EFFECTS OF IRRIGATION WITHDRAWALS ON BASE-FLOW IN THE FLINT AND APALACHICOLA RIVERS

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INTRODUCTION

Base-flow in the Apalachicola River is important for the provision of a federally authorized navigation project and for the ecological functioning of its estuary. This paper investigates the impacts of irrigation activities in the Flint River on base-flow in the Apalachicola River.

BACKGROUND

Downstream Uses

The Apalachicola River is formed by the confluence of the Flint and Chattahoochee Rivers at the Florida border (Figure 1). Throughout the early 1980s the Apalachicola estuary provided about 90 percent of the state's and 10 percent of he nation's oyster harvest, as well as sizable shrimp, blue crab, and fin fish yields. Although annual seafood landings are valued in the tens of millions of dollars, the real value of the estuary is in its role as a nursery. Over 95 percent of the commercial species harvested in the Gulf spend some critical portion of their life-cycle in an estuary.[12] Its high productivity is the result of good water quality, the estuary's physical form, its salinity regime, and energy subsidies in the form of nutrient/detrital transport from the river's floodplain. It is tied to a diurnal tidal cycle and a salinity regime defined by an annual cycle of spring floods and winter low flows and cyclical long-term fluctuations in river flow.[5]

As a commercial navigation project, the Apalachicola River is federally authorized to be maintained at a nine by one-hundred foot dimension. Availability of this depth is dependent on flow in the river. Channel dimensions may be provided by: 1) dredging, cutoffs, training works, and other open-river methods; 2) a series of locks and dams; and 3) flow regulation from upstream storage projects.[10] The Corps of Engineers has undertaken numerous structural modifications in an attempt to provide the authorized channel on a year-round basis. These include five dams on the Chattahoochee River, an extensive network of dike fields on the Apalachicola River, six cutoffs, removal of rock shoals at ten locations, and annual maintenance dredging and snagging.

Despite these efforts, the channel has not been available on a year-round basis. The authorized channel dimensions were available 80 percent of the time between 1970 and 1980, a relatively wet period[4,7] and has been available considerably less since then. The flow at which the authorized channel can be provided after dredging (11,300 cfs at the Blountstown, FL gage) has been available only 80 percent of the time for the 65 year period of record. The discharge that has been available on a reliable year-round basis (i.e., 95 percent of the time) is 7,800 cfs.

Water Resources

All three river basins are of concern relative to the issue of irrigation withdrawals. Although the Chattahoochee and Flint sub-basins are nearly equal in area, their effects on flow in the Apalachicola River differ. The Chattahoochee is a regulated stream whose flow is primarily from surface runoff. It typically contributes the major portion of flow in mean- to high-water events. In contrast, the Flint is unregulated and has a major spring-fed flow component and should contribute a larger share of flow during low-flow periods.

Although the Chattahoochee is regulated, management of its reservoirs is limited by the fact that the two reservoirs which contain over 80 percent of the conservation storage impound less than 18 percent of the water shed. Thus, the potential for refilling them during low-flow events is constrained and they must be managed conservatively. Furthermore, the majority of the designated storage capacity in these two reservoirs has been captured by recreational interests and adjacent land-owners or allocated to municipal water supply. Historically, the reservoir system has been shown to have had a limited effect on the overall flow regime of the Apalachicola River.[4,6,7]

Management options of the reservoirs are further constrained because hydropower facilities are managed as part of a grid with the Alabama-Coosa-Tallapoosa and Savannah basins. Providing water to Apalachicola Bay is not an authorized purpose of the federal reservoirs; thus the water is not released from the reservoir system to enhance shellfish productivity or major nursery areas.

From a groundwater perspective, the area of concern is the Dougherty Plain district of the Coastal Plain physiographic province. The underlying Floridan aquifer in the region makes the area well suited for irrigation wells. At the same time, however, the Floridan aquifer is closely linked hydrologically to the Flint River. Aquifer discharge to the Flint River downstream from Lake Worth dam has been computed to be one billion gallons per day.[9] The ground water level in the Upper Floridan aquifer is generally at a maximum during February through April, declines through summer, and is at a minimum during November and December, when flows in the Apalachicola River are also at a minimum. Seasonal water fluctuations in the aquifer near major agricultural and industrial centers can exceed 30 feet.[9] These seasonal depressions of the aquifer, in turn, translate into reduced flow in the Flint and its tributaries as they recharge the Floridan aquifer, and this translates into a reduction of base-flow in the Apalachicola River.

Irrigation

In the past twenty years the use of ground water for irrigation and the use of center-pivot type irrigation systems have increased substantially (Table 1). The combination of technological innovations in irrigation, a robust aquifer, and favorable profit margins for field crops in the early- and mid-1970s provided the incentives for the conversion of marginal land (woodland and pasture) into row crops.[13] Increased agricultural use of marginal land resulted in a need for additional fertilizers and pesticides which conveniently could be applied via sprinkler irrigation systems. Nearly three-fourths of the new marginal farmlands were used to grow soybeans and corn, crops with high water requirements.

Southwest Georgia typically receives about 50 inches of rain annually for crop production, but most of this occurs in the early spring when seedling row crops require less water. During the summer, when many crops need more water, rainfall typically declines. Although the amount of irrigated acreage has stabilized in recent years, Table 1 shows that the number of center-pivot systems continues to increase. These systems have the advantages of being relatively low cost compared to other types, adaptable to the sandy soils in the region, easy to operate, and low in maintenance.[8] Center-pivot irrigation systems provide the most efficient means for chemigation[2] and provide the most uniform application of water to both foliage and soil of all irrigation systems.

In 1970, the 22-county area in southwest Georgia and the middle Flint withdrew 13.19 million gallons per day (mgd) for irrigation purposes, 3.30 mgd from ground water sources, and 9.89 mgd from surface water sources.[1] In 1990, the same counties withdrew 211.22 mgd for irrigation, 54.34 from ground water, and 156.88 mgd from surface water.[3] Over 80 percent of the increase in water use in this region from 1970 to 1990 can be attributed to increases in irrigation withdrawals.

These increases in irrigation activity, the physical relationship between the Floridan aquifer and the Flint River, and the importance of inflow from the Flint River to base-flow in the Apalachicola River deserves closer study. This paper investigates whether base-flow in the Flint and Apalachicola Rivers has been affected by the recent increases in irrigation withdrawals.

METHODOLOGY

The process of evaluating man-induced changes to the flow of a river is complicated by the fact that flow normally varies both seasonally and annually. In a typical year, average daily flow in the Apalachicola River varies about ten-fold. The annual minimum flow has varied nearly three-fold over the period-of-record. The task here is to discern significant long-term change in flows in a system that has considerable inherent variation. To do this, effects of irrigation in the Flint basin on base-flow in the Apalachicola River are evaluated through two procedures: 1) comparison of the relative contributions of the Flint and Chattahoochee to flow in the Apalachicola River over time; and 2) analysis of changes in the flow of the Flint relative to similar rivers in the region using multiple mass balance analysis.

For the relative contribution analysis, mean monthly flow data for USGS gages on the Flint and Chattahoochee were compared with data from a gage on the Apalachicola River. Data from the gages for the Flint River at Newton, Georgia, and

Ichawaynochaway Creek at Milford, Georgia, were used for the Flint flow. These were combined with data for the Chattahoochee at Columbus, Georgia, and the Apalachicola at Chattahoochee, Florida. These gages were selected because of their available period of record and location within each sub-basin. All three gages consisted of continuous records from 1938 to 1992, with the exception of the Newton gage which was missing 1946, 1948, 1951-56, and 1990. Selection of the Flint and Chattahoochee gages provided a pair which measured similar drainage areas. The Flint River gages were located in the middle of the Dougherty Plain and downstream from some of the most intense irrigation activity in the region. The Chattahoochee gage provided a measurement of Apalchicola River flow immediately below the confluence of its two main tributaries.

To determine relative contributions, the monthly mean flow value for the gages on the Flint and Chattahoochee Rivers were divided into the corresponding monthly mean flow of the Apalachicola River at the Chattahoochee gage for the period 1938-1992. Data were grouped into two periods: before increased irrigation use (before 1970) and after the growth (1978 to 1992). For the multiple mass balance analysis, flow at a gage on the Flint River at Newton, Georgia, was compared with the total flow of five other streams in the region. This analysis isolates a trend in the divergence of one data set from another which has been labeled as a control. Selection of rivers for the control was based on similarities to the Flint basin in rainfall and land use. Rivers used in this analysis were the Econfina, Ochlockonee, Choctawhatchee, Withlacoochee, and Chipola Rivers in north Florida. The analysis consisted of a time-series comparison of the ten-year moving average of monthly data for the Flint gages to the combined and individual flow of the above rivers.

RESULTS

Figures 2a and 2b show the relative contributions of the Flint and Chattahoochee Rivers to the minimum monthly flows of the Apalachicola River before and after substantial increases in irrigation in the lower Flint basin. These figures show that the relative contributions of the Flint and Chattahoochee Rivers to flow in the Apalachicola Rivers have changed dramatically since irrigation activity in southwest Georgia increased in the 1970s. When compared with the pre-irrigation period, the relative contribution of the Flint to flow in the Apalachicola decreases in the post-irrigation period as flow in the Apalachicola decreases. Possible explanations for this change are: 1) base-flow in the Flint River has been lowered; 2) low-flow augmentation releases from the reservoir system in the Chattahoochee basin have altered the relative contribution relationship between the Flint and Chattahoochee Rivers; 3) rainfall patterns in the Flint and Chattahoochee basins have changed over time; 4) there have been significant land use changes in one of the basins which altered its hydrology; or 5) some combination of the above.

A review of rainfall data for gages throughout the Flint and Chattahoochee basins did not show differences to cause the above changes in relative flow relationships. A recent review of land use changes in the basin concluded that although there is a general trend in land use in the ACF basin from farmland to urban areas or reversion of farmland to woodland, the changing land use patterns were not believed to have a significant effect on river flows in the drainage basin.[7]

Figure 3 shows the ratio of flow in the Flint to that of the five other rivers prior to screening them. This figure also suggests that the base-flow of the Flint has been lowered since irrigation activities increased. These results support our conclusion that rainfall is not the cause of relationship changes noted in the relative flow contribution. As the Chattahoochee was not part of the comparison, the perceived lowering of base-flow in the Apalachicola River is independent of influence by low-flow augmentation releases from reservoirs in the Chattahoochee basin.

CONCLUSIONS

Based on the above analyses, we concluded that base-flow in the Flint has been reduced since the early 1970s. As irrigation withdrawals accounted for the majority of the increases in water use since the reduction in base-flow occurred, irrigation is the most probable cause for this reduction. Because of the ramifications of a base-flow reduction on fresh water inflow to Apalachicola Bay and to the availability of the federal channel, the issue warrants closer inspection. Furthermore, any hydrologic models developed in the current ongoing Comprehensive Water Resources Management Study of the ACF basin needs to account for these apparent inflow reductions. Using the long-term historical record for the Flint will provide an inaccurate portrait of the present. Depletion analysis, as has been done in several basins in the West, is needed.

If the base-flow of the Flint has been lowered as a result of irrigation activity, these withdrawals need to be controlled either through regulations or market mechanisms. As noted earlier, irrigation withdrawals in Georgia are essentially unregulated so long as the use does not seek to increase the capacity of an existing well. The root cause of the overuse of water by agriculture is a failure to price water properly. If the price of water reflects its true value (including all environmental and social costs), users should behave more conservatively. The use of economic incentives and disincentives to encourage development and use of alternative irrigations systems warrants further consideration.

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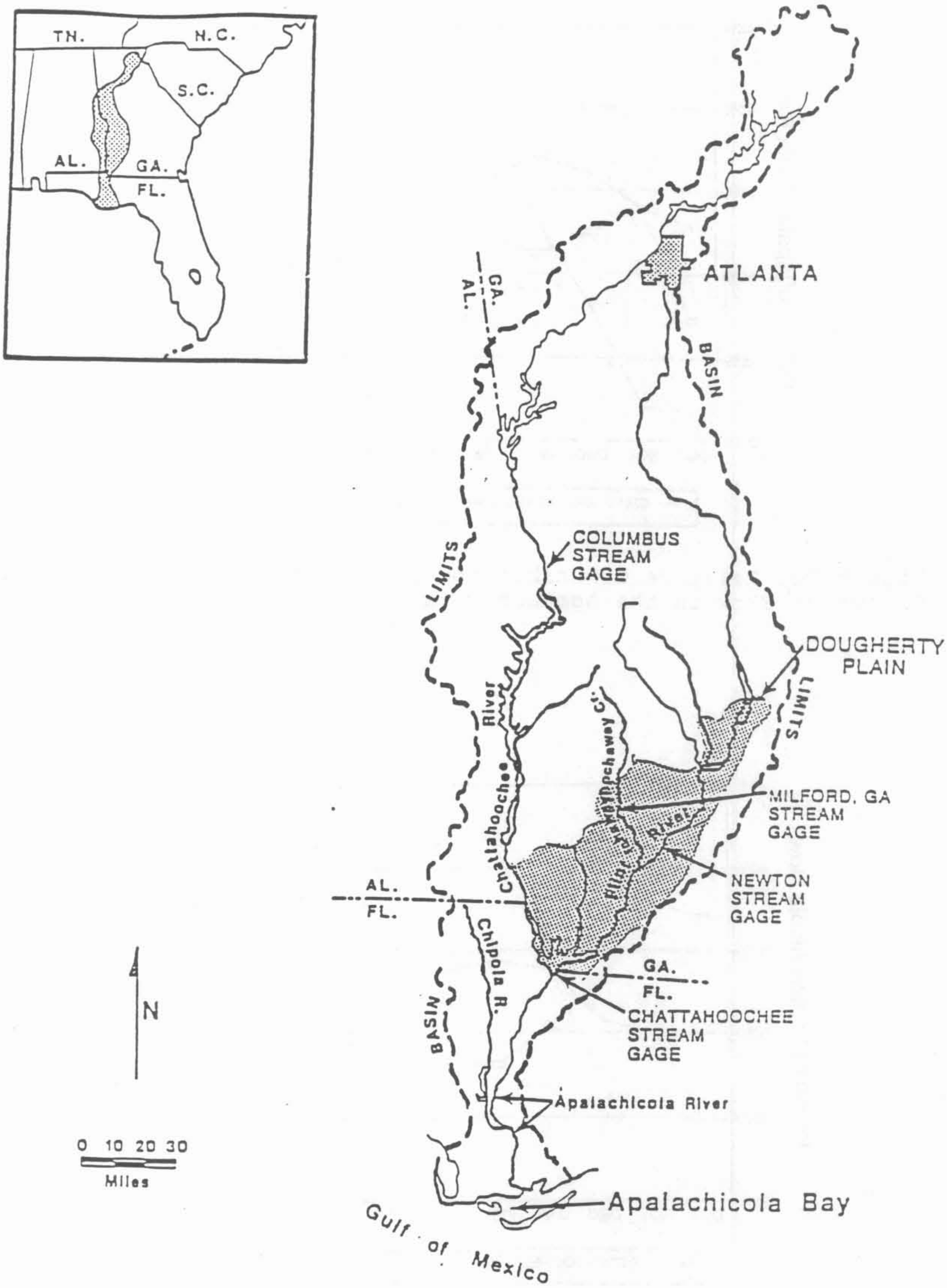

Figure 1. Geographic Features of the ACF Basin

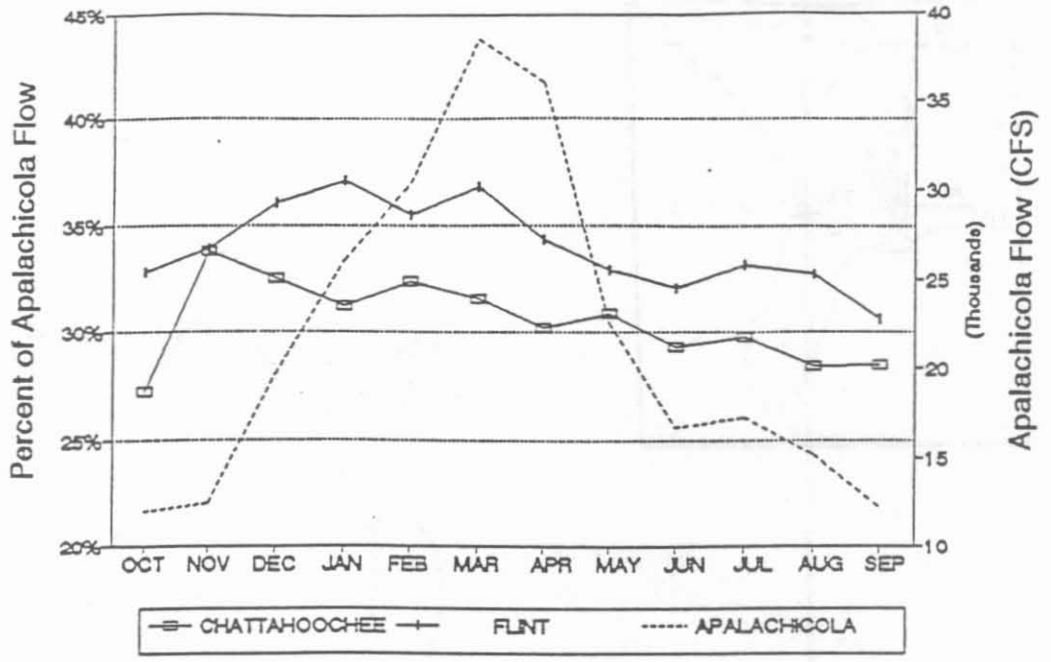

Figure 2a. Relative Contribution of the Flint and Chattahoochee Rivers to Flow in the Apalachicola River, 1939-1970.

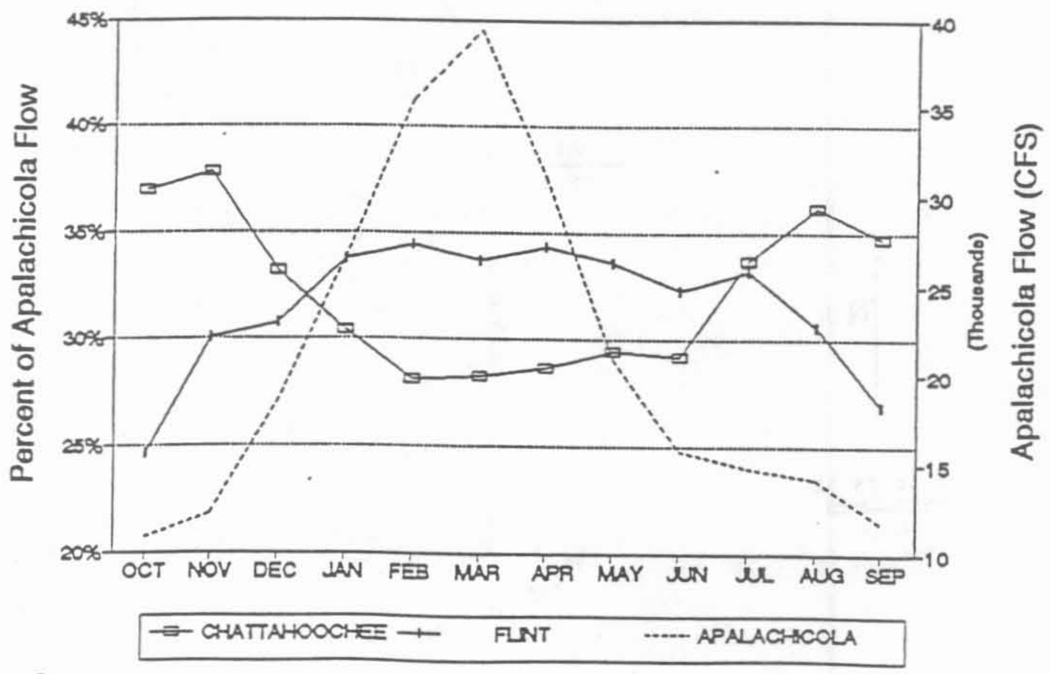

Figure 2b. Relative Contribution of the Flint and Chattahoochee Rivers to Flow in the Apalachicola River, 1979-1991.

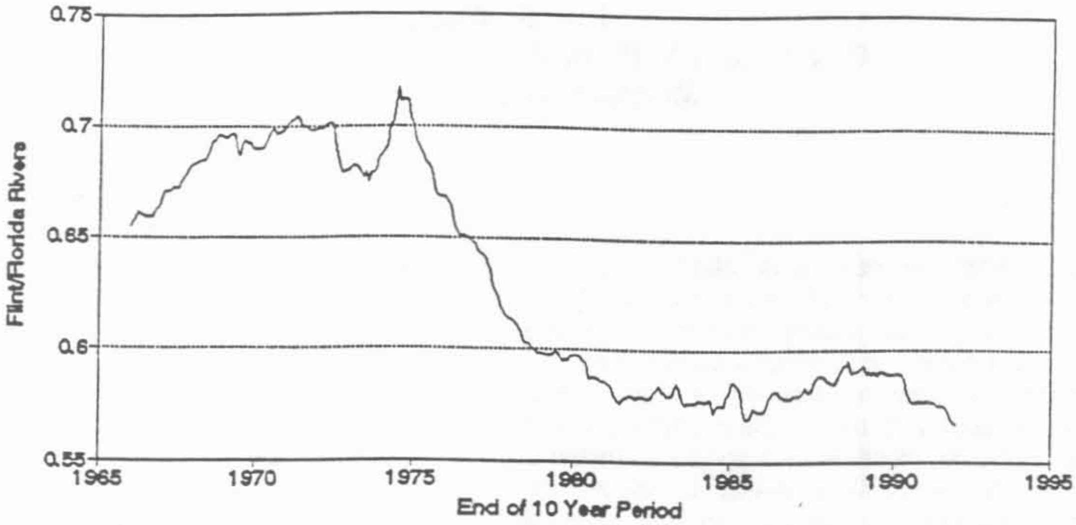

Figure 3. Ratio of Flow in the Flint River at Newton, GA to the Total Flow in Five Rivers in North Florida; 1966-1990.navigation

Table 1. Irrigation Acreage in Georgia: 1970-1989

	Total Acreage (all systems)	Center-pivot Systems (number)
1970	144,627	87
1973	193,857	238
1975	307,416	478
1978	722,075	1,636
1980	988,356	2,858
1982	1,104,992	3,597
1984	1,069,221	3,794
1986	1,128,584	4,191
1989	1,223,836	4,865

Source[1]