minute authorized to be withdrawn from sources inside the Ogeechee river basin is 5.82% higher than the corresponding land area based estimate (Table 5.3).

**Satilla River Basin**

Located in southeast Georgia, the Satilla river basin encompasses segments of 16 Georgia counties. Currently, there are 471 groundwater permits issued for agricultural use in the Satilla river basin. In total, these permits allow groundwater to be pumped at a rate of 227,014 gallons per minute. Similarly, 1,382 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 1,161,824 gallons per minute. Together, agricultural groundwater and surface water permits in the Satilla river basin authorize total freshwater withdrawals at a rate of 1,388,838 gallons per minute. This figure ranks 4th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 1,388,838 gallons of water per minute authorized to be withdrawn from sources inside the Satilla river basin is 9.10% higher than the corresponding land area based estimate (Table 5.3).

**Savannah River Basin**

Encompassing most of the eastern border of Georgia, the Savannah river basin includes segments of 28 Georgia counties. Currently, there are 95 groundwater permits issued for
agricultural use in the Savannah river basin. In total, these permits allow groundwater to be pumped at a rate of 49,756 gallons per minute. Similarly, 201 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 225,899 gallons per minute. Together, agricultural groundwater and surface water permits in the Savannah river basin authorize total freshwater withdrawals at a rate of 275,655 gallons per minute. This figure ranks 10th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 275,655 gallons of water per minute authorized to be withdrawn from sources inside the Savannah river basin is 8.43% lower than the corresponding land area based estimate (Table 5.3).

**St. Marys River Basin**

Located in southeast Georgia, the St. Marys river basin encompasses segments of 3 Georgia counties. Currently, there are 3 groundwater permits issued for agricultural use in the St. Marys river basin. In total, these permits allow groundwater to be pumped at a rate of 1,175 gallons per minute. Similarly, 6 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 7,500 gallons per minute. Together, agricultural groundwater and surface water permits in the St. Marys river basin authorize total freshwater withdrawals at a rate of 8,675 gallons per minute. This figure ranks 13th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 8,675 gallons of water per minute authorized to be withdrawn from sources inside the St. Marys river basin is 52.40% lower than the corresponding land area based estimate (Table 5.3).

**Suwannee River Basin**

Located in southern Georgia, the Suwannee river basin encompasses segments of 22 Georgia counties. Currently, there are 1,351 groundwater permits issued for agricultural use in
the Suwannee river basin. In total, these permits allow groundwater to be pumped at a rate of 692,193 gallons per minute. Similarly, 3,285 surface water permits are dispersed throughout the river basin. In total, these permits allow surface water to be pumped at a rate of 3,076,144 gallons per minute. Together, agricultural groundwater and surface water permits in the Suwannee river basin authorize total freshwater withdrawals at a rate of 3,768,337 gallons per minute. This figure ranks 2nd highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 3,768,337 gallons of water per minute authorized to be withdrawn from sources inside the Suwannee river basin is 4.94% higher than the corresponding land area based estimate (Table 5.3).

**Tallapoosa River Basin**

Located predominantly in Alabama, the Tallapoosa river basin crosses into western Georgia and encompasses segments of 6 Georgia counties. Currently, no groundwater permits have been issued for agricultural use in the Tallapoosa river basin. However, 14 surface water permits are currently dispersed throughout the Georgia portion of the river basin. In total, these permits allow surface water to be pumped at a rate of 3,658 gallons per minute. Together, agricultural groundwater and surface water permits in the Tallapoosa river basin authorize total freshwater withdrawals at a rate of 3,658 gallons per minute. This figure ranks lowest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 3,658 gallons of water per minute authorized to be withdrawn from sources inside the Tallapoosa river basin is 66.97% lower than the corresponding land area based estimate (Table 5.3).

**Tennessee River Basin**

Located predominantly in Tennessee, the Tennessee river basin crosses into north Georgia and encompasses segments of 11 Georgia counties. Currently, there are only 2
groundwater permits issued for agricultural use in the Tennessee river basin. In total, these permits allow groundwater to be pumped at a rate of 200 gallons per minute. Similarly, 51 surface water permits are dispersed throughout the Georgia portion of the river basin. In total, these permits allow surface water to be pumped at a rate of 36,505 gallons per minute. Together, agricultural groundwater and surface water permits in the Tennessee river basin authorize total freshwater withdrawals at a rate of 36,705 gallons per minute. This figure ranks 12th highest of the 14 river basins located in Georgia (Table 5.4). The actual figure of 36,705 gallons of water per minute authorized to be withdrawn from sources inside the Tennessee river basin is 15.31% higher than the corresponding land area based estimate (Table 5.3).
### Table 5.1. Watershed % Differences Across Source Categories for Estimated vs. Actual Permitting Figures

<table>
<thead>
<tr>
<th>Watershed Name</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW Permits</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW Permitted Withdrawals</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual SW Permitted Withdrawals</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW+SW Permitted Withdrawals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alapaha</td>
<td>3.73%</td>
<td>2.87%</td>
<td>-5.64%</td>
<td>-4.32%</td>
</tr>
<tr>
<td>Altamaha</td>
<td>8.21%</td>
<td>25.92%</td>
<td>0.86%</td>
<td>1.86%</td>
</tr>
<tr>
<td>Apalachee Bay-St. Marks</td>
<td>250.00%</td>
<td>549.64%</td>
<td>1,500.00%</td>
<td>3,217.78%</td>
</tr>
<tr>
<td>Apalachicola</td>
<td>172.73%</td>
<td>190.96%</td>
<td>0.00%</td>
<td>-47.10%</td>
</tr>
<tr>
<td>Aucilla</td>
<td>-37.74%</td>
<td>-42.10%</td>
<td>32.46%</td>
<td>25.28%</td>
</tr>
<tr>
<td>Broad</td>
<td>-14.51%</td>
<td>-11.54%</td>
<td>6.70%</td>
<td>8.80%</td>
</tr>
<tr>
<td>Canooche</td>
<td>4.41%</td>
<td>4.95%</td>
<td>-15.62%</td>
<td>-17.64%</td>
</tr>
<tr>
<td>Conasauga</td>
<td>35.98%</td>
<td>34.81%</td>
<td>40.99%</td>
<td>35.52%</td>
</tr>
<tr>
<td>Coosawattee</td>
<td>0.00%</td>
<td>-51.34%</td>
<td>42.64%</td>
<td>68.41%</td>
</tr>
<tr>
<td>Cumberland-St. Simons</td>
<td>224.40%</td>
<td>788.40%</td>
<td>636.61%</td>
<td>604.44%</td>
</tr>
<tr>
<td>Etowah</td>
<td>15.72%</td>
<td>164.48%</td>
<td>5.19%</td>
<td>-6.87%</td>
</tr>
<tr>
<td>Guntersville Lake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hiwassee</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ichaway-Nochaway</td>
<td>-2.59%</td>
<td>1.73%</td>
<td>-18.65%</td>
<td>-16.73%</td>
</tr>
<tr>
<td>Kinchafoonee-Muckalee</td>
<td>8.63%</td>
<td>15.01%</td>
<td>-6.98%</td>
<td>-6.86%</td>
</tr>
<tr>
<td>Little (in GA only)</td>
<td>-18.72%</td>
<td>-8.09%</td>
<td>-12.41%</td>
<td>-14.22%</td>
</tr>
<tr>
<td>Little (in GA-SC)</td>
<td>273.17%</td>
<td>230.23%</td>
<td>19.88%</td>
<td>8.25%</td>
</tr>
<tr>
<td>Little Ocmulgee</td>
<td>3.04%</td>
<td>14.05%</td>
<td>1.23%</td>
<td>5.49%</td>
</tr>
<tr>
<td>Little Satilla</td>
<td>-1.58%</td>
<td>-22.24%</td>
<td>20.81%</td>
<td>19.14%</td>
</tr>
<tr>
<td>Lower Chattahoochee</td>
<td>28.69%</td>
<td>24.68%</td>
<td>4.31%</td>
<td>9.29%</td>
</tr>
<tr>
<td>Lower Flint</td>
<td>-10.04%</td>
<td>-14.37%</td>
<td>85.69%</td>
<td>94.18%</td>
</tr>
<tr>
<td>Lower Ochlockonee</td>
<td>331.08%</td>
<td>604.28%</td>
<td>-29.38%</td>
<td>-27.54%</td>
</tr>
</tbody>
</table>

Blank cells indicate no data is available

* Negative values imply that land area based estimates are less than actual number of permits/permitted withdrawals; Positive values imply that land area based estimates are greater than actual number of permits/permitted withdrawals
<table>
<thead>
<tr>
<th>Watershed Name</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW Permits</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW Permitted Withdrawals</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual SW Permitted Withdrawals</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW+SW Permitted Withdrawals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Ocmulgee</td>
<td>-4.63%</td>
<td>-0.11%</td>
<td>13.58%</td>
<td>-0.11%</td>
</tr>
<tr>
<td>Lower Oconee</td>
<td>20.06%</td>
<td>30.98%</td>
<td>5.80%</td>
<td>10.20%</td>
</tr>
<tr>
<td>Lower Ogeechee</td>
<td>-7.37%</td>
<td>-5.88%</td>
<td>9.14%</td>
<td>2.35%</td>
</tr>
<tr>
<td>Lower Savannah</td>
<td>-22.52%</td>
<td>-15.69%</td>
<td>33.36%</td>
<td>-3.03%</td>
</tr>
<tr>
<td>Mid. Chattahoo.-Lake Hard.</td>
<td>72.91%</td>
<td>132.07%</td>
<td>-3.84%</td>
<td>-1.36%</td>
</tr>
<tr>
<td>Mid. Chattahoo.-W.F.G. Res.</td>
<td>203.18%</td>
<td>398.90%</td>
<td>114.60%</td>
<td>128.72%</td>
</tr>
<tr>
<td>Middle Flint</td>
<td>-3.78%</td>
<td>-10.81%</td>
<td>30.97%</td>
<td>9.32%</td>
</tr>
<tr>
<td>Middle Savannah</td>
<td>118.33%</td>
<td>76.78%</td>
<td>26.23%</td>
<td>57.81%</td>
</tr>
<tr>
<td>Middle Tennessee-Chickam.</td>
<td>-22.92%</td>
<td>-22.92%</td>
<td>-18.48%</td>
<td>-30.22%</td>
</tr>
<tr>
<td>Ocoee</td>
<td>-22.92%</td>
<td>-22.92%</td>
<td>-18.48%</td>
<td>-30.22%</td>
</tr>
<tr>
<td>Ogeechee Coastal</td>
<td>15.38%</td>
<td>24.02%</td>
<td>93.39%</td>
<td>43.75%</td>
</tr>
<tr>
<td>Ohooppee</td>
<td>12.44%</td>
<td>8.89%</td>
<td>12.40%</td>
<td>12.40%</td>
</tr>
<tr>
<td>Oostanaula</td>
<td>-12.80%</td>
<td>-12.80%</td>
<td>-2.25%</td>
<td>-8.27%</td>
</tr>
<tr>
<td>St. Marys</td>
<td>59.76%</td>
<td>1.36%</td>
<td>112.63%</td>
<td>95.01%</td>
</tr>
<tr>
<td>Satilla</td>
<td>-9.75%</td>
<td>-8.36%</td>
<td>-10.90%</td>
<td>-10.64%</td>
</tr>
<tr>
<td>Spring</td>
<td>-14.56%</td>
<td>-12.56%</td>
<td>-3.73%</td>
<td>-13.65%</td>
</tr>
<tr>
<td>Tugaloo</td>
<td>-29.53%</td>
<td>6.50%</td>
<td>30.05%</td>
<td>-28.05%</td>
</tr>
<tr>
<td>Upper Chattahoochee</td>
<td>-35.75%</td>
<td>-46.81%</td>
<td>7.53%</td>
<td>-9.76%</td>
</tr>
<tr>
<td>Upper Coosa</td>
<td>-42.86%</td>
<td>-45.00%</td>
<td>-28.11%</td>
<td>-33.49%</td>
</tr>
<tr>
<td>Upper Flint</td>
<td>64.17%</td>
<td>94.86%</td>
<td>2.96%</td>
<td>3.99%</td>
</tr>
<tr>
<td>Upper Little Tennessee</td>
<td>82.21%</td>
<td>139.27%</td>
<td>15.20%</td>
<td>17.84%</td>
</tr>
<tr>
<td>Upper Ochlockonee</td>
<td>85.57%</td>
<td>142.70%</td>
<td>5.11%</td>
<td>2.87%</td>
</tr>
<tr>
<td>Upper Ocmulgee</td>
<td>85.57%</td>
<td>142.70%</td>
<td>5.11%</td>
<td>2.87%</td>
</tr>
</tbody>
</table>

Blank cells indicate no data is available

* Negative values imply that land area based estimates are less than actual number of permits/permitted withdrawals; Positive values imply that land area based estimates are greater than actual number of permits/permitted withdrawals
Table 5.1 *Continued.* Watershed % Differences Across Source Categories for Estimated vs. Actual Permitting Figures

<table>
<thead>
<tr>
<th>Watershed Name</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW Permits</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW Permitted Withdrawals</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual SW Permits</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW+SW Permits</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW+SW Permitted Withdrawals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Oconee</td>
<td>11.52%</td>
<td>69.14%</td>
<td>0.33%</td>
<td>-0.95%</td>
<td>2.21%</td>
</tr>
<tr>
<td>Upper Ogeechee</td>
<td>-19.63%</td>
<td>-20.79%</td>
<td>8.02%</td>
<td>5.34%</td>
<td>-5.49%</td>
</tr>
<tr>
<td>Upper Savannah</td>
<td>18.89%</td>
<td>-5.63%</td>
<td>7.83%</td>
<td>-1.21%</td>
<td>8.23%</td>
</tr>
<tr>
<td>Upper Suwannee</td>
<td>166.84%</td>
<td>392.57%</td>
<td>547.70%</td>
<td>488.47%</td>
<td>384.47%</td>
</tr>
<tr>
<td>Upper Tallapoosa</td>
<td>-0.53%</td>
<td>-6.35%</td>
<td>-5.05%</td>
<td>65.72%</td>
<td>-4.35%</td>
</tr>
<tr>
<td>Withlacoochee</td>
<td>-0.53%</td>
<td>-6.35%</td>
<td>-5.02%</td>
<td>-5.10%</td>
<td>-3.63%</td>
</tr>
</tbody>
</table>

Blank cells indicate no data is available

* Negative values imply that land area based estimates are less than actual number of permits/permitted withdrawals; Positive values imply that land area based estimates are greater than actual number of permits/permitted withdrawals
Table 5.2. Groundwater + Surface Water Permitted Withdrawals Ranking at Watershed Level

**Ranking of Georgia’s 52 Watersheds for Combined Groundwater & Surface Water Agricultural Permitted Withdrawals**

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Watershed Name</th>
<th>Gallons Per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alapaha</td>
<td>1,706,646</td>
</tr>
<tr>
<td>2</td>
<td>Lower Flint</td>
<td>1,404,593</td>
</tr>
<tr>
<td>3</td>
<td>Spring</td>
<td>1,251,467</td>
</tr>
<tr>
<td>4</td>
<td>Satilla</td>
<td>1,233,494</td>
</tr>
<tr>
<td>5</td>
<td>Lower Ocmulgee</td>
<td>1,146,355</td>
</tr>
<tr>
<td>6</td>
<td>Little (South)</td>
<td>1,111,713</td>
</tr>
<tr>
<td>7</td>
<td>Ichaway-Nochaway</td>
<td>1,034,615</td>
</tr>
<tr>
<td>8</td>
<td>Middle Flint</td>
<td>936,864</td>
</tr>
<tr>
<td>9</td>
<td>Withlacoochee</td>
<td>936,698</td>
</tr>
<tr>
<td>10</td>
<td>Kinchafoonee-Muckalee</td>
<td>732,518</td>
</tr>
<tr>
<td>11</td>
<td>Upper Ochlockonee</td>
<td>582,419</td>
</tr>
<tr>
<td>12</td>
<td>Canoochee</td>
<td>508,208</td>
</tr>
<tr>
<td>13</td>
<td>Lower Chattahoochee</td>
<td>418,255</td>
</tr>
<tr>
<td>14</td>
<td>Ohoopee</td>
<td>399,952</td>
</tr>
<tr>
<td>15</td>
<td>Altamaha</td>
<td>381,676</td>
</tr>
<tr>
<td>16</td>
<td>Little Ocmulgee</td>
<td>325,006</td>
</tr>
<tr>
<td>17</td>
<td>Lower Ogeechee</td>
<td>283,627</td>
</tr>
<tr>
<td>18</td>
<td>Upper Ogeechee</td>
<td>274,898</td>
</tr>
<tr>
<td>19</td>
<td>Lower Oconee</td>
<td>250,955</td>
</tr>
<tr>
<td>20</td>
<td>Little Satilla</td>
<td>154,184</td>
</tr>
<tr>
<td>21</td>
<td>Brier</td>
<td>134,624</td>
</tr>
<tr>
<td>22</td>
<td>Upper Flint</td>
<td>111,839</td>
</tr>
<tr>
<td>23</td>
<td>Upper Ocmulgee</td>
<td>94,137</td>
</tr>
<tr>
<td>24</td>
<td>Middle Chattahoochee-Walter F. George Reservoir</td>
<td>91,015</td>
</tr>
<tr>
<td>25</td>
<td>Upper Oconee</td>
<td>88,467</td>
</tr>
<tr>
<td>26</td>
<td>Aucilla</td>
<td>83,800</td>
</tr>
</tbody>
</table>
Table 5.2 *Continued.* Groundwater + Surface Water Permitted Withdrawals Ranking at Watershed Level

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Watershed Name</th>
<th>Gallons Per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Lower Ochlockonee</td>
<td>73,505</td>
</tr>
<tr>
<td>28</td>
<td>Upper Chattahoochee</td>
<td>52,564</td>
</tr>
<tr>
<td>29</td>
<td>Etowah</td>
<td>45,727</td>
</tr>
<tr>
<td>30</td>
<td>Middle Chattahoochee-Lake Harding</td>
<td>44,272</td>
</tr>
<tr>
<td>31</td>
<td>Middle Savannah</td>
<td>35,990</td>
</tr>
<tr>
<td>32</td>
<td>Broad</td>
<td>32,423</td>
</tr>
<tr>
<td>33</td>
<td>Upper Coosa</td>
<td>31,235</td>
</tr>
<tr>
<td>34</td>
<td>Lower Savannah</td>
<td>26,715</td>
</tr>
<tr>
<td>35</td>
<td>Upper Savannah</td>
<td>20,160</td>
</tr>
<tr>
<td>36</td>
<td>Oostanaula</td>
<td>19,465</td>
</tr>
<tr>
<td>37</td>
<td>Apalachicola</td>
<td>18,600</td>
</tr>
<tr>
<td>38</td>
<td>Conasauga</td>
<td>17,925</td>
</tr>
<tr>
<td>39</td>
<td>Ocoee</td>
<td>17,370</td>
</tr>
<tr>
<td>40</td>
<td>Upper Suwannee</td>
<td>13,280</td>
</tr>
<tr>
<td>41</td>
<td>Middle Tennessee-Chickamauga</td>
<td>13,260</td>
</tr>
<tr>
<td>42</td>
<td>Little</td>
<td>13,145</td>
</tr>
<tr>
<td>43</td>
<td>Tugaloo</td>
<td>12,598</td>
</tr>
<tr>
<td>44</td>
<td>Coosawattee</td>
<td>10,140</td>
</tr>
<tr>
<td>45</td>
<td>St. Marys</td>
<td>8,675</td>
</tr>
<tr>
<td>46</td>
<td>Ogeechee Coastal</td>
<td>7,170</td>
</tr>
<tr>
<td>47</td>
<td>Hiwassee</td>
<td>6,075</td>
</tr>
<tr>
<td>48</td>
<td>Upper Tallapoosa</td>
<td>3,658</td>
</tr>
<tr>
<td>49</td>
<td>Apalachee Bay-St. Marks</td>
<td>2,408</td>
</tr>
<tr>
<td>50</td>
<td>Cumberland-St. Simons</td>
<td>1,160</td>
</tr>
<tr>
<td>51</td>
<td>Upper Little Tennessee</td>
<td>0</td>
</tr>
<tr>
<td>52</td>
<td>Guntersville Lake</td>
<td></td>
</tr>
</tbody>
</table>

Blank cells indicate no data is available.
Table 5.3. River Basin % Differences Across Source Categories for Estimated vs. Actual Permitting Figures

<table>
<thead>
<tr>
<th>River Basin Name</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW Permits</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW Permitted Withdrawals</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual SW Permitted Withdrawals</th>
<th>Difference Between Land Area Based Theoretical Estimates &amp; Actual GW+SW Permitted Withdrawals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altamaha</td>
<td>10.27%</td>
<td>16.02%</td>
<td>6.57%</td>
<td>5.61%</td>
</tr>
<tr>
<td>Chattahoochee</td>
<td>31.82%</td>
<td>29.63%</td>
<td>24.95%</td>
<td>25.45%</td>
</tr>
<tr>
<td>Coosa</td>
<td>1.65%</td>
<td>11.19%</td>
<td>3.42%</td>
<td>-0.06</td>
</tr>
<tr>
<td>Flint</td>
<td>-6.92%</td>
<td>-8.63%</td>
<td>7.78%</td>
<td>5.84%</td>
</tr>
<tr>
<td>Ochlockonee</td>
<td>81.28%</td>
<td>132.22%</td>
<td>-12.33%</td>
<td>-14.86%</td>
</tr>
<tr>
<td>Ocmulgee</td>
<td>-0.67%</td>
<td>4.24%</td>
<td>9.58%</td>
<td>12.99%</td>
</tr>
<tr>
<td>Oconee</td>
<td>18.57%</td>
<td>32.52%</td>
<td>4.05%</td>
<td>8.56%</td>
</tr>
<tr>
<td>Ogeechee</td>
<td>-6.71%</td>
<td>-10.54%</td>
<td>-5.30%</td>
<td>-4.48%</td>
</tr>
<tr>
<td>Satilla</td>
<td>-7.31%</td>
<td>-11.51%</td>
<td>-7.31%</td>
<td>-8.63%</td>
</tr>
<tr>
<td>Savannah</td>
<td>22.72%</td>
<td>36.13%</td>
<td>7.88%</td>
<td>2.33%</td>
</tr>
<tr>
<td>St. Marys</td>
<td>59.76%</td>
<td>-1.36%</td>
<td>112.63%</td>
<td>60.82%</td>
</tr>
<tr>
<td>Suwannee</td>
<td>-4.67%</td>
<td>-2.62%</td>
<td>-5.39%</td>
<td>-5.47%</td>
</tr>
<tr>
<td>Tallapoosa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tennessee</td>
<td>-21.86%</td>
<td>-19.37%</td>
<td>-10.82%</td>
<td>-15.29%</td>
</tr>
</tbody>
</table>

Blank cells indicate no data is available

* Negative values imply that land area based estimates are less than actual number of permits/permitted withdrawals; Positive values imply that land area based estimates are greater than actual number of permits/permitted withdrawals.
Table 5.4. Groundwater + Surface Water Permitted Withdrawals Ranking at River Basin Level

<table>
<thead>
<tr>
<th>Ranking</th>
<th>River Basin Name</th>
<th>Gallons Per Minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flint</td>
<td>5,471,896</td>
</tr>
<tr>
<td>2</td>
<td>Suwannee</td>
<td>3,768,337</td>
</tr>
<tr>
<td>3</td>
<td>Ocmulgee</td>
<td>1,565,498</td>
</tr>
<tr>
<td>4</td>
<td>Satilla</td>
<td>1,388,838</td>
</tr>
<tr>
<td>5</td>
<td>Ogeechee</td>
<td>1,073,903</td>
</tr>
<tr>
<td>6</td>
<td>Altamaha</td>
<td>781,628</td>
</tr>
<tr>
<td>7</td>
<td>Ochlockonee</td>
<td>760,732</td>
</tr>
<tr>
<td>8</td>
<td>Chattahoochee</td>
<td>606,106</td>
</tr>
<tr>
<td>9</td>
<td>Oconee</td>
<td>339,422</td>
</tr>
<tr>
<td>10</td>
<td>Savannah</td>
<td>275,655</td>
</tr>
<tr>
<td>11</td>
<td>Coosa</td>
<td>124,492</td>
</tr>
<tr>
<td>12</td>
<td>Tennessee</td>
<td>36,705</td>
</tr>
<tr>
<td>13</td>
<td>St. Marys</td>
<td>8,675</td>
</tr>
<tr>
<td>14</td>
<td>Tallapoosa</td>
<td>3,658</td>
</tr>
</tbody>
</table>
Figure 5.1. Overestimated and Underestimated Watersheds: Agricultural Groundwater Permits
Figure 5.2. Overestimated and Underestimated Watersheds: Agricultural Groundwater Permitted Withdrawals (GPM)
Figure 5.3. Overestimated and Underestimated Watersheds: Agricultural Surface Water Permits
Figure 5.4. Overestimated and Underestimated Watersheds: Agricultural Surface Water Permitted Withdrawals (GPM)
Figure 5.5. Overestimated and Underestimated Watersheds: Agricultural Groundwater + Surface Water Permits
Figure 5.6. Overestimated and Underestimated Watersheds: Agricultural Groundwater + Surface Water Permitted Withdrawals (GPM)
Figure 5.7. Overestimated and Underestimated River Basins: Agricultural Groundwater Permits
Figure 5.8. Overestimated and Underestimated River Basins: Agricultural Groundwater Permitted Withdrawals (GPM)
Figure 5.9. Overestimated and Underestimated River Basins: Agricultural Surface Water Permits

* Negative values imply that land area-based estimates are less than actual # of permits issued. Positive values imply that land area-based estimates are greater than actual # of permits issued.
Figure 5.10. Overestimated and Underestimated River Basins: Agricultural Surface Water Permitted Withdrawals (GPM)
Figure 5.11. Overestimated and Underestimated River Basins: Agricultural Groundwater + Surface Water Permits
Figure 5.12. Overestimated and Underestimated River Basins: Agricultural Groundwater + Surface Water Permitted Withdrawals (GPM)
CHAPTER 6

POLICY IMPLICATIONS, CONCLUSIONS, AND RECOMMENDATIONS

6.1. Policy Implications

The importance of sound water policy is increasingly becoming evident throughout Georgia and the United States. From the outset of this study, it was our intention to compile agricultural water permitting data that could assist those entrusted with future water policy decisions in the state of Georgia. The results of this study provide insight into the allocation of agricultural water withdrawals throughout the various watersheds and river basins in the state. Actual permitted withdrawals have been compared with land area based withdrawal estimates. Differences between these figures may illustrate areas where too many (or too few) withdrawals are permitted. This information has great value for future policy decisions regarding permitted agricultural water withdrawals.

This section will examine results for the Chattahoochee and Flint river basins. In doing so, policy implications will be considered, and a framework will be provided illustrating the type of analysis facilitated by this study. For the purposes of this section, the most logical category to analyze is the combined category (groundwater + surface water) for permitted withdrawals (gpm). Looking at this category provides a useful overview of the agricultural water-use picture in each river basin.
Chattahoochee River Basin

The Chattahoochee river basin originates near the Tennessee border and spans most of the western side of Georgia. The river basin is composed of 8,770 square miles of land area, all of which drains into the Chattahoochee River. Although it extends into Alabama and Florida, the majority (70%) of the land area making up the Chattahoochee river basin lies in Georgia. On its journey south, the Chattahoochee River flows through metropolitan Atlanta. There, water from the river is used to meet a bulk of the city’s freshwater needs. As a result of the vast water requirements of the Atlanta area, the Chattahoochee River is the most heavily used water resource in the state of Georgia (Georgia Department of Natural Resources, 2005).

Of the 14 river basins in Georgia, the Chattahoochee ranks 8th highest in total agricultural water withdrawals (Table 5.4). Our results indicate that land area based water withdrawal estimates exceed the actual amount of water permitted to be withdrawn throughout the river basin (Table 5.3). For the combined (groundwater + surface water) permitted withdrawals category, the error between estimated and actual figures is 27.5%. This indicates that permitted agricultural water withdrawals are authorized at a level that is nearly 30% lower than land area based figures project. The discrepancy between estimated and actual withdrawal figures in the Chattahoochee river basin is significantly higher than other river basins located predominately in Georgia. To understand why the errors between our estimates and the actual figures are so large, an analysis of the individual watersheds comprising the Chattahoochee river basin is helpful.

The Chattahoochee river basin is made up of four watersheds: Upper Chattahoochee, Middle Chattahoochee-Lake Harding, Middle Chattahoochee-Walter F. George Reservoir, and Lower Chattahoochee. Of these four watersheds, the Middle Chattahoochee-Walter F. George Reservoir shows the largest discrepancy between estimated and actual withdrawal figures. For
the most part, the source of this inconsistency is concentrated in a cluster of four neighboring counties: Clay, Marion, Randolph, and Webster. Incredibly, Randolph County’s average error for the combined categories (groundwater + surface water) is 377.51%. Figures of this magnitude are large enough to distort the results at both the watershed and river basin level.

The causes of these isolated errors may be numerous, but one explanation could be a breakdown in the fundamental assumption of this study: that agricultural entities are evenly distributed across county land areas. A breakdown in this assumption could produce skewed results similar to those observed in Clay, Marion, Randolph, and Webster counties.

It is clear that actual total permitted withdrawals in the Chattahoochee river basin are significantly less than the total permitted withdrawal estimates generated by our land area based calculations. Consequently, if looking solely at agricultural water use data, policy makers may be inclined to issue more agricultural withdrawal permits throughout the Chattahoochee river basin. Of course, this notion is contingent upon two key assumptions: (1) an even distribution of agricultural activity throughout the counties comprising the river basin and (2) other withdrawal sectors would not be adversely affected by an increased level of agricultural water withdrawals in the Chattahoochee river basin.

Flint River Basin

The Flint river basin originates at the southern edge of the Atlanta metropolitan region and continues south to the bottom of the state. The river basin drains 8,460 square miles and is home to a large portion of Georgia's agricultural sector. The Flint river basin is entirely contained inside the state of Georgia, and as it flows south, the Flint River spans nearly 350 miles (Georgia Department of Natural Resources, 2005).
Of the 14 river basins in Georgia, the Flint ranks highest in total agricultural water withdrawals (Table 5.4). Our results indicate that land area based groundwater withdrawal estimates are less than the actual amount of groundwater permitted to be withdrawn throughout the river basin (Table 5.3). Results also indicate that land area based surface water withdrawal estimates exceed the actual amount of surface water permitted to be withdrawn throughout the river basin (Table 5.3). For the combined (groundwater + surface water) permitted withdrawals category (gpm), the land area based estimate is 3.78% less than the actual withdrawal figure. This indicates that permitted agricultural water withdrawals are authorized at a level that is 3.78% (206,973 gpm) higher than land area based figures project.

Considering the vast amount of agricultural activity located in the Flint river basin, the above results are not unexpected. The majority of Georgia’s agricultural sector uses groundwater resources to facilitate irrigation practices. As such, it follows that the region would withdrawal more groundwater than projected by land area estimates. Unlike the Chattahoochee, the error between estimated and actual withdrawals in the Flint river basin is almost nonexistent. According to our land area based withdrawal distribution assumption, agricultural water withdrawals in the Flint river basin seem to be correctly dispersed. Policy makers could view the results of this study as an indication that agricultural water policy in the Flint river basin is correctly set. The process of converting county level data into river basin data did not uncover drastic discrepancies between actual withdrawal figures and land area based withdrawal estimates. Accordingly, if a river basin management system were implemented in the future, policy decisions in the Flint river basin could be made at the river basin level without significant concern over the use of converted county level data.
Interstate Water Compacts

Since 1997, there have been intermittent discussions over an interstate water compact between Alabama, Florida and Georgia. The compact would govern both the Chattahoochee and Flint river systems in an effort to manage water resources through the year 2030 (Georgia Department of Natural Resources, 2005). Over the years, various proposals have been made by the involved states, but negotiations have often stalled for various reasons. This study could lend valuable information to the debate, as it illustrates areas where Georgia’s agricultural sector withdrawals large portions of its water. If this study was extended to include other important Georgia water-use sectors, it could provide an insightful view of Georgia’s total water withdrawals, as well as illustrate areas where excess allocation may exist. Such information could be of immense value for drafters of an interstate water compact that would, in effect, further regulate freshwater withdrawals in Georgia.

6.2. Conclusions

This study was conducted with two basic objectives in mind. First, data from the Georgia Ag Permitting Database was organized into watershed and river basin segments. This facilitated an analysis of possible errors resulting from the use of data collected at the county level for watershed or river basin management practices. By comparing actual numbers of issued permits and permitted withdrawals (gpm) in each watershed/river basin with theoretical estimates based on land area, the specific error locations and degrees of severity were uncovered. This analysis was the major focus of the study. Additionally, the second objective was accomplished through the construction of a website capable of displaying the study results. In addition to acting as an organizational tool for the large quantity of tables and graphs generated by the study, the website
serves as a valuable instrument for Georgia water policy decisions and further academic research. The website can be viewed at http://www.georgiastats.uga.edu/gawater1.html.

The results of this study demonstrate that a certain level of error would exist if current county based water-use data was applied to a comprehensive watershed or river basin management system. In general, watersheds and river basins in south Georgia tend to have actual permitting numbers that are higher than land area based estimates. This result is not unexpected, as the majority of Georgia’s agricultural sector is located in this region. While the watersheds and river basins located in south Georgia tend to have higher actual permitting numbers than estimated numbers, the associated error percentages are relatively low. This implies that when ample data is available, actual permitting numbers tend to approximate land area based estimates (usually with a difference of less than 10%). This claim is evidenced by the fact that 4 of the 5 river basins with combined permitted withdrawals (gpm) exceeding one million gallons per minute (Table 5.4) show percentage discrepancies between actual and estimated figures of less than 10.00% (Table 5.3).

The results of this study also show that errors at the watershed level are more drastic than those at the river basin level. This may be a result of the smaller sample size of permits inherent in a watershed. Not unlike the risk management concept of diversification observed in portfolio management, the aggregated river basin level seems to reduce the magnitude of erroneous watershed estimates.

This study found that errors do exist between land area based agricultural water permitting estimates and actual figures derived from data that has been converted to the watershed or river basin level. In general, these errors could be a concern if the state of Georgia were to implement a comprehensive water management system at the watershed or river basin
level using data obtained at the county level. If such a water management system was considered, a shift would need to occur in the way water-use data is collected and referenced. Under a comprehensive watershed or river basin management system, collecting and referencing state water-use data at the appropriate watershed or river basin level could provide a more accurate basis for water policy decisions.

6.3. Recommendations

The obvious question to ask at the conclusion of this analysis is the following: Should Georgia keep its county level water management system, or should it consider a watershed or river basin management approach? After compiling and analyzing a vast amount of water-use data on the agricultural sector, it seems clear that the results of this study show two things. First, results for any watershed or river basin that is not entirely encompassed inside Georgia must be interpreted rather loosely. Since information regarding permitted withdrawals from neighboring states was not included in this study, outlying watersheds and river basins can not be analyzed with 100% accuracy. Second, as was mentioned in section 6.2, river basins tend to display lower error percentages than associated watersheds. Consequently, if Georgia moved away from the county level system, the river basin approach may be more conducive to converted county level water data.

With the above thoughts in mind, as well as the extensive environmental and efficiency benefits associated with the river basin method (Section 3.3), the state of Georgia may want to consider a move to the river basin management approach. The only exception to this recommendation would be the Chattahoochee river basin. With a land area that extends from metropolitan north Georgia all the way to agricultural south Georgia, the Chattahoochee is a unique river basin that may benefit from management at the smaller watershed level. This
approach would prevent extreme allocation errors in one location from affecting the policy
decisions of the entire river basin.

Finally, it is important to remember the impact that water has on our daily lives. Policy
decisions must be made intelligently, ensuring that future generations have sufficient access to
valuable freshwater resources. This study aimed to continue the discourse on water management.
Hopefully, in some small way, it will contribute to the process of establishing a management
system that will meet Georgia’s water needs for many years to come.
REFERENCES


Joint Comprehensive Water Plan Study Committee. Final Report of the Joint Comprehensive Water Plan Study Committee to the Governor and General Assembly. Senator Hugh Gillis, Co-Chairman and Representative Bob Hanner, Co-Chairman, 2002.


