A BASIN WATER PLAN FOR THE FLINT RIVER BASIN: RESEARCH DESIGN FOR AN UPDATING PROCESS

<u>Phase I Report</u>

Water Policy Working Paper #2002-005

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I. Purposes Of The Study

A Basin Water Plan brings together water supplies of a basin and the basin's present and future water needs, and examines the potential effects of satisfying these needs on such things as water quality and water availability. The purpose served by these examinations is to allow stakeholders in the basin to *anticipate* the potential for present and/or future problems in meeting the region's water needs, and to design strategies and policies that can mitigate, if not eliminate, these problems.

A Basin Water Plan prepared at any point in time should not -- indeed cannot -- be viewed as a "completed" work. Rather, it must be viewed as a "living document." This follows from the fact that conditions of water supply and/or water demands in a basin change over time, and such changes may take forms that were totally unanticipated at the time that the Plan was prepared. The Basin Water Plan is then best viewed as a part of a community's ongoing water planning *process* wherein the Plan is adapted as required by contemporary conditions.

A Basin Water Plan for the Flint River Basin was prepared by Georgia's Environmental Protection Division in 1997.[1] A number of significant changes have occurred since the preparation of this plan, changes that substantively diminish its usefulness. Most important among these changes are those related to our appreciation of the unreliability of present characterizations of water supplies and water use in the Basin, particularly water use in the

[1] Environmental Protection Division, Department of Natural Resources, *Flint River Basin Management*

agricultural sector. These changes obviate the need for Basin stakeholders to reassess the substance and scope of potential future water problems addressed in the 1997 study. In other words, a process for updating the Plan is required if the Plan is to remain relevant for conditions that now exist in the Basin. The initiation of such an updating process is the purpose of this study which began on July 1, 2001.

Our placement of emphasis on *process* is especially important for any discussion of a water plan for the Flint River Basin. This is because many if not most of the uncertainties to which reference is made above will not be resolved any time soon. The EPD's ongoing research programs aimed at improving our understanding of water supply and water use conditions will not be completed for another three years or so. Even after the completion of these studies, we can and *should* expect that many uncertainties will remain. These considerations result in our need for a basin water planning process that may be somewhat unique in the following interrelated ways. First, any discussion of designs for policy alternatives must be couched in terms of what is referred to in the decision sciences as *decision-making under uncertainty*. Second, and following from the first consideration, a premium is placed on policy alternatives that maintains flexibility — policies than can be relatively easily adapted to changes in the Basin as such changes become realized.

Ultimately, our Basin Water Plan will be organized in the following manner. Attention will be first focused on water supplies in the basin: surface water (section II) and ground water (section III). Water demands will be considered next: municipal and industrial demands (section IV), agricultural demands (section V), and ecological/environmental demands (section VI).

Plan 1997, (Atlanta: 1997).

Efforts to anticipate future policy problems in the Basin will be presented in section VII. Alternative strategies for policy designs that might address these problems will be discussed in section VIII.

Phase I of this work, which took place over the period July 1, 2001-June 3-, 2002, focuses on the water supply aspects of the Plan. Thus, drafts for sections I, II, and III (described above) are reported here. Phase II of the work, which will take place over the period July 1, 2002-June 30, 2002, will focus on water demand aspects of the plan.

II. Water Supplies In The Flint River Basin -- Surface Water

Estimates for monthly virgin flows in the Flint River for a 54 period of record are given in the Appendix. Unfortunately, these estimates -- the best information about surface water supplies in the Flint that exists to date --are flawed in a number of ways due to the estimation methods used, and to the lack of relevant data.[2] In what follows we describe the nature of these estimation methods and the resulting biases.

II.A Virgin Flows in the Flint River.[3] Concern in this section is with the volume of surface water that is available for all uses in the Flint River Basin. We refer to this volume as the "virgin flow" in the river. It is the volume of water that would be flowing in the river in the absence of human uses, and human obstructions in cases where dams have been built on the river. Virgin flow, as used here, is referred to in other contexts as "unimpaired flow," "unregulated flow," and "natural flow." The source of virgin flow is rainfall in the Basin, that makes its way to the river via natural drainage, and groundwater discharge into the river.

For our purposes, it is important to understand that virgin flow does not derive from observations — from readings of river gages, for example. Available virgin flow measures are *estimates*. The reasons that we can only estimate virgin flow are straightforward. We have no measures of river flows before the initiation of human uses of water. Thus, we can observe,

[2] The draft study of water use in the ACF Basin, recently released by the Corps of Engineers, continues the flaws described below.

[3] The bulk of this section was prepared by Ms. Amy (Hyun Jung) Park, a graduate student in the joint Georgia State University-Georgia Institute of Technology Ph.D. program in Policy Studies.

measure *via* river gages, flows in the river ***after*** human uses have affected the flows. The basic nature of the estimation process for obtaining measures for virgin flow is then the following. Estimates are made for virgin flows with specific "reaches" of the river. A "reach" is that part of the river basin that lies between two river gages (or in the case of the most upstream gage, between the headwaters of the river and the first gage).

* At any given river gage, take the difference, D, between the flow measured at the nearest upstream gage and the river gage in question. This measure, D, represents this reach's "contribution" to virgin flow *net* of human uses.

* Add to the number D all net withdrawals of water (diversions minus return flows) from the river by municipal, industrial, and agricultural water users.

* Subtract from D any discharges to the river of water obtained by water users from sources unrelated to the Flint River (e.g., municipal discharges of treated waste water when water is obtained from ground water sources that are not tributary to the Flint River).

This estimation process may be deceptively simple. This would be the case if there existed reliable, accurate measures for net withdrawals and discharges to(from) the river. In the case of municipal users and, to a lesser extent, industrial users this is pretty much the case: reasonably accurate measures exist for municipal withdrawals and discharges to the river. Reasonably accurate measures exist for industrial diversions of river waters; the availability and accuracy of industrial discharges may be more problematic.

However, the major weakness of existing estimates for virgin flow in the Flint River Basin derive from estimates for net depletions of river water in the agricultural sector. In principle, such depletions are calculated in a straightforward manner. For any period of time — a day, a month, or a year, for our purposes let us focus on a monthly measure:

1. the number of acres in all crops grown in the Basin that are irrigated during each month from surface (AS) or ground water (AG) sources would be recorded.

2. for each acre defined in (1), the amount of water (ws for acres irrigated with surface water, wg for acres irrigated with ground water) needed for irrigation during each month would be determined.
3. for ground water that must be pumped, any affects of such pumping on ground water discharges to the river — and therefore effects on river flows — would be calculated for each month. Such effects would be determined by, among other things, the volume of ground water pumped. These effects are then defined as f(AGwg).

4. return flows from water applied to irrigation from both surface (rs) and ground water (rg) sources would be calculated.

With these four sets of data, the adjustment (the addition) to D defined above to account for effects on river flows from agricultural water use (DG) would be obtained from the "simple" calculation:

$$DG = ASws - rs + f(AGwg) - rg$$

Of course, it turns out that the calculation of DG is not "simple." This is because of the present dearth of information available concerning *all* of the variables required for the calculation. In what follows we discuss each of these variables, how they are presently estimated for purposes of estimating virgin flow in the Flint River, and the biases in virgin flow measures that result from the process of estimating values for the variables.

II.B. Irrigated Acres: AS and AG. Unfortunately, there exists no reliable record for the number of irrigated acres in the Flint River Basin. It is known that substantial acreage under irrigation began in the late 1960s-early 1970s, but irrigated acreage was not included in the USDA's annually reported agricultural statistics until the mid-1990s (and irrigated acreage by county and by crop is *still* not reported). The EPD's water use permit files are of little help in these regards for several reasons. First, water use permits in the agricultural sector were not required until the late 1980s. Second, the accuracy of irrigated acreage reported on permit applications is problematic. Third, until only recently (beginning in the year 2000) EPD records did not identify sources of water — perennial or non-perennial streams — for surface water permits. And finally, since the Georgia Code does not allow for the forfeiture of agricultural water use permits for non-use,[4] the number of permits that are or have been used in any year — therefore total acreage under irrigation — cannot be determined.

Thus, permitted acreage for irrigation from ground water is on the order of 425,000 acres (from the Floridian aquifer); from surface water the total acreage is on the order of 200,000. The Comprehensive Study estimates that half of the acreage with surface water permits obtain water from ponds, non-perrenial streams, and other sources that do not affect flows in the Flint river. In the recent, 2002, Acreage Reduction Auction conducted by the EPD, acreage "elgible" for participation in the auction (land is actually irrigated from surface water, excluding surface water taken from non-perennial streams) totaled some 114,000, about 57% of total permitted acreage from surface water. However, we presently have no idea as to the proportion of the 425,000 permitted ground water acreage that is actually irrigated, and the EPD has yet to complete its audit of surface water permits. We must then say that at this point in time there exists no basis for estimating the actual number of acres that are in fact being irrigated in any year.

Virgin flow estimates given in the Appendix are based on estimated total permitted acreage in 1970, 1980, 1990, and 1995. Acreage for intermediate years are interpolated assuming linear growth from the beginning to the end of a decade. Setting aside possible — probable — biases resulting from this method of interpolation, the assumption that all permitted acreage is in fact under irrigation must be viewed as resulting in overestimates of actual irrigated

[4] Provisions for the forfeiture of municipal and industrial water use permits for non-use are quite stringent vis-a-vis such provisions in other states: the permit is forfeited for non-use over two consecutive years.

acreage, and thus to overestimates of virgin flow.

II.C Water use coefficients: ws and wg.[5] There have been a number of studies that have attempted to generalize a water use measure by averaging water use across regions in Southwest Georgia. In virtually all instances, these measures of water use are biased by inadequate consideration of one or more of the critically important determinants of water use. An example of *one* of these issues is exemplified by data given below in Table 1. We presently have at least three distinct estimates for agricultural water use in the Flint Basin, each of which average across such things as crops, water sources, etc.. Most importantly, all but one effectively ignores the hydrological cycle. Thus, as a part of Georgia, Florida, and Alabama's "Comprehensive Study" of water use in the ACF basin, estimates for agricultural water use in the Flint River Basin are provided.[6] The most striking limitation of these estimates — .6 acre feet/acre, 7.2 inches, as an average level of water use -- derives from the fact that they apply solely to "average" hydrological years -- it applies to years in which we are suffering neither relatively wet nor relatively dry conditions.

Consider irrigation in, for example, Americus, Georgia, located in Sumpter County in the heart of the Flint River Basin. Average rainfall over the 64-year period 1931-1995 at the Americus rain gage station during the months March-October was 32.6 inches. Differences in microclimates are made manifest by comparing monthly rainfall in Americus, during the 2000

[5] This section is taken directly from R. Cummings, N. Norton, and V. Norton, "What *Is* The Magnitude Of Agricultural Water Use In Southwest Georgia?" Working Paper, June 2002, Water Policy Center (Georgia State Univ. Or Albany State University).

[6] See statistical appendix to the agricultural report at Table 5: "expected future" water use in the Upper, Middle, and Lower Flint, year 2000: 635,500 acres using 344.2 mgd of water.

growing season, with rainfall in nearby Plains, Georgia. Note particularly the differences in rainfall during the critical month of June: 4.2" in Americus, only 1.2" in Plains which is only some 20 miles to the west.

Table 1

Rainfall And Irrigation Water Use: Examples

	- - - - -Average monthly rainfall during month:- - - - -									Comp	USGS
Period	March	April	May	June	July	Aug	Sept	Oct	Total	Study	Study[7]
	(...inches...)										
Americus Rain Gage											
1931-1995:[8]	5.2	3.9	3.4	4.4	6.1	4.3	3.1	2.2	32.6	7.2	
1996	6.4	4.8	5.0	4.7	4.7	2.5	3.0	2.0	33.1		8.8
1991	8.4	4.3	8.7	5.4	7.0	4.2	0.5	0.9	39.4		
1954	2.4	1.9	1.6	5.5	1.8	2.9	1.4	0.3	20.8		
1986	3.4	0.4	1.8	1.3	3.0	6.5	3.5	1.8	21.7		
2000	6.5	1.6	0.07	4.2	2.2	3.1	4.9	0.2	22.8		
Plains, GA Rain Gage											
2000	6.4	1.4	0.34	1.2	3.7	4.5	1.9	0.5	19.9		
Crop Needs[9]											
Weighted av, all crops	.5	.7	2.1	4.4	7.6	7.4	4.1	3.7	30.4		
Corn	.5	3.4	7.4	9.3	6.9				27.5		
Cotton		.1	1.0	3.5	8.6	7.1	4.3		24.6		
Peanuts		.1	1.0	3.4	7.2	7.8	3.1		22.6		

A weighted average of estimated crop water needs during the growing season for major

[7] Fanning, et. al., *Ibid* at Table 7 at p. 18.

[8] Rain gage for Americus, GA: station 3 SW. Data reported here and below are taken the National Weather Service web pages at (http://www.ncdc.noaa.gov/pub/data/coop-precip/georgia.txt).

[9] "Examples of Weekly Water Use For Selected Crops," *Op. Cit*. no date.

crops grown in this area prepared by the Georgia Extension Service is approximately 30 inches;[10] a good part of these water needs occurs during June, July, and August. The Comprehensive Study then seem to suggest that with average rainfall of 32.6 inches distributed over the March-October period in an "average" way, the requisite 30 inches of water needed by crops is satisfied with irrigation applications of 7.2 inches. In other words, due to such things as differences

between the intra-seasonal distribution of rainfall and crop needs, the average 32.6 inches in rainfall provides for about 76% of the 30 inches required by the crops.

[10] "Examples of Weekly Water Use For Selected Crops," mimeo, provided to the authors by the Georgia Farm Bureau, prepared (according to the Farm Bureau) by the UGA Extension service as a guide for irrigation requirements in Southwest Georgia, no date.

Before moving to the key question: suppose it isn't an "average year," we have a second estimate for agricultural water use in the Basin provided by a recently published study sponsored by the U.S. Geological Survey.[11] This study, which does not appear to give explicit consideration to climatic conditions, estimates irrigation applications for corn, cotton, peanuts, pecans, turf, and "other" crops, to average 8.8 inches *for the year 1996.* Looking at data given in Table 1 above, 1996 does not appear to differ in any significant way from an "average" year -- the seasonal total amount of water is slightly higher than the average, but rainfall during July and August was lower than the average. We are unable to explain the 22% difference in estimated irrigation requirements in the USGS and Comprehensive Study, but in either case we appear to be roughly talking about *average* hydrologic years (as reflected by rainfall). These two studies suggest that in average years irrigation is required to make up some 30% to 35% of the crops' water needs. What might this imply for a <u>*non*</u>-average year? We simply do not have data that would allow us to assess irrigation applications during a wet year, like 1991. In terms of dry years, consider rainfall at the Americus, and Plains, Georgia rain gages during three of the drier years of record: 1954, 1986, and 2000, given above in Table 1. Three observations are important for our purposes. First, problems of comparing inter-annual rainfall measures are immediately obvious from these data. Looking at either the Americus or Plains gage data, it is obvious that two years can have similar *seasonal* totals (e.g., at the Americus gage: 21.7" in '86; 20.8" in '54), but the *intra*-annual distribution of the total can have significant implications for irrigation needs of crops (for the same gage and years: for June, 1.3 inches in '86, 5.5 inches in '54).

[11] Fanning, et. al., "A Field and Statistical Modeling Study to Estimate Irrigation Water Use At Benchmark Farms Study Sites in Southwestern Georgia, 1995-1996," USGS Water-Resources Investigations Report 00-4292, Atlanta, GA, 2001,

Second, as noted above, rainfall can be very different at locations in close proximity to each other — compare monthly rainfall at the two gages for the year 2000. Third, and finally, using data at the Americus gage for the three dry years '54, '86, and '00, and assuming that rainfall is 70% effective in meeting crop needs, a seasonal water deficit for "all crops" would be between 14.4 inches and 15.8 inches. Unfortunately, neither of the studies examined above provide data that would allow insights as to the extent that irrigation in fact made up these deficits.

An estimate for irrigation applications over a 12-month period that includes the first seven months of a dry year — indeed, the driest year on record: 2000 — is available from an ongoing agricultural water use study conducted by the AES. Their (admittedly tentative, unrefined, draft) estimate for irrigation applications in the Flint River Basin during this 12 month period, August 1, 1999 through July 31, 2000, is an average of 12 inches per acre.

However, when we look closely at 2000 data, a number of questions arise concerning this estimate. Compare seasonal rainfall during 2000 in Americus, Georgia with seasonal crop needs for "all crops" given in Table 1. If rainfall is roughly 70% effective in meeting crop water needs, the 16 inches of "effective" rainfall reported at the Americus gage for the march-October period plus an average of 12 inches in irrigation — totaling 28 inches — would come close to meeting seasonal crop needs: 30.4 inches.

However, a closer examination of the AES data raises serious questions as to the reliability of the 12 inch estimate for agricultural use of irrigation waters during a severe drought. This is particularly the case when AES data for individual farm parcels are examined. As an example, for corn the AES reports irrigation during the month of May, 2000, for 34 individual parcels (Table 2). As can be seen from Table 1 above, there was hardly any rain during the month of May. With corn requiring (on average) 7.4 inches of water during May, it is difficult to understand why irrigation is reported as being *less than half* of this amount for 14 of the 34 parcels (41%). Indeed, irrigation of only 2 inches or less are reported for 8 parcels; *zero*

Table 2
AES Irrigation Applications For Corn:

Individual farm parcels during May, 2000

Parcel ID	Irr. Amt. (inches)	Parcel ID	Irr. Amt. (inches)	Parcel ID	Irr. Amt. (inches)	Parcel ID	Irr. Amt. (inches)
1	6.4	25	4.5	46	2.8	60	2.6
2	6.0	25	7.7	47	2.0	61	1.3
7	3.7	31	3.6	48	1.8	63	2.9
8	0.3	32	3.8	51	10.5	65	3.6
10	8.0	35	1.8	52	6.1		
12	9.1	38	5.3	53	3.3		
16	6.9	39	9.7	54	0		
19	2.3	40	7.1	56	1.8		
20	3.9	41	0	58	4.1		
21	6.5	45	9.0	59	3.3		

irrigation is reported for two parcels.[12]

Considering during corn's five-month water needs during the irrigation season, March through July, rainfall during these months reported at the Plaines, GA, rain gage[13] (these data are given above in Table 1), and monthly irrigation for all parcels included in the AES report for the months of March-July, 2000, the implied water deficits are calculated assuming rainfall as being 100% effective in providing crop needs, and as being 70% effective, and reported below in Table 3. Examination of the data in Table 3 makes clear the basis for our concern with the AES data as

Table 3
Water Deficits For Corn Implied By AES Reports Of

[12] Dr. Hook, with the AES, specifically states that "zero amounts (for irrigation amounts, inches) are valid values of applied irrigation, not missing observations." Email message from Dr. Hook to Mr. Nolton Johnson, Environmental Protection Division, September 15, 2000.

[13] Rainfall in May, 2000 was greater at the Plains gage than at the Americus gage. See Table 1

Irrigation By Individual Farm Parcels: March-July, 2000

Month	#Parcels*	Irrigation (inches)	Water Needs (inches)	Rainfall (inches)	.7Rainfall (inches)	Deficit Rainfall (inches)	Deficit .7Rainfall (inches)
March	27	0.8	0.5	6.4	4.5	-6.7	-4.8
April	31	1.5	3.4	1.4	1.0	0.5	0.9
May	34	4.5	7.4	0.3	0.2	2.6	2.7
June	36	4.8	9.3	1.2	0.8	3.3	3.7
July	36	0.8	6.9	3.7	2.6	2.4	3.5

Source: data made available by the AES, August, 2000.
* The number of months for which irrigation is reported varies from parcel to parcel. Thus, for example, the 36 parcels for which irrigation is reported for June is not the same 36 parcels for which irrigation is reported for July.

a source for a reliable estimate for water use. Referring to data given in Table 3, even if rainfall was 100% effective in satisfying crop needs, a water deficit of between 30% to 40% of crop water needs is implied for the critical months of May, June, and July.

Of course, these anomalies may be explained by any number of factors. As but one example, reports of small irrigation applications may apply to farmers irrigating from non-perennial streams that dried up during the summer of 2000. We can only speculate as to possible explanations until the AES report is made public. Until analyses of conditions underlying these reports of irrigation application, however, the reliability of any conclusions regarding agricultural water use in the Flint River Basin must remain as an open question.

In summary, our present knowledge of agricultural water use in Southwest Georgia is presently limited to what appear to be reasonable estimates of such use during "average" years provided by the Comprehensive Study and the recent U.S. Geological Survey studies: on the order of 7 inches per acre. Unfortunately, this measure is of very limited use for water resources planning and policy design in this region. Water scarcity — the basis for concern with planning and policy design — is not a critical problem during average years. The region's problems arise during drought years.

The AES study includes observations on agricultural water use during one of Georgia's most severe droughts — summer 2000. Unfortunately, data made available to the authors leave them little choice but to reject their acceptance as credible measures of water use at this point in time. The rationale for this conclusion is obvious from data given in Tables 2 and 3. Referring again to corn, the 26 parcels for which irrigation is reported for all of the months March-July yield an average measure of water use of 11.6 inches. However, this average is drawn from individual observations ranging from 0.4 inches (for the <u>entire</u> five-month irrigation season, which includes one month, May, in which rainfall was virtually zero) to as much as 23.2 inches. The standard error associated with this average measure is 5.9 inches, implying that the "true" average measure for irrigation applications during summer 2000 (at a 95% confidence level) lies between 0 inches and 23.4 inches. Hopefully, later reports from the AES will provide some basis for more reliable measures for water use during drought periods. Until that time, or until other measures are developed, we remain ignorant as to agricultural water use during critically important periods of drought.

Received estimates for virgin flows in the Flint (Appendix) are calculated using the Comprehensive Study's estimate for water use in an "average" year — about 7 inches. It then follows that virgin flow estimates are <u>over</u>estimated for "wet" years (with water use only some 4 inches, too much water is "added in" to the virgin flow calculation), and underestimated for dry years (with water use at some 12 to 18 inches, too little water is "added in" to the virgin flow calculation).

II.D Agricultural return flows: rs, rg. There is little more that can be said about agricultural return flows other than the simple fact that little or nothing is known about them. Indeed, for analyses of agricultural water use by the States of Georgia, Alabama, and Florida during the 10-plus years that they have been negotiating a compact on the ACF Basin, agricultural return flows are *assumed* to be zero. Similarly, in the State's calculation of virgin flows in the Flint River rs and rg are assumed to be zero.

It is surely the case that agricultural return flows are *not* zero. Received estimates of virgin flows in the Flint are accordingly underestimated. However, there presently exists no basis for estimating them.

II.E River effects from ground water use: f(AGwg). The U.S. Geological Survey has developed a hydrological model of the Floridian aquifer in the Flint River Basin. Setting aside criticisms of the accuracy of this model, the model predicts that the continuous pumping of one acre foot of water from the aquifer will reduce ground water discharge into the Flint River by .6 acre feet. Of course, irrigation does not involve continuous pumping: pumping is intermittent throughout the summer season. Georgia water planners are ignorant of the effect on ground water discharge to the Flint of intermittent pumping. They're quite sure it isn't .6 a.f. per a.f. pumped; they think it unlikely that it is zero. Therefore, a mid-point is used. It is *assumed* that each acre foot of ground water (from the Floridian aquifer) reduces discharge to the Flint River by .3 a.f.. The river effects of pumping are assumed to be lagged in time: 70% of the reduction takes place in the month that pumping takes place, 30% in the following month. The spatial distribution of such effects (i.e., at what points along the Flint the reductions in discharge occur) is *assumed to be* *independent* of where the pumping takes place. Thus, effects on discharge above the Albany gage is the same when pumping takes place at locations upstream from Albany as when it takes place below downstream from Albany, for example, around Bainbridge.

Unlike the case with parameters discussed above, we are unable to define the direction of bias in estimates of virgin flows that might be associated with this crude estimate for pumping effects on ground water discharge to the Flint. Given the heavy concentration of ground water use in the more southerly areas of the Basin, it appears to us likely that effects measured at Albany and Newton are overestimated. But in terms of the gross measure of virgin flows given in the Appendix, we are unable to comment on how such measures may be biased by this process.

II.F The Reliability of estimates for virgin flow in the Flint River: Summary. Given the manner in which virgin flow estimates for the Flint River (given in Appendix) are calculated, biases in the measures are summarized in Table .

Table
Summary of Biases in Estimates for Virgin Flow

Estimate	Effect of Virgin Flow
Estimates for irrigated acreage	overestimates
Estimates for water use/acre	overestimates in wet years; underestimates in dry years
Estimates for return flows	overestimates
Estimates for pumping effects on the River	??

Notwithstanding our total ignorance of the direction of biases associated with the method used for calculating pumping effects on the River, we suggest that it seems clear that virgin flow numbers given in the appendix are overestimated in “normal,” or average years as well as in “wet” years. We are unable to weigh the opposing biases in drought years, and are therefore unable to speculate as to the net direction in biases for these data.

III. Water Supplies In The Flint River Basin — Ground Water[14]

A 21 -county, intensely farmed area in southwestern Georgia was selected for the purpose of delineating the distribution of permitted irrigation water use, and evaluating the availability of irrigation water from the area aquifers and streams. Prior to 1970, very little cropland was irrigated within this region; however, between 1970 and 1971 irrigated cropland increased by 60 percent, and from 1976 through the fall of 1977, irrigated cropland increased almost 100 percent. At the present time, more water is withdrawn for agricultural irrigation in

[14] The bulk of this section is taken directly from a draft report prepared by Mr. David W. Hicks, “Distribution of Permitted Agricultural Water Use and Water Availability in the Flint River Basin, Southwest Georgia” (Paul B. Krebs & Associates, Inc., Albany GA, 2001). The author acknowledges Dr. Ronald Cummings, Georgia State University, for his financial commitment to this project, and to Mr. Jerry Usry, Executive Director of the Flint River Water Policy and Planning Center, Albany State University, for his continued support. Special thanks is given to Mr. Napoleon Caldwell, Georgia Department of Natural Resources, Environmental Protection Division, for providing water permitting data which were critical to the completion of this project. Appreciation is also extended to Mr. Derek Fussel, Georgia Department of Natural Resources, who assisted in the development of the GIS database.

southwestern Georgia than in any other part of the state.

Because of the dynamic connection between many of the area streams and aquifers, that are heavily used for irrigation supplies, the Georgia Department of Natural Resources, Environmental Protection Division (EPD), invoked a moratorium on additional development of specific groundwater and surface-water resources within the Flint River watershed until 2005, when ongoing studies are scheduled for completion. As a means to protect stream flows during periods of severe drought, the Georgia General Assembly enacted the Flint River Drought Protection Act during the 2000-2001 legislative session. Although most of the large-volume irrigation sources are included in the EPD moratorium, less used groundwater supplies in specific parts of the Flint River watershed were excluded.

The purpose of this section is to expand understanding of irrigation water use in southwestern Georgia and to identify under-utilized groundwater supplies. To these ends, we describe the distribution of permitted irrigation withdrawals from groundwater and surface-water sources by county and by subwatershed in the middle and lower Flint River Basins. It describes the GIS database. The lithologic character, thickness, potential yield, and areal extent of the area aquifers are discussed. The permitted withdrawal rate is compared to the median monthly streamflow from each subwatershed. Areas where direct surface-water withdrawal from perennial streams may be supplemented or replaced by groundwater supplies are identified. Information was obtained on more than 6,000 irrigation water use permits from the 1999, 2000, and 2001 EPD files. Geologic, hydrologic, and geophysical data from more than 200 wells were analyzed in this study. These data were primarily obtained from the files of the United States Geological Survey (USGS), Georgia District Office. Although not tabulated in this report, these data are on file and available for review at the USGS District Office in Atlanta, Georgia.

An Arc View GIS database was developed to store, analyze, and display data pertinent to permitted irrigation water use from the aquifers and streams in the region. Irrigation from ponds was not included in the GIS database because of questionable validity of the data. However, an analysis of permitted pond-supplied irrigation was included in the county summaries, but pond data were not included in the stream sub-basin analyses.

Streamflow statistics were developed using data obtained from the USGS where continuous streamflow and stage data are collected from many of the area streams in cooperation with various federal, state, and local agencies, and research organizations. Median monthly flows were graphically calculated and correlated with the maximum computed surface-water withdrawal rate based on the 2000 EPD permit data for each of the sub watersheds.

III.A Geographic Setting. The study area includes all, or parts of Marion, Schley, Stewart, Webster, Sumter, Dooly, Crisp, Lee, Terrell, Randolph, Calhoun, Dougherty, Worth, Turner, Mitchell, Baker, Early, Miller, Seminole, Decatur, and Grady Counties in southwestern Georgia. The 21-county area is located in the Dougherty Plain district, the western part of the Tifton Upland district, and the southern part of the Fall Line Hills district of the Coastal Plain physiographic province.[15] The crest of the Solution Escarpment forms the topographic high and surface-water divide between the Flint River Basin and the Suwannee and Ochlochnee Basins to the east.

The Flint River and its tributary streams drain the 21-county study area. Together, they form five subwatersheds within the study area: (1) middle Flint River; (2) Kinchafoonee and

[15] Clark, W. Z., Jr., and Zisa, A. C, 1976, Physiographic map of Georgia: Georgia Dept. of Natural Resources, Geologic and Water Resources Div., 1:2,000,000.

Muckalee Creeks; (3) Ichawaynochaway Creek; (4) Spring Creek; and (5) lower Flint River.

The Dougherty Plain is an inner lowland (cuesta) that was formed by the stripping away of sediments and by solution of the underlying carbonate sediments. It is bounded on the west by the Chattahoochee River, the north and northwest by the Fall Line Hills, and on the east by the crest of the Solution Escarpment on the western limb of the Pelham Escarpment. The Dougherty Plain is nearly level and relief seldom exceeds 20 ft. It is characterized by karst topography that is marked by numerous shallow, flat-bottomed or rounded sinkholes. Many of the depressions are filled with low-permeability material and hold water much of the year.

Active solution in the Dougherty Plain has transferred most of the drainage from the surface to underground channels. Only the larger streams are perenial. The major surface streams are the Flint River and its primary tributaries: Muckalee, Kinchafoonee, Fowltown, Chickasawhatchee, Kiokee, and Cooleewahee Creeks which enter the Flint River from the western part of the Dougherty Plain. Only Fowltown, Kiokee, and Cooleewahee Creeks originate within the Dougherty Plain, and because of their limited drainage basins and the internal drainage characteristics of this region, they often cease to flow during periods of minor drought.

Abrams, Mill, Piney Woods, Dry, and Raccoon Creeks drain the northeastern and eastern parts of the Dougherty Plain. These streams generally flow westward to the Flint River. Because of the karst nature of the landscape in the Dougherty Plain and the Solution Escarpment areas on the eastern side of the Flint River, these streams also cease to flow during periods of minor drought when reduced precipitation drains to the subsurface and overland runoff is limited. Runoff from these streams seldom discharges into the Flint River, but disappears into wetlands at the base of the Solution Escarpment.

The Fall Line Hills is characterized by a gently rolling landscape with relatively flat interstream divides and steeply dipping valley walls. The relief, combined with the easily eroded, sandy soils of this district, have resulted in the development of a somewhat dendritic drainage landscape. This district is highly dissected by streams and has little level land, which is primarily limited to the interstream divides. The boundary between the Dougherty Plain and the Fall Line Hills districts is marked by the 250-foot contour line on topographic maps.[16] The northeastern part of the Fall Line Hills is separated from the Tifton Upland district by the northern extension of the Pelham Escarpment on the eastern side of the Flint River. Pachitla, Spring, Ichawaynochaway, and Chickasawhatchee Creeks are tributary to the lower Flint River basin and drain this area. These streams originate in the Fall Line Hills district as springs or seeps that emerge from the permeable parts of the Lisbon Formation or the Tallahatta Formation of middle Eocene age.

Although the western part of the Tifton Upland district is within the Flint River Drought Protection Area, the streams are not tributary to the Flint River. The crest of the Solution Escarpment forms the topographic and surface-water divide between the Flint River Basin and the Ochlockonee and Withlacoochee River Basins to the east. Several ephemeral streams carry surface runoff westward down the slopes of the Solution Escarpment and go underground in swampy areas after traveling a short distance across the Dougherty Plain. In the western part of the Tifton Upland district, streams generally emerge from swampy areas near the crest of the Solution Escarpment and drain to the south and southeast through Little and Ochlochonee

[16]Clark, W. Z., Jr., and Zisa, A. C, 1976, Physiographic map of Georgia: Georgia Dept. of Natural Resources, Geologic and Water Resources Div., 1:2,000,000.

Rivers.

III.B Geololgy. The Coastal Plain physiographic province, of which the study area is a part, extends from the Fall Line at its northernmost edge toward the southeast. Sedimentary rocks, dipping gently to the southeast, underlie the Coastal Plain. The oldest exposed sediments of Late Cretaceous to early Tertiary age are composed of sand, clay, and gravel, and occur in a band just south of the Fall Line. These sediments are overlain by sand and limestone of Paleocene, early Eocene, and middle Eocene ages. The next younger deposits are carbonate rocks, primarily limestone, of late Eocene and Oligocene age.[17] The sediments of the Coastal Plain extend to a depth of at least 5,000 ft and dip to the southeast by as much as 25 ft/mi in the study area, and progressively thicken in that direction (Hicks, et al, 1981).[18]

The sedimentary units show lateral variations in lithology and thickness that represent changing environments throughout the depositional history of the area. Transgressions and regressions of the sea caused the depositional environment at any given locality to change from one depositional cycle to the next. Where changes in sea level were rapid, a transitional sequence may be missing from the sedimentary record.

This section provides a general overview of the geologic sequences present in this part of the Georgia Coastal Plain and of hydrologic importance to this study. The reader is referred to

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[17] Pollard, L. D., Grantham, R. G., and Blanchard, H. E., Jr., 1978, A preliminary appraisal of the impact of agriculture on ground-water availability in southwest Georgia,: U.S. Geological Survey Water-Resources Investigation 79-7, 21 p.

[18] Hicks, D. W., Krause, R. E., and Clarke, J. S., 1981, Geohydrology of the Albany area, Georgia, Georgia Geol. Survey Info. Circ. 57, 31 p.

the referenced literature, herein cited, for a more in-depth and detailed description of the geology of this region.

III.B.1 Stratigraphy: Upper Cretaceous Series. The Upper Cretaceous Series can be divided into six formations within the study area. From youngest to oldest they are: the Tuscaloosa, Eutaw, and Blufftown Formations, the Cusseta Sand, the Ripley Formation, and the Providence Sand. Only a discussion of the Providence Sand is included in this report. At the type locality at Providence Canyon, Stewart County, the Providence is about 85 ft thick and is divided into two members: the lower Perote Member and an upper unnamed sand member.[19] The basal, Perote Member, consists of dark-gray, highly micaceous, carbonaceous silt or very-fine sand. The upper sand member consists primarily of medium to coarse, silty sand. South and east of the outcrop area, the upper member is a massively bedded marine sand locally containing layers of carbonate material. Downdip near Albany, the basal unit of the Providence consists of a slightly dolomitic coquina that grades upward into a fossiliferous siltstone. The upper part of the Providence is a very fine- to coarse-grained calcareous, clayey, micaceous sandstone.

The thickness of the Providence is fairly uniform in the study area, increasing only slightly downdip to the southeast where it attains a maximum of thickness of about 100 ft.[20]

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[19] Clarke, John S, Faye, Robert E., and Brooks, Rebekah, 1984, Hydrogeology of theClayton aquifer of southwest Georgia: Georgia Geol. Survey Hydrologic Atlas 13, six plates.

[20] Hicks, D. W., Krause, R. E., and Clarke, J. S., 1981, Geohydrology of the Albany area, Georgia, Georgia Geol. Survey Info. Circ. 57, 31 p.

III.B.2 Clayton Formation. The Clayton Formation of the Midway Group, unconformably overlies the Providence Sand. Clarke, et al, 1984, areally divided the Clayton Formation into three separate lithologic units: (1) a clastic province in Quitman, northwestern Randolph, southeastern Stewart, northwestern Webster, northern Schley, and parts of Macon Counties in which the principal sediments are sand and clay; (2) a carbonate province where the principal sediments are limestone and calcareous sand extending south throughout most of the study area; and (3) a transitional province that occurs between the clastic and carbonate provinces and contains sedimentary elements common to both areas.[21] Throughout most of the carbonate province, the Clayton Formation can be divided into three lithologic units. The lowermost unit is a fine to medium calcareous sand containing varying amount of silt and glauconite. The middle unit is a massive limestone composed of highly calcitized fossils in a recrystallized, slightly sandy limestone matrix that forms a tough, coherent rock. The upper unit consists of fine to medium, calcareous, quartz sand.[22]

The thickness of the Clayton Formation varies considerable throughout the study area. In the northern part of the area the formation averages about 100-ft thick, however, in southern Sumter County the formation attains a maximum thickness of about 25 ft. In southeastern Terrell and western Lee Counties, the limestone part of the Clayton Formation is about 125-ft thick, but progressively thins downdip toward Albany where it is about 70-ft thick.

III.B.3 Eocene SeriesEocene sediments of the Hatchetigbee, Tallahatta, and Lisbon sequence represent the entire Claibome Group and the upper part of the Wilcox Group, and

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[21] Clarke, John S, Faye, Robert E., and Brooks, Rebekah, 1984, Hydrogeology of theClayton aquifer of southwest Georgia: Georgia Geol. Survey Hydrologic Atlas 13, six plates.

[22] Hicks, D. W., Krause, R. E., and Clarke, J. S., 1981, Geohydrology of the Albany area, Georgia, Georgia Geol. Survey Info. Circ. 57, 31 p.

unconformably overlie the Paleocene sediments.[23] Like the Clayton Formation, the Eocene sediments exhibit areally different lithologic characteristics and can be informally divided into an updip clastic section, a downdip shallow marine sequence, and a deeper marine sequence.

The sediments are near land surface in much of Early, Calhoun, Terrell, Stewart, Sumter, and Dooly Counties. In this area the sediments of the Lisbon Formation are less easily eroded and are primarily limited to exposures on ridges and interstream areas. The Tallahatta Formation is a relatively thin bed of clean, well-sorted quartz sand. Its extent is also limited to the interstream areas. The Hatchetigbee Formation is characterized by a significant increase in clay and a decrease in permeability.

Downdip, where the shallow marine sequence is prevalent, the Eocene Series is very difficult to subdivide because it consists throughout of lithologically similar alternating layers of thin- to medium-bedded sands, sandy clays, and siltstones, all of which are highly glauconitic and commonly calcareous. The part of the Series most commonly used as an aquifer is the Tallahatta Formation that consists of sand, limestone, and coquina throughout much of this area.

South-southeast and west-northwest of Albany, Dougherty County, the permeability of the Eocene deposits are diminished by an increase in content of finegrained sediments. The sedimentary sequence present in the area to the south-southeast represents a deeper marine depositional environment. The limestone and coquina layers prevalent in the shallow marine sequence are replaced with green silt and shale in this downdip area.

The Eocene sediments range in thickness from less than 10 ft in the extreme northwestern Sumter County area, to more than 400 ft in Baker and Mitchell Counties. The sediments are

[23] *Ibid.*

continuous throughout much of the remainder of the Coastal Plain, but are difficult to map because of very sparse geologic data and the absence of any definite lithologic or faunal breaks. In the northeastern part of the study area in Dooly County, the Tallahatta Formation may be as much as 200-ft thick. The Tallahatta thins in the western part of the study area in Randolph, Calhoun, Clay, and Early Counties where the clay content increases and the permeability decreases.

III.B.4 Ocala Limestone and Clinchfield Sand. The Ocala Limestone of late Eocene age overlies the Lisbon Formation and the Clinchfield Sand where present. The Ocala Limestone thins in the study area and is not a mapable unit northwest of a line extending southwest to northeast from eastern Early County through Calhoun, Terrell, northwestern Lee, and southern Sumter Counties. Throughout much of the northern part of the study area, where present, the Ocala Limestone can be subdivided into lower, middle, and upper lithologic units. In southern Lee and eastern Terrell Counties, and northern Dougherty County, the lower unit, which generally is highly fractured, consists of alternating layers of sandy limestone and medium-brown, recrystallized dolomitic limestone. The lower unit has well-developed secondary permeability along solution enlarged joints, and fractures.[24] In the remainder of the study area south of Dougherty County, the Ocala is not clearly separated into different lithologic units, but more closely resembles the sediments and the permeability characteristics of the lower lithologic unit.

North of the Dougherty County area, the Ocala Limestone is underlain by the Clinchfield

[24] Hicks D. W., Gill, H. E., and Longsworth, S. A., 1987, Hydrogeology, chemical quality, and availability of ground water in the Upper Floridan aquifer, Albany area, Georgia, U. S. Geological Survey Water-Resources Investigations Report 87-4145, 52 p.

Sand. The Clinchfield generally consists of medium to coarse, fossiliferous, calcareous, quartz sand and sandstone. The Clinchfield Sand is an ancient beach deposit that attains a maximum thickness of about 35 ft northwest of Leesburg, Lee County, and is absent south of Albany.

III.B.5 Structural Alterations. Major structural features that affect the aquifers in the study area include: (1) the Andersonville Fault[25] in southern Schley,[26] northern Sumter, and western Dooly; (2) the Structural Belt in northern Terrell,[27] Sumter, and southwestern Dooly; and (3) the Gulf Trough[28] in Mitchell, Colquitt, lift, Irwin, and Ben Hill Counties.

[25] Zapp, A. D., 1943, Andersonvillle bauxite district, Georgia: U. S. Geological Survey Strategic Minerals Investigations Preliminary Map.

[26] Kellam, Madeleine F., and Gorday, Lee L., 1990, Hydrogeology of the Gulf Trough-Apalachicola Embayment area, Georgia, Georgia Geol. Survey Bull. 94,74 p.

[27] Owen, Vaux, Jr., 1958, Summary of ground-water resources of Lee County, Georgia: Georgia Geol. Survey Min. Newsletter, v. 11, no. 4, p. 118-121.

[28] Kellam, Madeleine F., and Gorday, Lee L., 1990, Hydrogeology of the Gulf Trough-Apalachicola Embayment area, Georgia, Georgia Geol. Survey Bull. 94,74 p. Vorhis, Robert C., 1972, Geohydrology of Sumter, Dooly, Pulaski, Lee, Crisp, and Wilcox Counties, Georgia, U. S. Geological Survey Hydrologic Investigations Atlas HA-435, two plates. Wait, R. L., 1960, Source and quality of ground water in southwestern Georgia: Georgia Geol. Survey Info. Circ. 18, 74 p.

The Andersonville Fault has primarily affected sediment continuity within the Clayton Formation. The fault trends east to west and is upthrown on the south side. The fault has been reported to be nearly vertical with a maximum sediment displacement of about 100 ft at the top of the Clayton Formation.[29] There are no data to suggest that the fault has affected other geologic formations in this area.

Owen[30] reported that layers within the Upper Cretaceous sediments (Providence Sand) and the Clayton Formation had dips that increased significantly within the area identified as the Structural Belt. He concluded that the increased dip may be the result of monoclinal flexure, a fault, or a series of faults in echelon. Clarke, et al.[31] reported the dip of the top of the Clayton limestone unit steepens from about 18 ft/mi north of the belt to about 66 ft/mi within the belt. The increase is less pronounced at the ends of the belt, where the dip diminished from about 66 ft/mi to about 33 ft/mi.

[29] Clarke, John S, Faye, Robert E., and Brooks, Rebekah, 1984, Hydrogeology of theClayton aquifer of southwest Georgia: Georgia Geol. Survey Hydrologic Atlas 13, six plates.

[30] Owen, Vaux, Jr., 1958, Summary of ground-water resources of Lee County, Georgia: Georgia Geol. Survey Min. Newsletter, v. 11, no. 4, p. 118-121.

[31] Clarke, John S, Faye, Robert E., and Brooks, Rebekah, 1984, Hydrogeology of theClayton aquifer of southwest Georgia: Georgia Geol. Survey Hydrologic Atlas 13, six plates.

The southwest to northeast trending Gulf Trough, or Apalachicola Embayment, has a very pronounced affect on the groundwater hydrology in the Tifton Uplands district east of the 21-county study area. However, the western extension of the structural feature extends into Mitchell, Colquitt, and Grady Counties in southwestern Georgia. The Gulf Trough is speculated to have originated as a graben that may have dropped as much as 700 ft at its deepest point.[32] The depressional feature that resulted from the faulting was later filled by marine sediments of significantly lower permeability than the surrounding sediments.[33]

III.C Hydrology. Water in the 21-county study area is obtained from the many streams that drain the area and from four groundwater reservoirs, or aquifers. From deepest to shallowest the aquifers are: the Providence, Clayton, Claiborne, Wilcox (where present), and Upper Floridan. Although groundwater is available from the deeper Cretaceous aquifers, high drilling costs, relatively low yields, and higher concentrations of dissolved solids and chloride in the area south of Albany, make development of these aquifers undesirable.

III.C.1 Aquifer Properties.

III.C.1(i) Providence Aquifer. The Providence aquifer receives recharge where it occurs near land surface along a northeast-trending line about 50 mi north-northeast of Albany, Dougherty County, primarily in Stewart, Webster, Marion, Schley, and Macon Counties. The aquifer is used primarily for municipal water supply from the Webster and Sumter Counties area

[32] Kellam, Madeleine F., and Gorday, Lee L., 1990, Hydrogeology of the Gulf Trough-Apalachicola Embayment area, Georgia, Georgia Geol. Survey Bull. 94,74 p.

[33] Zimmernian, E. A., 1977, Ground-water resources of Colquitt County, Georgia: U. S. Geological Survey Open-File Report 77-56, 41 p.

to Dougherty County in the south. It is not used as a water supply south of Dougherty County.

In the northwestern part of the study area, the Providence aquifer is tapped at a depth of about 250 ft below land surface. At Americus, Sumter County, the aquifer is tapped at a depth of about 370 ft. Downdip at Albany, Dougherty County, the Providence is tapped at depths ranging from 640 ft, in the northwestern part of the county, to 960 ft below land surface in the southeastern part of the county. Well yields from the Providence are highly variable and are dependent on the percentage of finegrained sediment within the formation. In the Dawson, Sasser, northwestern Albany area, yields of 500 gal/min have been reported from the Providence. Because it is usually tapped in conjunction with other aquifers in multi-aquifer wells, the performance of the Providence alone has not been tested in most areas. However, it is believed that the aquifer's hydraulic properties are similar in the southern Sumter, northern Lee and western Dooly County areas, thus, the potential aquifer yield should be comparable to that observed in the Dawson and Albany areas. Well yields of about 500 gal/min are possible from properly constructed screened wells.

III.C.1(ii) Clayton Aquifer. The Clayton aquifer is recharged in a relatively small outcrop area primarily in Quitman, Randolph, Stewart, Webster, Schley, and Marion Counties . Because of the relatively small outcrop area, water availability from the aquifer is somewhat limited. Heavy pumping from the Clayton aquifer for agricultural water use in the Randolph, Terrell, and Lee County areas, and heavy municipal and industrial pumping from the aquifer in the Dougherty County area, has resulted in large groundwater-level declines. Water levels in the Clayton aquifer have declined as much as 140 to 150 ft in the Albany area since the 1940's.[34] As

[34] Hicks D. W., Gill, H. E., and Longsworth, S. A., 1987, Hydrogeology, chemical quality, and availability of ground water in the Upper Floridan aquifer, Albany area, Georgia, U. S. Geological Survey Water-Resources

a result of the high volume of use and the resultant water-level declines, the Georgia EPD imposed development restrictions on the Clayton aquifer in the early 1990's.[35] These restrictions limited the use of the Clayton aquifer to the current permit holders, and new Clayton wells could only be drilled as replacement wells when an existing Clayton well failed.

III.C.1(iii) Eocene Aquifers. The Claiborne aquifer extends over much of the northern part of the 21-county study area. It is relatively thin in the areas where it is recharged in parts of Early, Calhoun, Randolph, Terrell, Sumter, and Dooly Counties, but progressively thickens in a downgradient direction to the east and southeast from the recharge areas. Although, the principal Eocene aquifer in the study area is the Claiborne, in parts of several of the northern counties, the Wilcox Sand is an additional source of water. In these areas, a properly constructed Claiborne-Wilcox well can produce a significant quantity of water.

Generally, the Claiborne aquifer progressively thins and becomes less productive in a west-northwesterly direction toward the recharge area. In the eastern Calhoun County, eastern Randolph County, central Terrell County, northwest Sumter County, and northwest Dooly County areas, the aquifer is very thin and generally is not capable of producing more than a few hundred gallons per minute. At Leary, the Claiborne aquifer is about 110-ft thick, but is only capable of producing about 150 to 250 gals/min. Thus, in this part of the study area, wells tapping the Claiborne aquifer do not produce an adequate water supply for irrigation directly, and must be pumped into storage ponds to be used for supplemental irrigation.

Investigations Report 87-4145, 52 p.

[35] Nolton Johnson, Georgia EPD, oral commun., 2001.

In the northern Baker and northeastern Mitchell County area, the Claiborne aquifer is practically unused because of the high yield and accessibility of Upper Floridan aquifer. However, a municipal supply well drilled in northern Baker County at Newton penetrated about 250 ft of Claiborne sediments. The well was completed in the Claiborne aquifer and tested at more than 300 gals/min.[36] Borehole geophysical data collected in this well indicate that a properly constructed, screened, gravel-packed well, in this area may produce yields in excess of 500 gals/min. However, additional hydrogeologic exploration and testing would be required before the yield and sustainability of the Claiborne aquifer could be evaluated in this area.

[36] Stevenson & Palmer Engineering, Inc., written commun., 1995

In Dougherty County, wells tapping the Claiborne aquifer typically can produce from 1,000 to 1,400 gals/min.[37] However, because of potentially large drawdown associated with screened, gravel-packed wells, a safe pumping rate of about 750 gals/min is generally maintained. Production supply wells constructed at Miller Brewery in Albany tap the Claiborne aquifer and are capable of producing more than 1,000 gals/min (USGS, unpublished data). Wells tapping the Claiborne are generally screened from a depth of about 125 to 350 ft below land surface. Additional water is obtained from the Wilcox Sand in several wells owned by the Albany Water, Gas, and Light Commission in the northwestern part of the city. In this area the Wilcox is at a depth of about 400 to 500 ft below land surface, and averages about 30 to 50 ft in thickness. When tapped in conjunction with the Claibome aquifer, properly constructed wells can safely produce more than 1,000 gals/min.

Wells tapping the Claiborne and Wilcox aquifers in northern Dougherty, Lee, southeastern Sumter, Crisp, northeastern Worth, and southern Dooly Counties should be capable of safely supplying 800 to 1,200 gals/min, if properly constructed. In this part of the study area, the sand, limestone, and coquina beds of the Claiborne and Wilcox aquifers are more than 200-ft thick. In Dooly County, at the City of Vienna Industrial Park, the Claiborne and Wilcox aquifers extend from a depth of about 190 to 410 ft below land surface (USGS, unpublished data). In this area the Claiborne and Wilcox aquifers may be capable of producing more than 1,200 gals/min. In the Lee County area near Smithville, a recently installed irrigation well tapped about 100 ft of the Claiborne aquifer, and 30 ft of the Wilcox aquifer. The completed well was reported to

[37] Hicks, D. W., Krause, R. E., and Clarke, J. S., 1981, Geohydrology of the Albany area, Georgia, Georgia Geol. Survey Info. Circ. 57, 31 p.

produce about 1,400 gals/min (Grady Thompson, Bishop Well Services, oral commun., 2001). It is in this six-county part of the study area that properly constructed and spaced wells tapping the Claiborne and Wilcox aquifers could be utilized as alternate irrigation water supplies. Additional hydrogeologic testing, and the installation of long-term groundwater-level monitoring wells would be required before additional development of this water resource should be pursued.

III.C.1(iv) Upper Fioridan Aquifer. In the Dougherty Plain district and adjacent areas of southwestern Georgia, the Upper Fioridan aquifer is used extensively for supplemental agricultural irrigation and as an essential source of municipal, industrial, and domestic water supplies. The Upper Fioridan thins to the northwest and generally thickens to the south and southeast. In western Early, Calhoun, Terrell, and Sumter Counties, and other counties to the northwest, the Upper Fioridan aquifer is not a viable water source. In the remainder of the study area, it is the chief source for large withdrawals and for natural springflows within, and adjacent to, many of the area streams.

The Upper Fioridan aquifer is the shallowest major groundwater reservoir in the 21-county study area, and is generally covered by only 20 to 80 ft of overburden.[38] It is preferentially recharged throughout the Dougherty Plain and the Solution Escarpment. Maximum recharge occurs from rainfall during the period December through March in areas where the overburden is thin and permeable. The myriad wetlands present in the karst landscape likely play a significant role in the recharge of the Upper Fioridan and in its sustainability.

The aquifer includes lithologic units of sand, clay, limestone, and dolomite of middle

[38] Hicks D. W., Gill, H. E., and Longsworth, S. A., 1987, Hydrogeology, chemical quality, and availability of ground water in the Upper Floridan aquifer, Albany area, Georgia, U. S. Geological Survey Water-Resources Investigations Report 87-4145, 52 p.

Eocene age and younger, that form, in ascending order, the Clinchfield Sand, the Ocala Limestone, and the Suwannee Limestone. The Upper Fioridan aquifer reaches a thickness of more than 400 ft in the southeastern part of the study area. In the northern part of the study area, mainly north of Dougherty County, the Upper Floridan aquifer consists of the Ocala Limestone and the Clinchfield Sand. The Clinchfield Sand is not present south of this area. In the eastern part of the area, in parts of Dooly, Crisp, Worth, and Mitchell Counties the aquifer consists of the Suwannee Limestone and the Ocala Limestone.

The ability of the Upper Floridan to store and transmit water to a well is controlled by the thickness and the hydraulic conductivity of the aquifer. Where the aquifer is thin, its capacity to store and transmit water is limited. The hydraulic conductivity, which is a measure of the ease with which water can move through the aquifer, varies significantly throughout the study area. Because of the high variability of each of these factors, there is a wide range of aquifer performance.

Because of well-developed secondary permeability, mainly in the lower part of the Ocala Limestone, in many areas the aquifer is capable of storing and transmitting large volumes of groundwater. In an area of southwestern Dougherty County where the aquifer exhibits extensively developed secondary permeability, an aquifer test was conducted where a single well produced more that 4,400 gals/min with insignificant drawdown. However, in the northwestern part of the study area, often times the aquifer barely will produce a sufficient supply of water for ancillary uses.

III.C.2 Streamflow. In southwestern Georgia, practically all streams originate as groundwater seeps or springs. Along their flow paths, stream flow is primarily sustained by precipitation for the principle part of the year; however, the stream flow is augmented by variable rates of groundwater inflow, which during historic low-flow periods of the year can account for a substantial part of the total stream flow. Typically, rates of groundwater discharge to streams are at a maximum during late winter and spring when the aquifer systems are generally fully recharged and groundwater levels are at their annual highs. However, the rates of groundwater discharge are progressively diminished through the spring and summer months as regional groundwater levels decline in response to increased pumping stresses on the aquifers. During late summer and fall, when precipitation historically is sparse, the base flow of many streams is maintained almost solely by groundwater discharging directly into the streams through springs and seeps in the stream channels, or groundwater discharging from off-channel springs and flowing to the streams. In the lower Flint River basin, the Upper Floridan aquifer is dynamically connected to many of the streams. In particular, the Upper Floridan aquifer discharges large volumes of groundwater into the Flint River through natural springs and through myriad fractures and fissures within the Ocala Limestone in the streambed.

III.C.2(i) Middle Flint River Subwatershed. The Middle Flint subwatershed includes parts of Marion, Schley, Macon, Dooly, Sumter, Crisp, Lee, Dougherty, and Worth Counties. Lake Blackshear in Sumter and Crisp Counties, and Lake Chehaw in Lee and Dougherty Counties, are the major hydrologic features within this subwatershed; and the Flint River is the only regionally significant stream. The USGS operates only three streamflow gaging stations in this area; Flint River at Montezuma, station 02349500 (Macon County), Flint River near Oakfield, 02350512 (Lee/Worth Counties), and Lime Creek near Cobb, 02350080. Although numerous streams within this area are perenial and extensively used for irrigation supplies, they are not monitored.

III.C.2(ii) Kinchafoonee and Muckalee Creeks Subwatershed. Kinchafoonee Creek and Muckalee Creek watersheds are combined into one subwatershed because of the shared drainage basin and because of similar hydrologic characteristics. Each stream has a relatively dense, dedritic stream network with numerous perenial supporting streams. The Kinchafoonee Creek headwaters in Stewart, Chattahoochee, and Marion Counties in the area where the Claiborne aquifer is recharged. The stream meanders through Webster, Terrell, and Lee Counties and terminates near its confluence with Muckalee Creek at Lake Chehaw. Streamflow is monitored at USGS gaging stations at Preston (02350600) and near Dawson (02350900). The gaging station near Dawson has been in continuous operation for 14 years.

Muckalee Creek headwaters in Marion County also as seepage and springflows from the Claiborne aquifer, and flows southeasterly through Schley, Sumter, and Lee Counties where it terminates at its confluence with Kinchafoonee Creek at Lake Chehaw. The Muckalee is monitored by the USGS at streamflow gaging stations near Americus (02351500) and near Leesburg (02351890). The station near Leesburg has been operated continuously for about 19 years.

Long-term, median daily streamflow data for Kinchafoonee and Muckalee Creeks were used to develop an estimate of a hypothetical combined median monthly streamflow. Median daily values for each of the two stations were mathematically combined in order to develop an estimate of median monthly streamflow from the subwatershed. Obviously, conditions of flood and drought can significantly alter the observed streamflow. These streams are susceptible to rapid rises and frequent flooding because of very high rates of rainfall runoff resulting from the clayey surface soils present within the stream basins and the topographic relief in the upper part of the basins.

III.C.2(iii) Ichawaynochaway Creek Subwateshed. Ichawaynochaway Creek headwaters in southern Webster County as seepage and springflow from the Claiborne aquifer. From the headwater area, it flows through Terrell, Calhoun, and Baker Counties and skirts along the boundary between the Fall Line Hills and the Dougherty Plain physiographic districts. Throughout most of its flow path, the Ichawaynochaway flows through the Claiborne aquifer hydrogeologic province. Only in its southernmost reach in southern Baker County does the Ichawaynochaway flow across the Dougherty Plain and interact with the Upper Floridan aquifer.

Major tributaries to the Ichawaynochaway Creek are Pachitla Creek in Randolph and Calhoun Counties, and Chickasawhatchee Creek in Terrell, Dougherty, Calhoun, and Baker Counties. The USGS operates numerous streamflow gaging stations in the Ichawaynochaway subwatershed including a gage on Pachitla Creek in Calhoun County (02353400), on Chickasawhatchee Creek at Elmodel, on Ichawaynochaway Creek at Milford (02353500) and near Morgan (02353265). The streamflow gaging station near Milford has been operated continuously for more than 62 years. Computations of median monthly streamflow were made using data from the USGS gaging station near Milford. For the same reasons as in the Kinchafoonee and Muckalee subwatershed, streamflow in the Ichawaynochaway subwatershed is also susceptible to frequent and rapid rises in stage resulting from rainfall runoff.

III.2.C(iv) Spring Creek Subwatershed. Spring Creek headwaters in Clay, Calhoun, and Early Counties in the Fall Line Hills physiographic district. The stream emerges as seeps and springflows from the Claiborne aquifer and flows south-southeasterly through Early, Miller, Seminole, and Decatur Counties and terminates at Lake Seminole in the southwestern corner of Georgia. Numerous wetland ponds, which are likely hydraulically connected to the Upper Floridan aquifer, are tributary to Spring Creek in the Early County area. In the Seminole and Decatur County area, north of Lake Seminole, numerous large springs emerge from the Upper Floridan aquifer and contribute significant volumes of groundwater to the stream. Only Aycock Creek in southern Miller County is of importance as a tributary stream. Spring Creek is a direct tributary to Lake Seminole, and as a result, its streamflow characteristics are strongly affected by the level of the lake in much of Seminole and Decatur Counties.

The USGS operates streamflow gaging stations at two sites in the Spring Creek subwatershed. A gaging station is operated near Reynoldsville (02357150) and near Iron City (02357000). The station near Iron City has been operated continuously for more than 52 years. Median daily streamflow records from this station were used to estimate the median monthly streamflow from the Spring Creek subwatershed.

III.C.2(v) Lower Flint River Subwatershed. The most southerly streamflow gaging station operated on the Flint River is located at Newton (02353000). The Flint River and the Upper Floridan aquifer are hydraulically connected within the Lower Flint subwatershed and water may be frequently exchanged between the aquifer and the river depending on the relative aquifer and stream levels. Generally, the aquifer discharges significant volumes of groundwater into the river through large springs in the streambed and from springs that emerge adjacent to the stream channel. Because of this significant component of the streamflow that is not quantified in the river reach from Newton to Lake Seminole, it is not possible to develop a median monthly streamflow that represents stream discharge from this subwatershed.

III.D Agricultural Water Use. Between 1970 and 1980, the southwestern Georgia area experienced an unprecedented increase in the agricultural use of water resources. Irrigated acres increased from 130,000 m 1976, to 261,000 in 1977.[39] By 1980, irrigated farmland had increased to more than 452,000 acres, and the combined surface water and groundwater use in the Dougherty Plain was more than 312 million gallons per day (Mgals/day). Statewide, more than 580 Mgals/day were withdrawn during 1980 for agricultural use (Pierce, et al, 1984). During 1995, an estimated 722 Mgals/day of water was withdrawn to irrigate about 1.1 million acres of cropland, statewide.[40] According to the 2000 Georgia EPD permit files, the 21-county study area has a combined groundwater and surface-water authorized withdrawal rate of more than 9.3 billion gallons per day (Bgals/day).[41]

The dramatic increase in irrigation water use in this region was the result, primarily, of the introduction of large-acreage, self-propelled, center-pivot irrigation systems. In the Dougherty Plain district, the land is flat to gently rolling, has few streams and, therefore, is highly adaptable to large center-pivot irrigation systems. The flat landscape, coupled with a bountiful supply of groundwater and surface water and a climate suitable for multicropping, are

[39] Pollard, L. D., Grantham, R. G., and Blanchard, H. E., Jr., 1978, A preliminary appraisal of the impact of agriculture on ground-water availability in southwest Georgia,: U.S. Geological Survey Water-Resources Investigation 79-7, 21 p.

[40] Fanning, Julia, L., Schwarz, Gregory E., and Lewis, William C., 2001, A field and statistical modeling study to estimate irrigation water use at benchmark farms study sites in southwestern Georgia, 1995-96, U. S. Geological Survey Water-Resources Investigations Report 00-4292, 32 p.

the necessary ingredients for a highly productive agricultural environment.

In the north and northwestern part of the 21-county study area, the Fall Line Hills district is highly dissected by streams and has little level land; thus, the landscape is not adaptable to large-acreage, center-pivot irrigation systems. In addition, water supply in this district is not as prolific as in the Dougherty Plain. For these reasons, the agricultural growth observed in the Dougherty Plain district developed more slowly in the Fall Line Hills.

The rapid and large increases in agricultural irrigation that occurred during the late 1970's and early 1980's drastically changed the pattern of water use in the State, significantly affected the States' strategy of water management, and brought about a need to more carefully evaluate the State's use and availability of water resources.

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[41] Georgia EPD, written communication, 2000.

III.D.1 Georgia Agricultural Water Use Permitting System. In 1988, the Georgia Legislature enacted a law that requires a withdrawal permit be obtained for each irrigation water source exceeding 100,000 gals/day on a monthly average. The Georgia EPD, Water Resources Management Branch, is responsible for issuing and monitoring these permits. Although agricultural water users are required by law to obtain a withdrawal permit, they are not required to meter or report water used for irrigation.[42] As a result, monitoring of irrigation water use historically has not been a high priority for EPD.

[42] Fanning, Julia, L., Schwarz, Gregory E., and Lewis, William C., 2001, A field and statistical modeling study to estimate irrigation water use at benchmark farms study sites in southwestern Georgia, 1995-96, U. S. Geological Survey Water-Resources Investigations Report 00-4292, 32 p.

However, during the mid 1990's, results of USGS investigations and proposed resource reallocations, heightened water-availability concerns and created conflicts among the States of Alabama, Florida, Georgia, and the U.S. Army Corps of Engineers.[43] As a result of these concerns, the States of Alabama and Florida brought legal action against Georgia in an effort to limit development of the water resources within the Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint River Basins. This action promoted the Georgia EPD to more closely evaluate the allocation of water resources for all uses, including agriculture. Because of concerns of the potential loss of aquatic habitat in streams of southwestern Georgia, the Georgia Legislature enacted the Flint River Drought Protection Act during late 2000 and 2001. The intent of this act is to provide Georgia EPD with a mechanism and authority to remove cropland from surface-water irrigation within the Flint River basin during periods of prolonged drought. In addition, this act enabled Georgia EPD to compensate farmers for lost revenue as a result of the inability to irrigate.

The heightened awareness of water-resource allocations in southwestern Georgia has brought about several investigations involving agricultural water use in this region. Close examination of the Georgia Agricultural Permitting System has yielded a litany of errors, missing information, duplication of permits, and most alarming, over permitting of specific water resources. As a result, Georgia EPD has placed a 5-year moratorium on additional agricultural development from streams and from the Upper Floridan aquifer within the Flint River Drought Protection Area.

[43] Torak, Lynn J., and McDowell Robin John, 1996, Ground-water resources of the lower A-C-F river basin in parts of Alabama, Florida, and Georgia—Subarea 4 of the A-C-F and A-C-T river basins, U. S. Geological Survey Open-File Report 95-321, 145 p.

This report provides a county- and subwatershed-level assessment of the distribution of currently issued agricultural withdrawal permits within the 21-county study area, and a comparative analysis of the sustainable surface-water resources. Clearly, this analysis is not based on actual water use, but is based, solely, on the quantity of waters of southwestern Georgia that are authorized to be withdrawn for agricultural purposes by the Georgia EPD permitting system.

III.E Geographic Information System. Database display data was acquired from the Georgia EPD permit files. Digital map coverages were created depicting the 21-county study area. Shape files were then created to display and analyze the potential groundwater and surface-water use characteristics within each of the sub watersheds. Data were extracted from the shape files into a tabular format where potential withdrawal and irrigated acreage could be summarized. Maps were then created using the GIS to display the distribution of groundwater and surface-water withdrawal permits within each sub watershed. However, because the project GIS database requires a coordinate location for each data entry, many permits stored in the EPD file were rejected and not included in the database. Thus, the analyses provided in this report do not include all permits stored in the EPD permit files.

III.E.1 Distribution of Groundwater Agricultural Water-Use Permits. In 1977, the installed pumping capacity of irrigation systems using groundwater as a source within the Dougherty Plain district was about 1.8 Bgals/day.[44] The 1980 water use census did not include information on pumping capacity; thus, the 1977 data are the most recent that reflect historic

[44] Pierce, Robert, R, Barber, Nancy L., and Stiles, Harold R., 1984, Georgia Irrigation, 1970-80: A Decade of growth, U. S. Geological Survey Water-Resources Investigations Report 83-4177, 29 p.

water use capacity.

According to the 2000 Georgia EPD permit database, there are about 4,746 groundwater permits issued to agricultural water users in the 21-county study area. A total of about 7.2 Bgals/day, is permitted for agricultural withdrawal from groundwater sources in the 21-county area of southwestern Georgia.[45] Because of data inaccuracies and omissions in the Georgia EPD database, the estimate of acres irrigated is not precise. However, data provided in the EPD database indicates that approximately 664,000 acres are irrigated by groundwater in the study area. Mitchell County has the largest irrigated acreage (92,731 acres), and Decatur County has the largest permitted withdrawal (about 1.08 Bgals/day) of the 21-counties in the study area.

<u>III.F Permitted Groundwater Withdrawals by Subwatershed.</u> The Geographic Information System database, developed as a part of this study, was used to evaluate the distribution of permitted groundwater withdrawals by subwatershed in order to provide a correlation with surface-water use. Many permits were excluded from this analysis and could not be entered into the GIS database because of missing, or erroneous location data. Thus, the summed total permitted withdrawal from the five subwatershed analyses will be substantially less than the total permitted withdrawal volume of about 7.2 Bgals/day.

<u>III.F.1 Middle Flint River Subwatershed.</u> Groundwater use in the Middle Flint subwatershed is primarily from the Upper Floridan aquifer; however, the Claiborne aquifer is more widely used as an alternate source than in the other sub watersheds. In southeastern Sumter, Dooly, and northeastern Crisp Counties, the Claiborne aquifer is a viable alternate groundwater source. Total permitted groundwater use in this study area component is about

[45] Georgia EPD, written commun., 2000

474.4 Mgals/day.

III.F.2 Kinchafoonee and Muckalee Creeks Subwatershed. Groundwater use in the Kinchafoonee and Muckalee subwatershed is also primarily from the Upper Floridan aquifer, but in northern Lee County and eastern Terrell County the Claiborne aquifer is used as an alternate source. Total permitted groundwater use in this area is about 294.7 Mgals/day.

III.F.3 Ichawaynochaway Creek Subwatershed. In Webster, Stewart, Randolph, western Terrell, and northern Calhoun Counties, groundwater is not available from the Upper Floridan aquifer. In addition, the Claiborne aquifer generally is not a viable alternate source. Thus, groundwater withdrawals from this part of the subwatershed are primarily from the Clayton aquifer. In the southern part of the subwatershed, in southeastern Calhoun and Baker Counties, the Upper Floridan aquifer is a very good source for irrigation supplies and it is in this part of the subwatershed that the major part of the irrigation water is withdrawn from groundwater sources. Total permitted groundwater withdrawal in this subwatershed is about 412.7 Mgals/day.

III.F.4 Spring Creek Subwatershed. In the headwater area of the Spring Creek subwatershed, in southeastern Clay, western Calhoun, and northern Early Counties, the Upper Floridan aquifer does not provide a viable irrigation water source. In this area, most groundwater for irrigation use is provided by the Clayton aquifer. The Claiborne aquifer is not capable of providing an adequate supply to use as a direct irrigation source, but is used at a few sites to supply ponds. In the southeastern Early, Miller, Seminole, and Decatur County areas, the Upper Floridan aquifer is heavily used for irrigation supply. Total permitted groundwater withdrawal in this subwatershed is about 1.34 Bgals/day.

The Arc View GIS database was used to evaluate the distribution of potential irrigation withdrawals from each subwatershed in order to determine the potential impact on the area streamflow from irrigation withdrawals. Permits where the irrigation source was not clearly identified, or identified as a pond, were not included in this evaluation. In addition, permits with missing, or erroneous location data were not entered into the GIS database. Thus, the subwatershed data and analyses herein reported are based solely on permits authorizing direct stream withdrawals for irrigation that could be located using the Georgia EPD data files within the 21-county area. Thus, the summed total permitted withdrawal from the subwatershed analyses will be less than the total permitted withdrawal from the 21 -county area.

III.F.5 Middle Flint River Subwatershed. The permitted direct stream withdrawals within the Middle Flint subwatershed are focused primarily in the area adjacent to Lake Blackshear. The majority of irrigation permits are located on streams that are tributary to Lake Blackshear and the Flint River in the Sumter, Dooly, and Crisp County areas. Although streams are somewhat sparse in this subwatershed, about 192.5 Mgals/day are permitted for withdrawal. The streamflow equivalent for this pumping rate is approximately 298 cfs.

III.F.6 Kinchafoonee and Muckalee Creeks Subwatershed. Permitted withdrawal within this subwatershed is primarily directly from the main-stem streams. Many of the streams that are tributary to Kinchafoonee and Muckalee have relatively small drainage basins and, thus, cease to flow during years of moderate drought. Even though, many of these streams are shown as "blue line streams" on the USGS topographic maps, their strearnflow is not dependable as an irrigation source for late-season crops. Total permitted withdrawal from the Kinchafoonee and Muckalee subwatershed is about 299 Mgals/day, or a strearnflow equivalent of about 463 cfs. This authorized pumping rate would exceed the combined, median monthly strearnflow of the

Kinchafoonee and Muckalee Creeks during the months of June, July, August, September, and October.

III.F.7 Ichawaynochaway Creek Subwatershed. The potential impact on the strearnflow within the Ichawaynochaway Creek subwatershed is much greater than that in the other subwatersheds in the 21-county study area. Farmers are permitted to withdraw more that 368 Mgals/day from streams in this basin. The streamflow equivalent of this pumping rate is about 570 cfs, which exceeds the median monthly streamflow at the Milford gaging station (02353500) from April until December.

III.F.8 Spring Creek Subwatershed. The Spring Creek subwatershed supports the fewest permits of the subwatersheds in the 21-county study area. Total permitted irrigation withdrawal is about 52 Mgals/day, or a streamflow equivalent of approximately 81 cfs. The median monthly streamflow at the Iron City gaging station (02357000) is not exceeded by this authorized pumping rate even during the late summer and fall months.

III.F.9 Permitted Withdrawals from Ponds. The permitted withdrawal from ponds was not included in the subwatershed analysis because it is not clear what impact, if any, pond storage and subsequent withdrawal may have on the sustainability of streamflow. It is assumed that most of the water is accumulated in the ponds during the winter months, and that baseflow of the streams is not affected during the late spring and summer. Many pond-supplied irrigation systems are operated so that the pond will have minimal impact on streamflow because water is collected in the pond during the winter, rainy season when runoff is abundant. Subsequently, the water is withdrawn from the pond during the late spring and early summer months when irrigation demand is at a peak. Other pond-irrigation systems are operated similarly, but the pond source is maintained by pumping a well into the pond when runoff becomes sparse in late spring and summer. There are numerous ways that farmers maintain and operate pond-supplied systems. It is for this reason, that permitted pond water use was not included in the subwatershed streamflow analysis. However, it is important that the potential permitted withdrawal from pond sources be quantified.

According to the Georgia EPD files, there are more than 800 irrigation permits that identify a pond as the source, or the source is unknown in the 21-county study area. Most of the pond irrigation sites are located in areas where a viable groundwater or stream source is not available. Ponds and unknown sources reportedly irrigate about 190,800 acres of farmland in the 21-county area. The combined permitted withdrawal rate for all pond and unknown-source sites is about 1.2 Bgals/day. The streamflow equivalent of this pumping rate is more that 1,845 cfs.

III.G. Summary. A 21-county, intensely farmed area in southwestern Georgia was selected for the purpose of delineating the distribution of permitted irrigation water use and availability from the area aquifers and streams. Prior to 1970, very little cropland was irrigated within this region; however, between 1970 and 1971 irrigated cropland increased by 60 percent, and from 1976 through the fall of 1977, irrigated cropland increased almost 100 percent. The study area includes all, or parts of Marion, Schley, Stewart, Webster, Sumter, Dooly, Crisp, Lee, Terrell, Randolph, Calhoun, Dougherty, Worth, Turner, Mitchell, Baker, Early, Miller, Seminole, Decatur, and Grady Counties in southwestern Georgia in the Fall Line Hills, Tifton Upland, and Dougherty Plain districts of the Coastal Plain physiographic province. The Flint River and its tributary streams drain the study area. Together, they form five subwatersheds within the study area: (1) middle Flint River; (2) Kinchafoonee and Muckalee Creeks; (3)

Ichawaynochaway Creek; (4) Spring Creek; and (5) lower Flint River.

Sedimentary rocks, dipping gently to the southeast, underlie the Coastal Plain. The oldest exposed sediments of Late Cretaceous to early Tertiary age are composed of sand, clay, and gravel, and occur in a band just south of the Fall Line. These sediments are overlain by sand and limestone of Paleocene, early Eocene, and middle Eocene ages. The next younger deposits are carbonate rocks, primarily limestone, of late Eocene and Oligocene age. The sediments of the Coastal Plain extend to a depth of at least 5,000 *ft* and dip to the southeast by as much as 25 feet per mile in the study area, and progressively thicken in that direction.

Major structural features that affect the aquifers in the study area include: (1) the Andersonville Fault in southern Schley, northern Sumter, and western Dooly; (2) the Structural Belt in northern Terrell, Sumter, and southwestern Dooly; and (3) the Gulf Trough in Mitchell, Colquitt, Tift, Irwin, and Ben Hill Counties.

Water in the study area is obtained from the many streams that drain the area and from four groundwater reservoirs, or aquifers. From deepest to shallowest the aquifers are: the Providence, Clayton, Claiborne (Claibome-Wilcox, where present), and Upper Floridan. Although groundwater is available from the deeper Cretaceous aquifers, high drilling costs, relatively low yields, and higher concentrations of dissolved solids and chloride in the area south of Albany, make development of these aquifers undesirable.

Yields are dependent on the thickness and hydraulic conductivity of the aquifers and vary significantly amongst the aquifers, as well as areally. The Upper Floridan aquifer is the most extensive within the study area, and is capable of producing several thousand gallons per minute from single wells. In the Dougherty Plain district and adjacent areas of southwestern Georgia, the Upper Floridan aquifer is used extensively for supplemental agricultural irrigation and as an essential source of municipal, industrial, and domestic water supplies.

In southwestern Georgia, practically all streams originate as groundwater seeps or springs. Along their flow paths, stream flow is primarily sustained by precipitation for the principle part of the year; however, the stream flow is augmented by variable rates of groundwater inflow, which during historic low-flow periods of the year can account for a substantial part of the total stream flow. Typically, rates of groundwater discharge to streams are at a maximum during late winter and spring when the aquifer systems are generally fully recharged and groundwater levels are at their annual highs. However, the rates of groundwater discharge are progressively diminished through the spring and summer months as regional groundwater levels decline in response to increased pumping stresses on the aquifers. During late summer and fall, when precipitation historically is sparse, the base flow of many streams is maintained almost solely by groundwater discharging directly into the streams through springs and seeps in the stream channels, or groundwater discharging from off-channel springs and flowing to the streams. In the lower Flint River basin, the Upper Floridan aquifer is dynamically connected to many of the streams. In particular, the Upper Floridan aquifer discharges large volumes of groundwater into the Flint River through natural springs and through myriad fractures and fissures within the Ocala Limestone in the streambed.

Between 1970 and 1980, the southwestern Georgia area experienced an unprecedented increase in the agricultural use of water resources. Irrigated acres increased from 130,000 in 1976, to 261,000 in 1977. By 1980, irrigated farmland had increased to more that 452,000 acres, and the combined surface water and groundwater use in the Dougherty Plain was more than 290 million gallons per day (Mgals/day). According to the 2000 Georgia EPD permit files, the 21-county study area has a combined groundwater and surface-water authorized withdrawal rate of more than 9.3 billion gallons per day (Bgals/day). Records indicate that there are about 4,746 groundwater permits issued to agricultural water users in the 21-county study area. A total of about 7.2 Bgals/day, is permitted for agricultural withdrawal from groundwater sources in the study area. During 1980, estimated surface-water use in southwestern Georgia from all sources was about 80.8 Mgals/day. At present, the permitted surface-water withdrawal in the 21-county area from all sources is about 2.1 Bgals/day. This water is applied to more than 190,800 acres of farmland. In addition to these potential withdrawals from within the study area, about 67.6 Mgals/day are authorized for withdrawal from within the upper Flint River subwatershed, which is upstream from the study area. Thus, potential agricultural surface-water withdrawal from the Flint River Basin is more than 2.7 Bgals/day, which is an equivalent streamflow of more than 4,177 cubic feet per second (cfs). Permitted irrigation withdrawal exceeds the historic median monthly streamflow in the Kinchafoonee and Muckalee Creeks subwatershed, and in the Ichawaynochaway Creek subwatershed throughout most of the summer and fall months. However, the permitted irrigation withdrawal does not exceed the historic median monthly flow in the Spring Creek subwatershed.

The permitted withdrawal from ponds was not included in the subwatershed analysis because it is not clear what impact, if any, pond storage and subsequent withdrawal may have on the sustainability of streamflow. It is assumed that most of the water is accumulated in the ponds during the winter months, and that baseflow of the streams is not affected beyond late spring. According to the Georgia EPD files, there are more than 800 irrigation permits that identify a pond as the source, or the source is not defined in the 21-county study area. Many of the pond irrigation sites are located in areas where a viable groundwater or stream source is not available. Ponds and unknown sources reportedly irrigate about 190,800 acres of farmland in the study area. The combined permitted withdrawal rate for all pond and unknown-source sites is about 1.2 Bgals/day. The streamflow equivalent of this pumping rate is more that 1,845 cfs.

In summary, water use permits issued for irrigation in the 21-county study area clearly exceed the available surface-water resources of southwestern Georgia. Because of our limited understanding of the groundwater and surface-water interactions, and the effects of groundwater pumping on streamflow, the impact of groundwater withdrawals at the permitted level cannot be predicted. However, it is unlikely that the water resources of the southwestern Georgia area could support a combined groundwater, stream, and pond pumping rate of more than 9.3 Bgals/day.

III.H Preliminary Conclusions.[46] The analyses given above identifies two areas in the Flint River Basin where increased ground water use *might* take place without adverse effects:

1. the Claiborne aquifer in No. Dougherty, Lee, S.E. Sumpter, Crisp, N.E. Worth, and So. Dooly counties, which are in the Kinchafoonee and Mucklee Creek sub-basin, where wells might produce yields on the order of 1,000 gpm.

2. North Baker and N.E. Mitchell counties, where the Claiborne aquifer is practically unused because of the high yield and accessibility of upper Floridan aquifer. This area is in the Ichawaynochaway creek sub-basin, where, according to Hicks, wells might yield 500 gpm.

(We emphasize the tentative nature of results from the study. The author gives emphasis to the fact that much more hydrological testing and exploration is needed before conclusions can be drawn concerning the feasibility of transferring water use from surface to ground water sources.)

[46] Conclusions are taken from Water Policy Working Paper #2001-002, section III.C.

In the two areas above, specified by Hicks, we identified 30 permits for surface water use in Lee County, with permitted use for the irrigation of 9,753 acres; and 21 surface permits in North Baker County for irrigation of 16,631 acres (for a total of 51 permits and 26,384 permitted acres).

Assume, for illustrative purposes, that (a) all of the 26,384 acres have actually been under irrigation, (b) during drought years irrigators withdraw 24 inches per acre for the irrigation season, (c) four of the 24 inches represent return-flow to the stream, and (d) 42% of the total irrigation application occurs in June. If, and we stress ***if***, further research confirmed the feasibility of shifting those 51 surface water use permits to ground water use, the effect would be to increase in-stream flows by approximately 200 mgd (there should be little effect of ground water pumping from the Claiborne aquifer on Flint River surface flows). Given these assumptions, the transfer of these 51 permits from surface to ground water use could have the effect of increasing stream flows during this critical month of June by as much as 115 cfs in the Kinchafoonee and Mucklee Creek sub-basin, and 195 cfs in the Ichawaynochaway Creek sub-basin. During drought periods such as that experienced during the summer of 2000, such increases could offer *significant* improvement in the riverine environment in these areas (for example, during a period of several days during June, 2000, flows in Ichawaynochaway creek were below 24 cfs). Of course, factors such as evaporation from the increased stream flows, and loss of flows as a result of infiltration of the increased stream water back into the ground would impact on the net effects of this type of action.

Should such a transfer system be shown to be hyrologically feasible, the economic feasibility of a state program to finance such shifts is reasonably straightforward. To serve the

9,753 acres of surface permitted irrigated acres in Lee county (assuming that each new well would yield about 1,000 gpm, and that each well irrigates 160 acres), 61 wells would be required. The estimated costs for drilling a well and installing a pump is about $50,000.[47] Given this per-well cost, shifting the 9,753 acres from surface irrigation to ground water irrigation would cost approximately $3 million. In Baker County, to serve the 16,631 irrigated acres indicated above, 208 wells (with an average yield of 500 gpm, each serving 80 acres) would be required and would cost about $10.4 million.

Thus, at a cost of approximately $13.4 million ($508/acre), surface water irrigated acres would be reduced by 26,384 acres for ***all** future years*. This compares with $4.5 million spent in the March 17, 2001 Flint River Drought Protection auction to reduce surface irrigation by 33,100 acres for **one year only**, at per acre costs as high as $200/acre, and averaging $135/acre. If these data can be considered as somewhat indicative of the actual situation, the implied policy question is whether it would be more prudent to retire all surface permits in drought years only at $135 per acre, or to retire some surface permits permanently at about 3.8 times ($508) that per acre cost .

[47] Estimates for well costs were kindly provided by Mr. Doyle Medders, Sylvester, GA (August 3, 2001).