Professional Paper SJ95-PP1

PROJECTED AQUIFER DRAWDOWNS
CITY OF LEESBURG WELLFIELDS
LAKE COUNTY, FLORIDA

by
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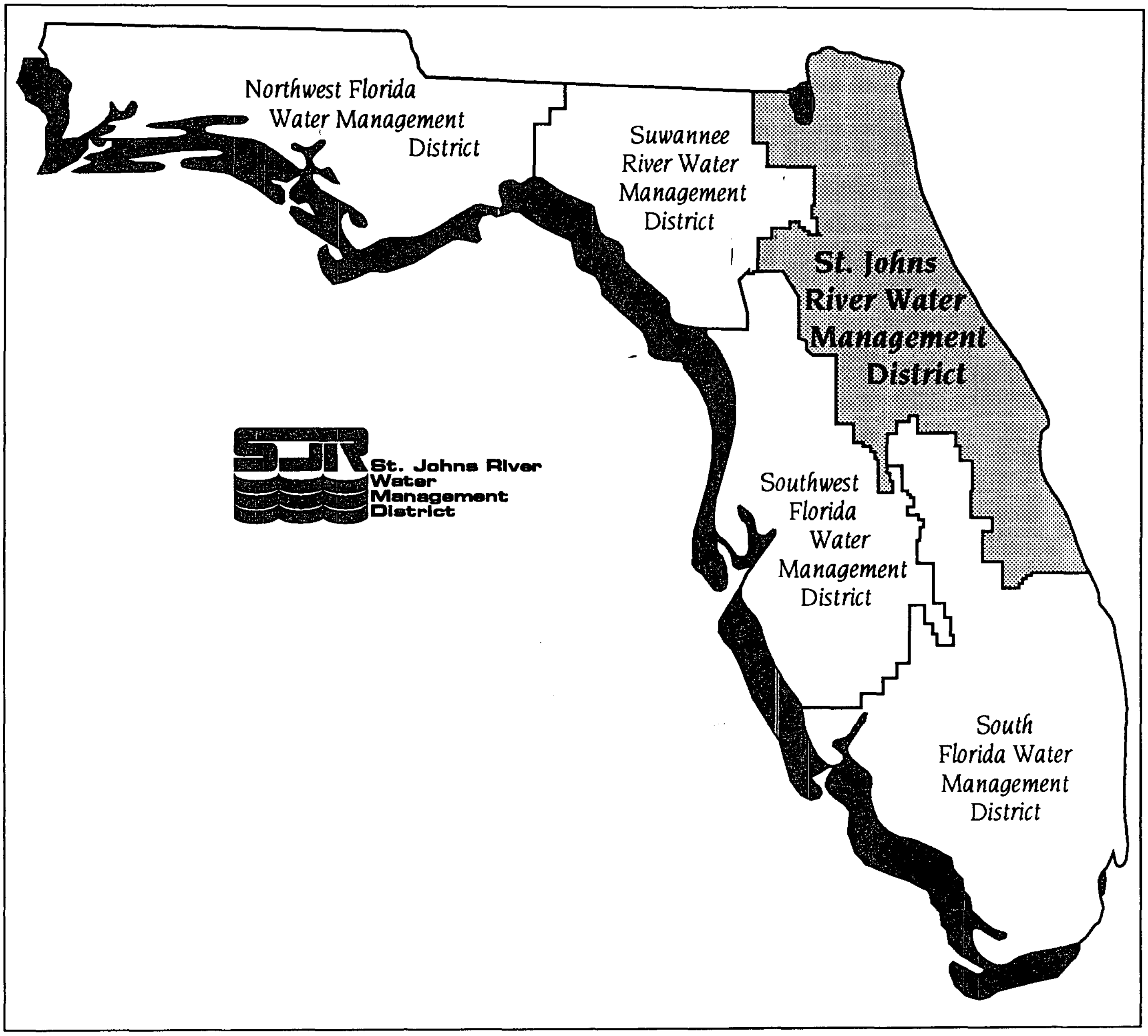

The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued availability while maximizing environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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ABSTRACT. This paper is part of an assessment of water supply needs and sources, in which the St. Johns River Water Management District has been required to identify areas expected to have inadequate water resources to meet the water supply demand in 2010. Two linear analytical ground water models, MLTLAY and DRAWDOWN, were used to simulate changes in the potentiometric surface of the surficial aquifer and the Floridan aquifer systems based on 1988 pumpage values and 2010 projected pumpages for the City of Leesburg. MLTLAY calculates the drawdown in a multi-layered, coupled, leaky-artesian aquifer. DRAWDOWN calculates the drawdown in a two-layered, coupled, leaky-artesian aquifer. These methods assume homogeneous, isotropic, and steady-state conditions. Simulated 1988 drawdowns at the downtown wellfield ranged from 0.2 to 2.5 feet (ft) in the surficial aquifer system (SAS), from 0.5 to 7.0 ft in the Upper Floridan aquifer (UFA), and from 1.5 to 4.2 ft in the Lower Floridan aquifer (LFA). Simulated 2010 drawdowns at the downtown wellfield ranged from 0.4 to 7.0 ft in SAS, from 1.3 to 19.3 ft in UFA, and from 4.1 to 11.5 ft in LFA. The change in drawdowns from 1988 to 2010 at the downtown wellfield ranged from 0.2 to 4.5 ft in SAS, from 0.8 to 12.3 ft in UFA, and from 2.6 to 7.3 ft in LFA. Simulated 1988 drawdowns at the airport-mall wellfield ranged from 0.1 to 0.2 ft in SAS and from 0.2 to 1.2 ft in UFA. Simulated 2010 drawdowns at the airport-mall wellfield ranged from 0.9 to 1.0 ft in SAS and from 3.4 to 4.7 ft in UFA. The change in drawdowns from 1988 to 2010 at the airport-mall wellfield was approximately 0.8 ft in SAS and ranged from 3.2 to 3.5 ft in UFA. Projected 2010 pumpages at the downtown wellfield could have a pronounced effect on UFA; at the airport-mall wellfield, projected 2010 pumpages could have less of an effect on SAS and UFA.

Section 17-40.501, *Florida Administrative Code*, requires the St. Johns River Water Management District (SJRWMD) to identify "specific geographical areas that have water resource problems which have become critical or are anticipated to become critical within the next 20 years." As part of this identification, SJRWMD is assessing water supply needs and sources to determine those areas expected to have inadequate water resources to meet the projected 2010 water demand. Regional numerical ground water models and local analytical ground water models were used as part of the overall assessment.

The evaluation discussed here is based on the results of analytical modeling used to simulate the impacts associated with ground water withdrawals at the City of Leesburg wellfields. For the purposes of this report, the wells from which the City of Leesburg withdraws its water have been grouped into two wellfields—the downtown wellfield and the airport-mall wellfield (Figures 1 and 2). This evaluation was used as part of the overall assessment of water supply needs and sources to arrive at the projected 2010 districtwide elevation of the potentiometric surface of the Floridan aquifer system and the change in the elevation of the water table of the surficial aquifer system.

Within the area covered by the City of Leesburg wellfields, the Upper Floridan aquifer is the primary source of water supply. The Lower Floridan aquifer is a secondary source of water and is found in the Avon Park Formation and the Oldsmar Formation. The Upper Floridan aquifer in this area is composed of the Ocala Limestone, where present. The Hawthorn Group acts as a confining unit, separating the Floridan aquifer system from the overlying surficial aquifer system. The surficial aquifer system is composed of sands and clayey sands approximately 75 feet (ft) thick (Scott 1978).

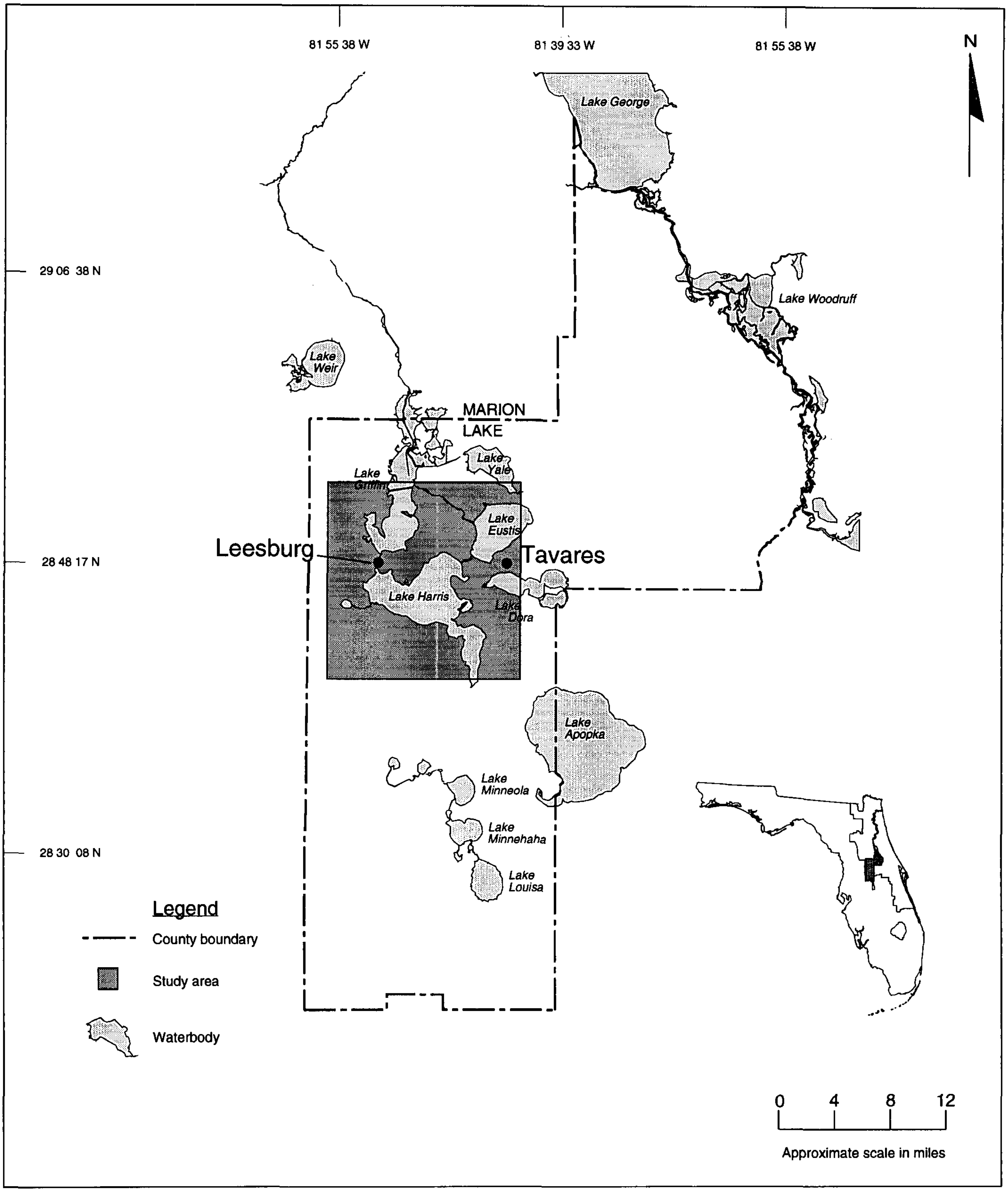


Figure 1. Location of the model domain for the City of Leesburg wellfields

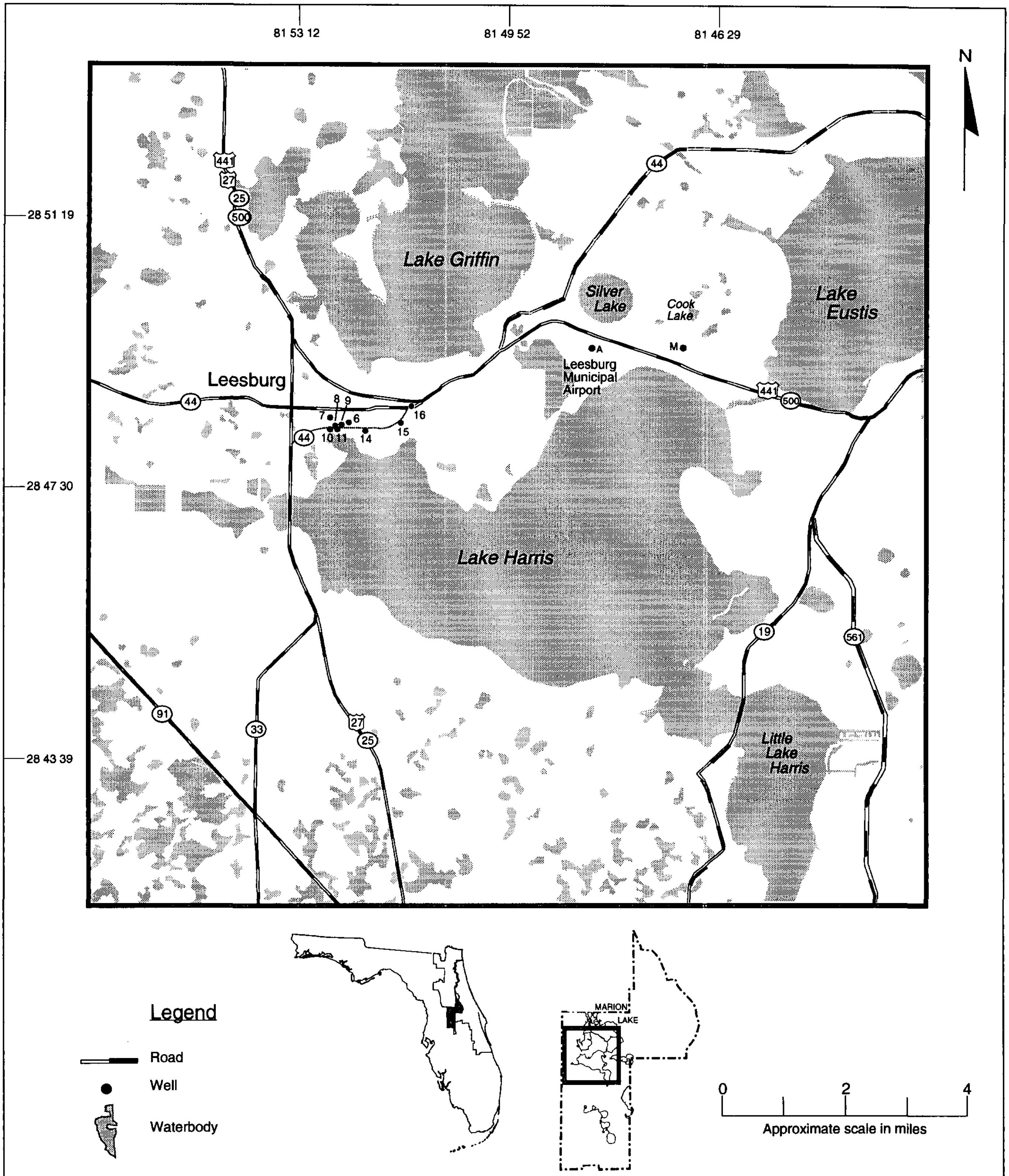


Figure 2. Model domain and locations of wells in the downtown and airport-mall wellfields, City of Leesburg

Note: Well A = airport and well M = mall.

In 1988, the City of Leesburg had nine wells at the downtown wellfield and two wells at the airport-mall wellfield. Water withdrawn from the two wellfields supplies the city's public supply water system and is used for residential household, commercial, and industrial purposes. In 1988, the city withdrew 4.0560 million gallons per day (mgd) from the two wellfields, and the city projects withdrawals of 12.1357 mgd in 2010 (Mark O'Dell, pers. com. 1994; Cynthia Moore, pers. com. 1994).

METHODS

The City of Leesburg wellfields were evaluated using the MLTLAY and DRAWDOWN models (SJRWMD unpublished). MLTLAY uses a linear analytical solution to calculate the amount of drawdown in a coupled, multi-layered, leaky-artesian aquifer (Motz 1981). DRAWDOWN also uses a linear analytical solution to calculate the amount of drawdown in a coupled, two-layered, leaky-artesian aquifer (Motz 1981). Both methods assume that homogeneous and isotropic conditions are present in the aquifer system. The models simulate steady-state conditions.

The transmissivities at the two wellfields vary substantially (Table 1), yet the drawdowns from the wellfields intersected each other when the wellfields were run

Table 1. Aquifer characteristics used in the DRAWDOWN and MLTLAY models, City of Leesburg wellfields

Aquifer Characteristics	Value
Evapotranspiration reduction coefficient	0.0008 (ft/day)/ft
Transmissivity—Surficial aquifer (downtown wellfield)	7,500 gpd/ft
Transmissivity—Upper Floridan aquifer (downtown wellfield)	165,000 gpd/ft
Transmissivity—Upper Floridan aquifer (airport-mall wellfield)	604,000 gpd/ft
Transmissivity—Lower Floridan aquifer (downtown wellfield)	300,000 gpd/ft
Leakance—Surficial aquifer to Upper Floridan aquifer	0.009 (gpd/ft^2)/ft
Leakance—Upper Floridan aquifer to Lower Floridan aquifer	0.0004 (gpd/ft^2)/ft

Note: (ft/day)/ft = feet per day per foot
gpd/ft = gallons per day per foot
(gpd/ft^2)/ft = gallons per day per square foot per foot

as two separate models. To account for this condition while still maintaining differing transmissivities at the wellfields, one model domain was used and two models were run. The downtown wellfield model (using MLTLAY) and the airport-mall wellfield model (using DRAWDOWN) were run individually with the respective aquifer parameters, then the grids created from each model run were superimposed and added together to obtain a cumulative drawdown result. MLTLAY was used to simulate drawdown at the downtown wellfield because a multiple aquifer system, consisting of the surficial aquifer system, the Upper Floridan aquifer, and the Lower Floridan aquifer, is present and pumping occurs in the Upper Floridan and Lower Floridan aquifers. DRAWDOWN was used to simulate drawdowns at the airport-mall wellfield because pumping occurs only in the Upper Floridan aquifer; therefore, it was necessary to model only a two-layer system consisting of the surficial aquifer system and the Upper Floridan aquifer.

The model domain was chosen to be large enough to include the most significant drawdown in the areas around the wellfields. Drawdown actually occurs beyond the extent of the model domain. The dimensions of the model domain have no bearing on the drawdown results. The model domain, which was 74,000 ft long and 74,000 ft wide, was selected to incorporate both wellfields into one model.

Aquifer characteristics used in the model include transmissivity of the surficial aquifer system and the Upper Floridan and Lower Floridan aquifers, leakance of the confining unit between the surficial aquifer system and the Upper Floridan aquifer, leakance of the middle semi-confining unit separating the Upper Floridan and Lower Floridan aquifers, and the evapotranspiration reduction coefficient (Table 1). Transmissivity values of the Floridan aquifer system at both wellfields were derived from short-term pumping tests at the well sites (Mark O'Dell, pers. com. 1992) (Table 2). An average value for the transmissivity of the Upper Floridan and Lower Floridan aquifers for the downtown wellfield was computed using a method that estimates the transmissivity of an aquifer from the specific capacity of a well (Theis et al. 1963). Based upon the elevation and thickness of the middle semi-confining unit (Tibbals 1990), it appears that wells 14, 15, and 16 penetrate the Lower Floridan aquifer. The calculated transmissivities for wells 14, 15, and 16 were averaged together to obtain a transmissivity value to be used in the model for the Lower Floridan aquifer. The calculated transmissivities for wells 6 through 11 were averaged together to obtain a transmissivity value to be used in the model for the Upper Floridan aquifer.

The transmissivity of the surficial aquifer system was determined using the following formula:

$$\textit{Transmissivity} = \textit{saturated aquifer thickness} \cdot \textit{hydraulic conductivity}$$

Well logs indicated that the thickness of the surficial layer of sediments averages 75 ft in this area (Scott 1978). Geologic information indicates that the surficial sediments

Table 2. Pump test results, City of Leesburg wellfields

Wellfield	Well	Pumpage (gallons per minute)	Drawdown (feet)	Duration (minutes)	Casing Diameter (inches)	Transmissivity (gpd/ft)
Downtown	6	913	15.5	45	12	114,000
	7	1,070	9.5	45	12	227,000
	8	544	13.5	45	12	76,000
	9	913	13.5	45	12	132,000
	10	1,590	10.0	45	12	327,000
	11	1,470	23.0	45	16	120,000
	14	1,405	17.0	45	18	156,000
	15	2,100	8.5	45	30	466,000
	16	2,100	14.0	30	30	266,000
Airport-mall	Airport	1,000	3.5	30	12	594,000
	Mall	1,500	5.0	30	14	614,000

Note: gpd/ft = gallons per day per foot

Source: Mark O'Dell (pers. com. 1992)

are composed of clayey sands at the wellfields (Scott 1978). Within the model domain, an irregular distribution of medium to fine-grained sand, silt, and peat also is present. Based on the composition and thickness of surficial sediments, a hydraulic conductivity of 100 gallons per day per square foot was used to estimate the transmissivity of the surficial aquifer (Freeze and Cherry 1979).

The leakance value for the confining unit separating the surficial aquifer system and the Upper Floridan aquifer, measured in gallons per day per square foot per foot, was averaged from data in Jammal & Associates (1986) and Tibbals (1981, 1990). The leakance value for the middle semi-confining unit separating the Upper and Lower Floridan aquifers was taken from Tibbals (1981, 1990).

The evapotranspiration reduction coefficient, measured in feet per day per foot, was determined using a graph from Tibbals (1990, p. E10). The evapotranspiration reduction coefficient describes the rate at which evapotranspiration is reduced per unit of water table drawdown. It is based upon a depth to the water table of 9 ft below land surface. The depth to the water table was determined using land surface elevations from U.S. Geological Survey quadrangles near the wellfields. The depth to the water table, however, may be lower than the value used in the calculation, because of the number of lakes in the area.

Well pumpage rates for 1988 and 2010, measured in million gallons per day, were used in the model (Table 3). Pumpage for each well at the downtown wellfield was calculated using data from the city's 1988 Consumptive Use Permits (SJRWMD 1988).

Table 3. Pumpage values used in the models, City of Leesburg wellfields

Wellfield	Well	1988 Calculated Pumpage (mgd)	2010 Projected Pumpage (mgd)
Downtown	6	0.3053	0.8396
	7	0.3171	0.8719
	8	0.1879	0.5167
	9	0.3053	0.8396
	10	0.5402	1.4855
	11	0.4603	1.2659
	14	0.4463	1.2270
	15	0.5073	1.3951
	16	0.5073	1.3951
Airport-mall	Airport	0.021	0.9042
	Mall	0.458	1.3951
Totals		4.0560	12.1357

Note: mgd = million gallons per day

At the downtown wellfield, the pump capacities (SJRWMD 1988) were added and the summed figure was divided into the pump capacity for each well (Table 4). The resultant fraction was multiplied by the total wellfield withdrawal to yield the pumpage for each individual well for 1988 and 2010. Pumpage values for the airport-mall wellfield in 1988 were provided by Mark O'Dell (Cynthia Moore, pers. com. 1994). Projected 2010 withdrawals at the airport-mall were calculated using the same method used for the downtown wellfield. The models treat pumping as a continuous event; therefore, the wells were not turned on and off in the model.

The 2010 projected pumpage for both wellfields is 12.1357 mgd (Mark O'Dell, pers. com. 1994; Cynthia Moore, pers. com. 1994). No new wells beyond those in existence in 1988 are planned for either wellfield through 2010. The model-calculated drawdowns are based on the assumption that all wells were pumping. In reality, however, all of the wells in the wellfields are never pumped simultaneously.

Table 4. Well characteristics, City of Leesburg wellfields

Wellfield	Well	Latitude	Longitude	Total Depth (feet)	Casing Depth (feet)	Open Hole (feet)	Average Pumping Rate*	Pump Capacity*
Downtown	6	284827	815222	390.0	57.3	332.7	902.8	909.7
	7	284831	815240	352.0	94.2	257.8	937.5	1,069.4
	8	284824	815235	376.5	104.7	271.8	555.6	548.6
	9	284825	815229	272.0	97.5	114.5	902.8	909.7
	10	284821	815240	94.0	90.0	4.0	1,597.2	1,590.3
	11	284821	815233	321.0	83.0	238.0	1,361.1	1,472.2
	14	284820	815206	938.0	851.0	87.0	1,319.4	1,402.8
	15	284827	815132	738.0	380.0	358.0	1,500.0	2,100.0
	16	284841	815122	840.0	380.0	460.0	1,500.0	2,100.0
Airport-mall	Airport	284932	814828	500.0	350.0	150.0	972.2	1,000.0
	Mall	284933	814700	550.0	350.0	200.0	1,500.0	1,500.0

*Measured in gallons per minute

Source: SJRWMD (1988)

RESULTS

The drawdowns listed in Table 5 are the drawdowns calculated from running each model individually, before the grids were superimposed and added to obtain the cumulative effect of the drawdowns. The difference between the individual and cumulative model drawdowns is not significant.

At the downtown wellfield, the change in simulated drawdowns from 1988 to 2010 at the pumping wells ranged from 0.2 to 4.5 ft in the surficial aquifer system, from 0.8 to 12.3 ft in the Upper Floridan aquifer, and from 2.6 to 7.3 ft in the Lower Floridan aquifer (Table 5). Simulated 1988 drawdowns at the downtown wellfield ranged from 0.2 to 2.5 ft in the surficial aquifer system, from 0.5 to 7.0 ft in the Upper Floridan aquifer, and from

Table 5. Simulated drawdowns in the City of Leesburg wellfields for 1988 and 2010

Wellfield	Well	Simulated 1988 Drawdown (feet)				Simulated 2010 Drawdown (feet)				Drawdown Difference (feet)		
		Pumping Rate (gpm)	Surficial Aquifer System	Upper Floridan Aquifer	Lower Floridan Aquifer	Pumping Rate (gpm)	Surficial Aquifer System	Upper Floridan Aquifer	Lower Floridan Aquifer	Surficial Aquifer System	Upper Floridan Aquifer	Lower Floridan Aquifer
Downtown	6	210	1.9	5.0	1.8	580	5.1	13.6	5.0	3.2	8.6	3.2
	7	220	1.9	5.2	1.5	610	5.2	14.2	4.1	3.3	9.0	2.6
	8	130	2.0	5.5	1.6	360	5.4	15.1	4.3	3.4	9.6	2.7
	9	210	2.1	5.7	1.7	580	5.8	15.8	4.6	3.7	10.1	2.9
	10	375	2.5	7.0	1.5	1,030	7.0	19.3	4.1	4.5	12.3	2.6
	11	320	2.4	6.8	1.6	880	6.7	18.8	4.4	4.3	12.0	2.8
	14	310	0.6	1.7	3.7	850	1.7	4.6	10.2	1.1	2.9	6.5
	15	350	0.2	0.6	4.2	970	0.5	1.7	11.5	0.3	1.1	7.3
	16	350	0.2	0.5	4.1	970	0.4	1.3	11.3	0.2	0.8	7.2
Airport-mall	Airport	1	0.1	0.2	NA	630	0.9	3.4	NA	0.8	3.2	NA
	Mall	310	0.2	1.2	NA	970	1.0	4.7	NA	0.8	3.5	NA

Note: gpm = gallons per minute
NA = not applicable

1.5 to 4.2 ft in the Lower Floridan aquifer. Simulated 2010 drawdowns at the downtown wellfield ranged from 0.4 to 7.0 ft in the surficial aquifer system, from 1.3 to 19.3 ft in the Upper Floridan aquifer, and from 4.1 to 11.5 ft in the Lower Floridan aquifer.

At the airport-mall wellfield, the change in simulated drawdowns from 1988 to 2010 at the pumping wells was 0.8 ft in the surficial aquifer system and ranged from 3.2 to 3.5 ft in the Upper Floridan aquifer. Simulated 1988 drawdowns at the airport-mall wellfield ranged from 0.1 to 0.2 ft in the surficial aquifer system and from 0.2 to 1.2 ft in the Upper Floridan aquifer. Simulated 2010 drawdowns at the airport-mall wellfield ranged from 0.9 to 1.0 ft in the surficial aquifer system and from 3.4 to 4.7 ft in the Upper Floridan aquifer.

Simulated drawdowns for each wellfield were superimposed and contoured for the surficial aquifer and the Upper Floridan aquifer for both wellfields (Figures 3–6). The differences between the drawdowns in 1988 and 2010 also were contoured (Figures 7 and 8).

Discussion

The relatively large projected drawdowns at the downtown wellfield are due to the proximity of the wells in the wellfield and a projected increase in withdrawal of 8.0797 mgd from 1988 to 2010. The wells at the airport-mall wellfield have lower drawdowns due to the lower pumpage rates and high transmissivities at the wells.

Due to withdrawals from other existing legal users, there is more impact on the ground water system than is evident from modeling only the City of Leesburg public water supply wells; however, the City of Leesburg is the largest withdrawer of water in this area.

Conclusions

Based on the results of the model, the simulated drawdowns for the projected 2010 pumpages at the downtown wellfield could have a pronounced effect on the Upper Floridan aquifer. This effect can be attributed to three reasons: (1) the nine wells in the downtown wellfield are located in an area of approximately one square mile, (2) the nature of the aquifer, and (3) the City of Leesburg projects increases in withdrawal from 1988 to 2010 greater than 8 mgd. Little effect is expected on the surficial aquifer system due to increased withdrawals.

Based on the results of the model, the simulated drawdowns for the projected 2010 pumpages at the airport-mall wellfield are small and probably will have less impact on

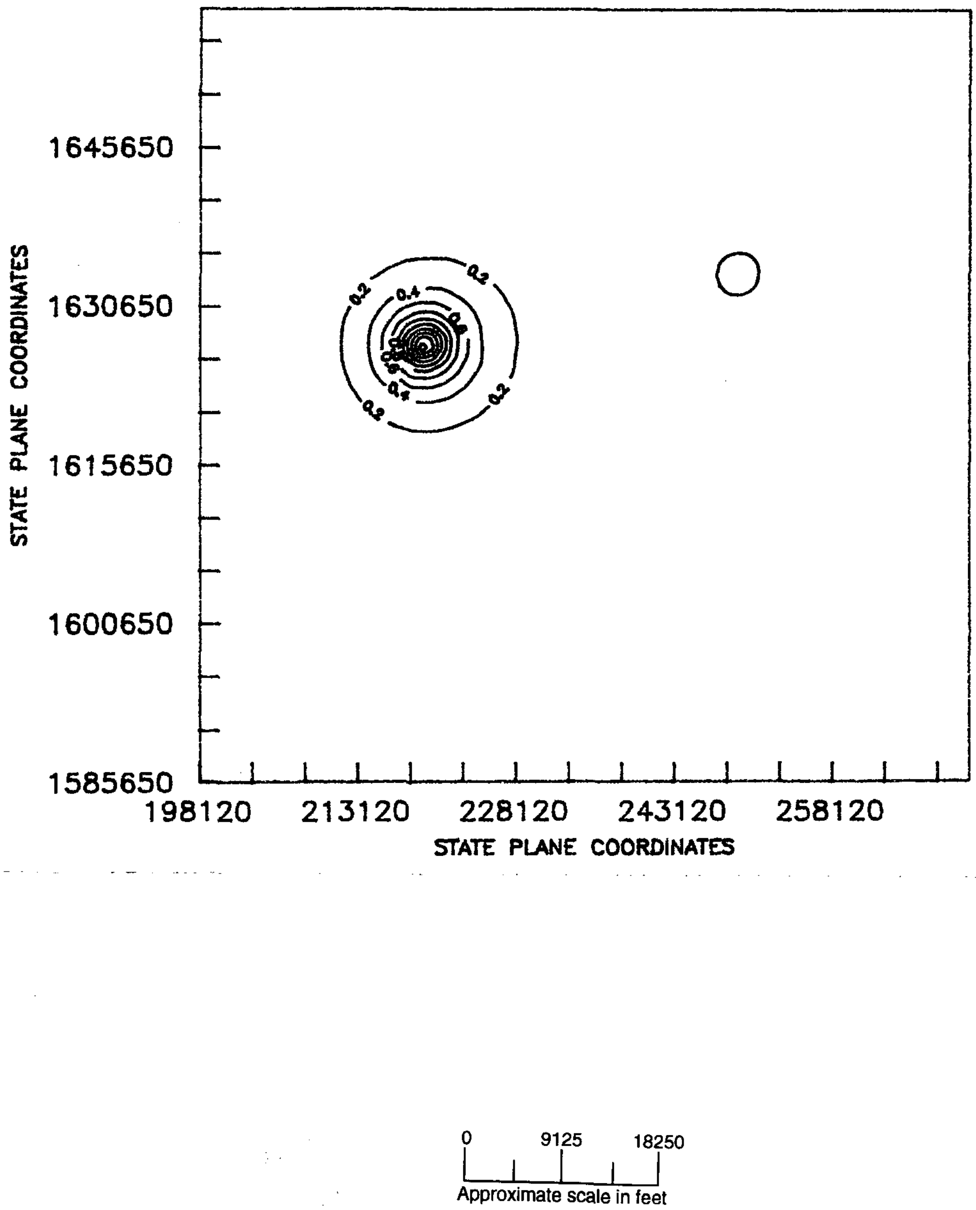


Figure 3. **Simulated 1988 drawdowns in the surficial aquifer system at the City of Leesburg wellfields (measured in feet)**

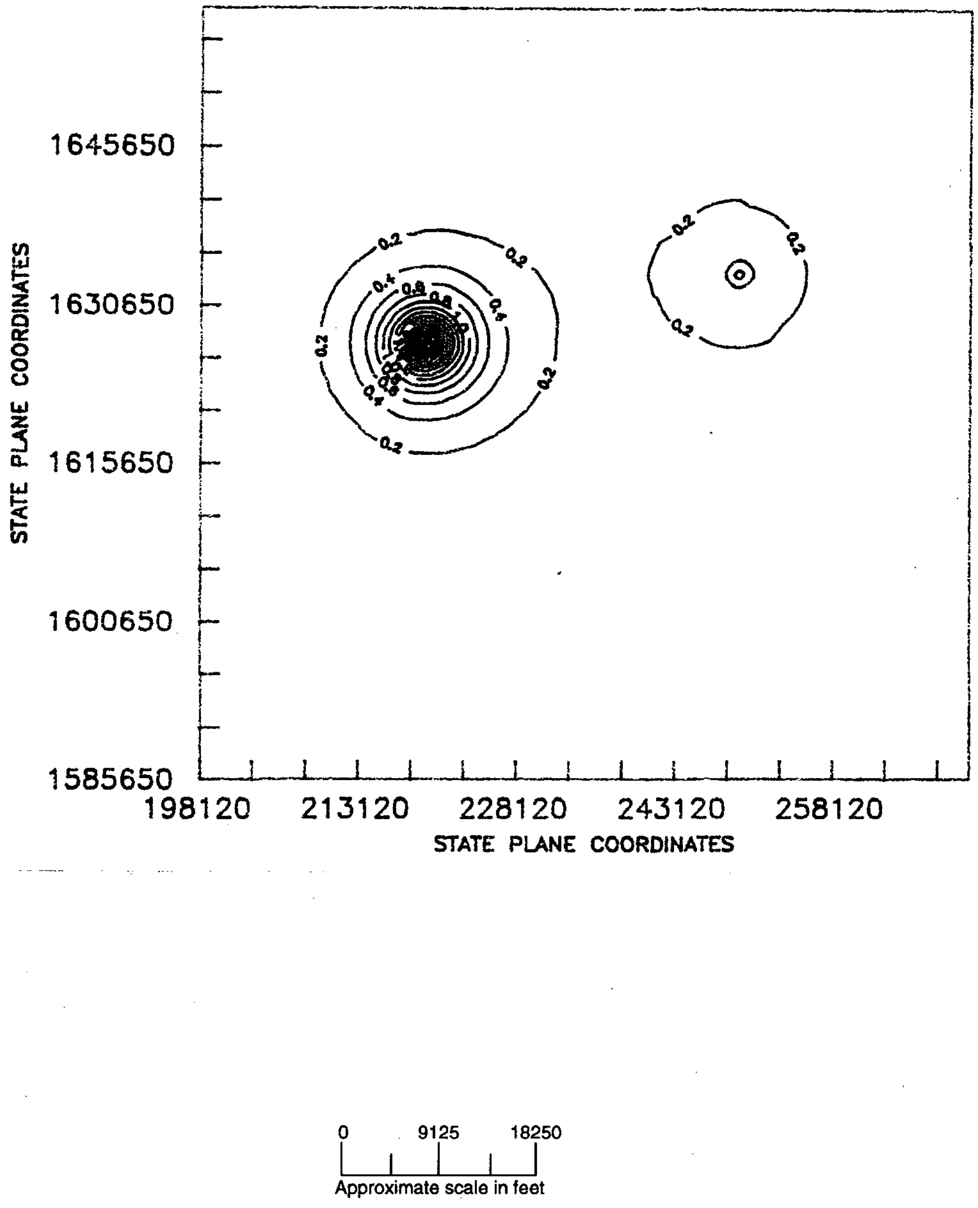


Figure 4. **Simulated 1988 drawdowns in the Upper Floridan aquifer at the City of Leesburg wellfields (measured in feet)**

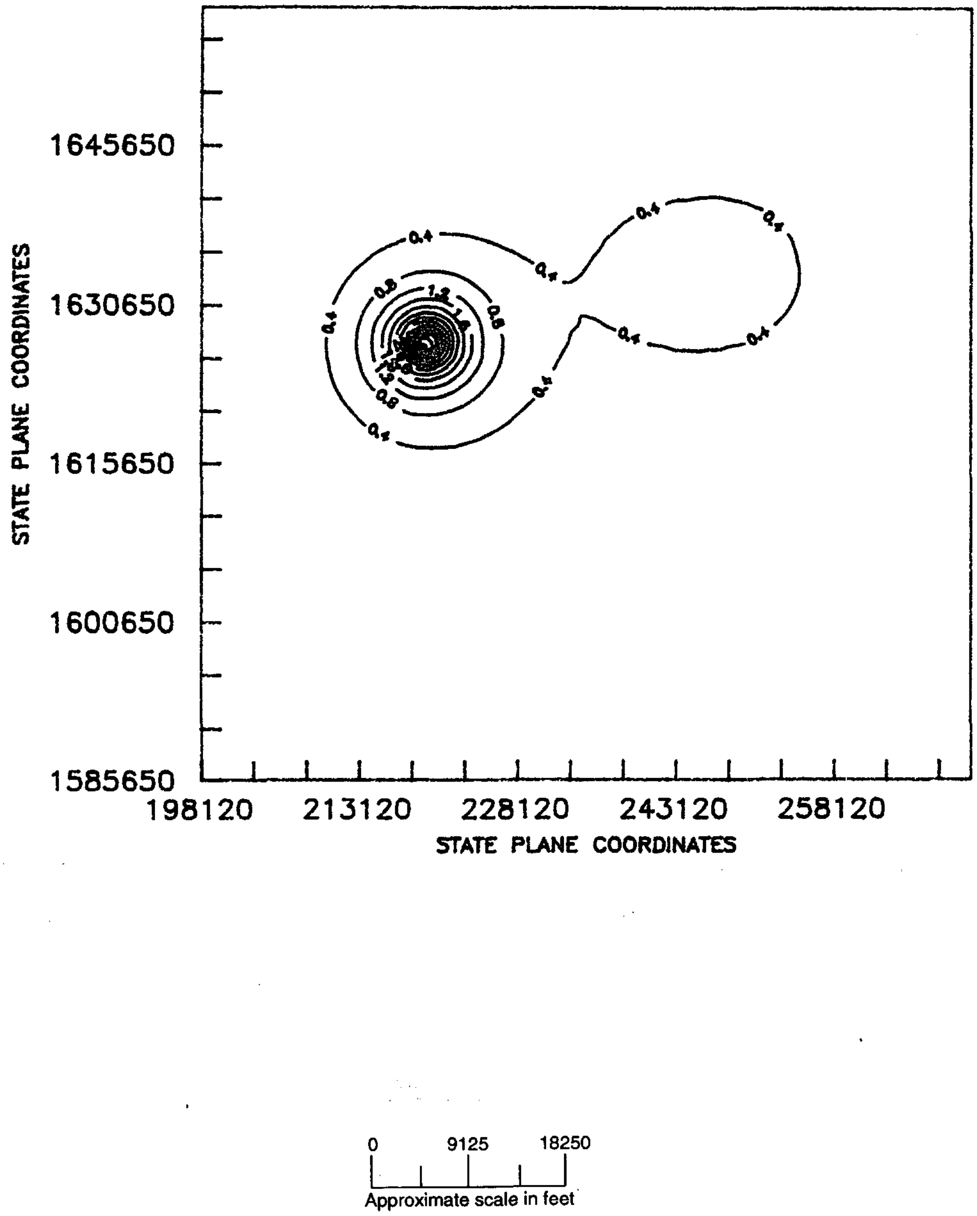
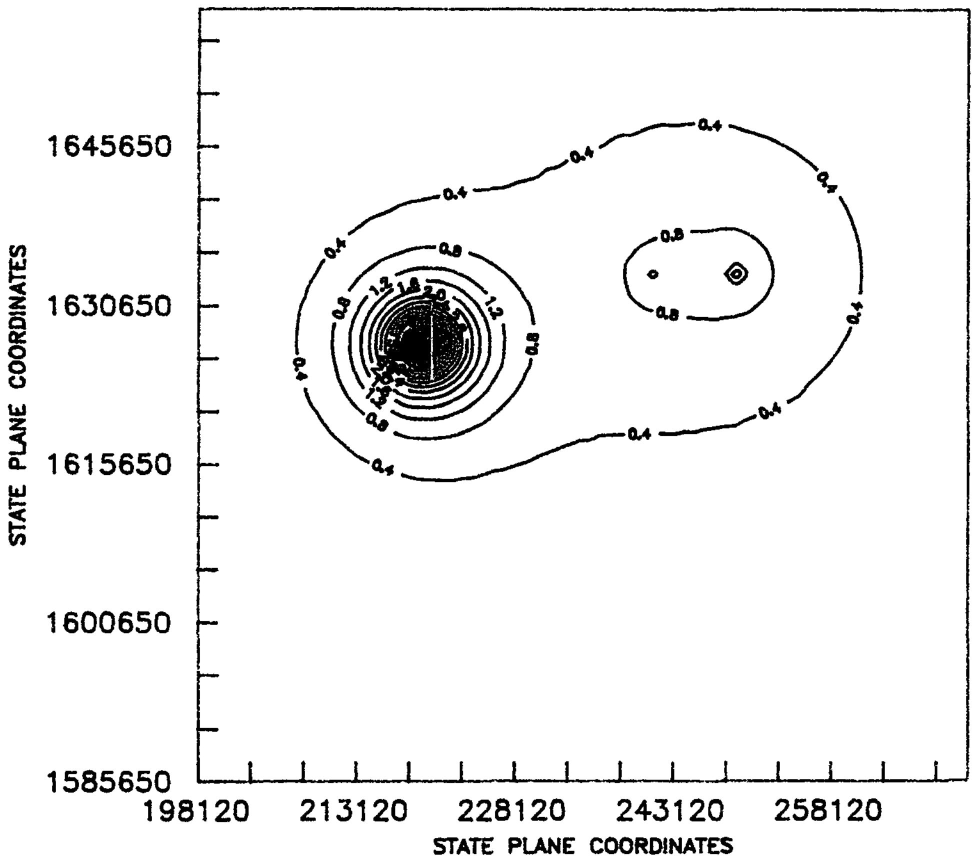


Figure 5. **Simulated 2010 drawdowns in the surficial aquifer system at the City of Leesburg wellfields (measured in feet)**



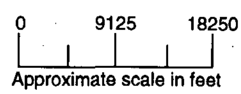


Figure 6. **Simulated 2010 drawdowns in the Upper Floridan aquifer at the City of Leesburg wellfields (measured in feet)**

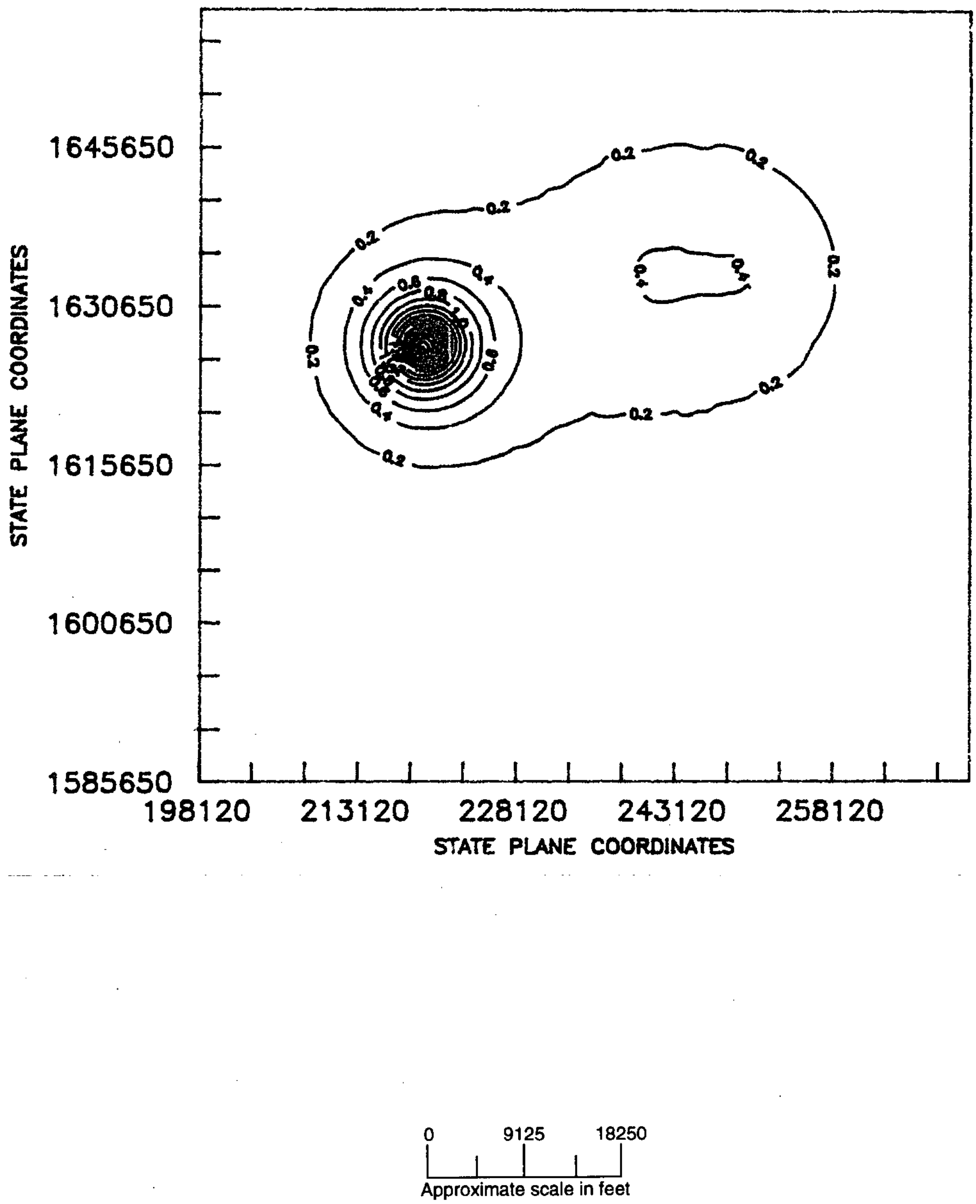


Figure 7. **Differences in simulated drawdowns between 1988 and 2010 in the surficial aquifer system at the City of Leesburg wellfields (measured in feet)**

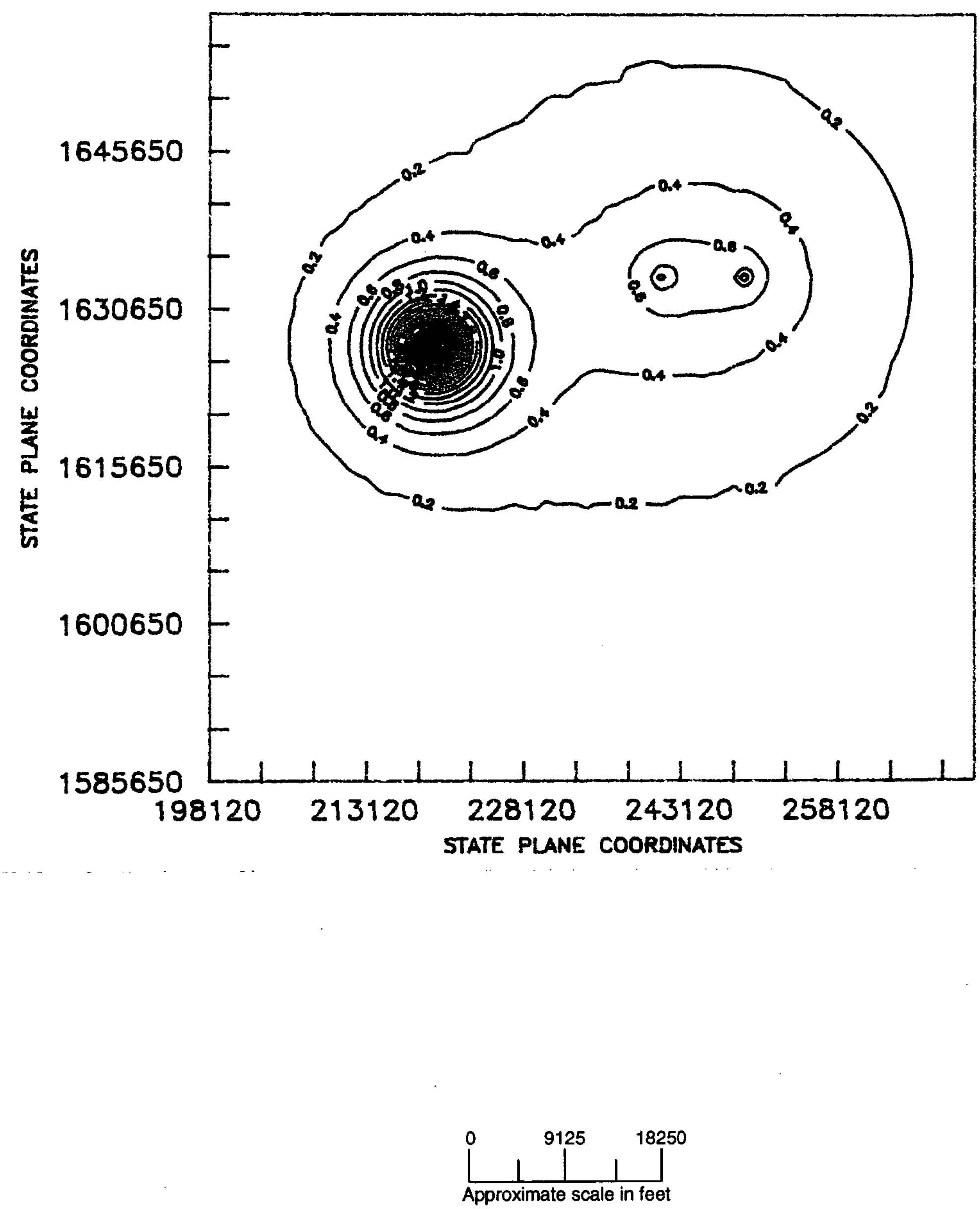


Figure 8. **Differences in simulated drawdowns between 1988 and 2010 in the Upper Floridan aquifer at the City of Leesburg wellfields (measured in feet)**

the Floridan aquifer and surficial aquifer systems than will the withdrawals at the downtown wellfield.

The results of this study have been incorporated with regional ground water flow models into the overall water supply needs and sources assessment to provide a basis to ensure that future increased withdrawals at the wellfields occur in a manner that is not detrimental to the water and vegetative resources. Data collected from this analytical modeling provide the ground work for future evaluations and monitoring needs.

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CONVERSION TABLE

Multiply	By	To Obtain
foot (ft)	0.3048	meter (m)
million gallons per day (mgd)	3.785×10^3	cubic meters per day (m^3/d)
gallons per day per foot (gpd/ft)	1.242×10^{-2}	square meters per day (m^2/d)
gallons per day per square foot (gpd/ft^2)	4.075×10^{-2}	meters per day (m/d)
gallons per day per square foot per foot ([gpd/ft^2]/ft)	0.1337	meters per day per meter ([m/d]/m)
feet per day per foot ([ft/d]/ft)	1.0	meters per day per meter ([m/d]/m)