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PROJECTED AQUIFER DRAWDOWNS CITY OF ST. AUGUSTINE WELLFIELD ST. JOHNS COUNTY, FLORIDA

by

David J. Toth, Ph.D., P.G.

David J. Toth
Professional Geologist
License No. PG110
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St. Johns River Water Management District
Palatka, Florida

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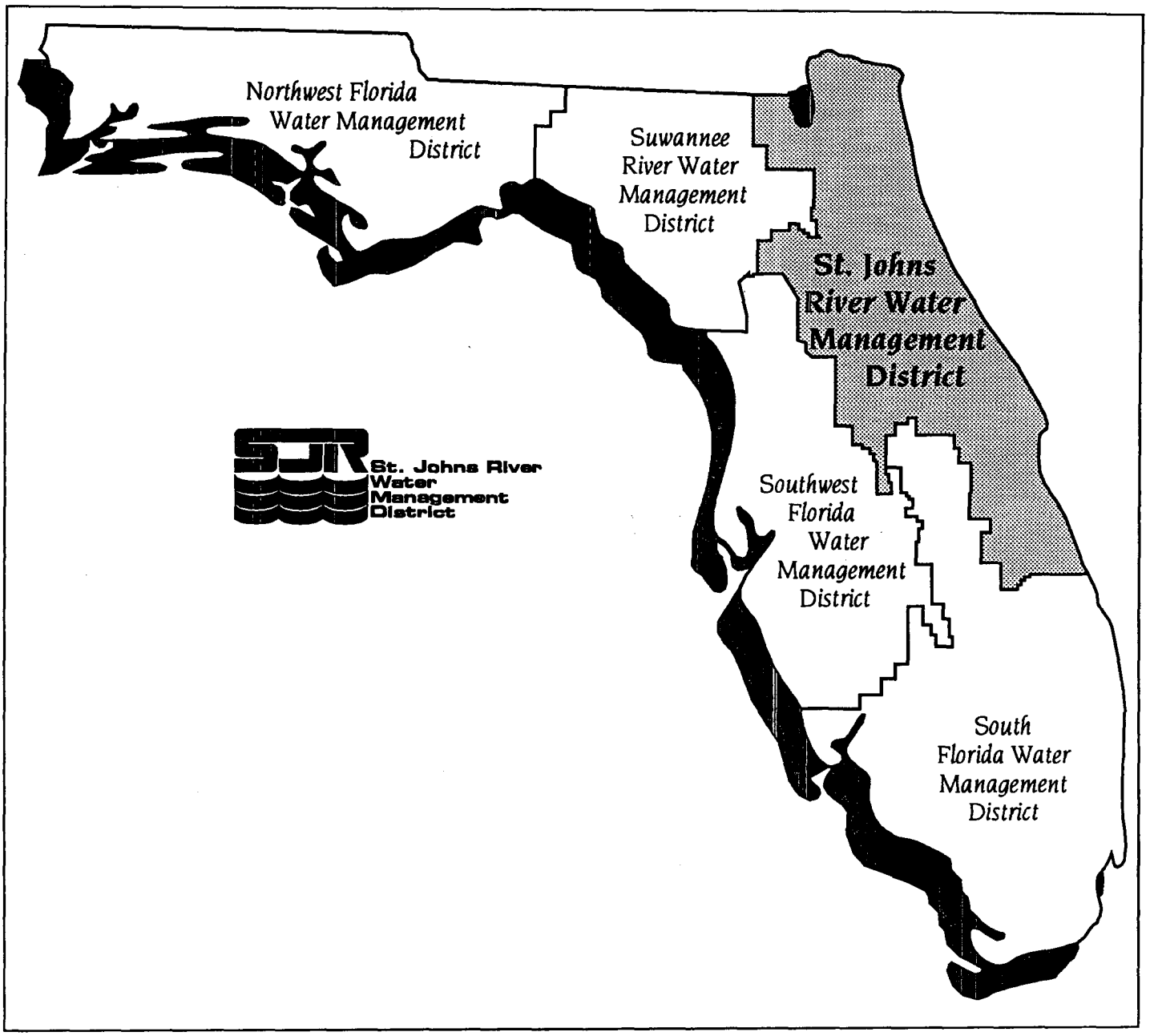

The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued 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 analytical models, MLTLAY and SURFDOWN, were used to simulate changes in the water table and the potentiometric surfaces of the surficial aquifer system (SAS) and the Upper Floridan aquifer (UFA) based on 2010 projected pumpages at the City of St. Augustine wellfield. The MLTLAY model calculates drawdowns in a multilayered, leaky-artesian aquifer system. The SURFDOWN model calculates drawdowns for a coupled two-aquifer system. Both models assume homogeneous, isotropic, and steady-state conditions. Simulated 1988 drawdowns at the wells ranged from 1.54 to 5.13 feet (ft) for SAS and from 3.75 to 4.26 ft for UFA. Simulated 2010 drawdowns ranged from 5.69 to 13.24 ft for SAS and from 11.95 to 12.30 ft for UFA. The change in drawdown from 1988 to 2010 was about 1.75 ft for the water table and ranged from 1.77 to 8.77 ft for SAS and from 7.72 to 8.20 ft for UFA. The simulated drawdown for projected pumpages at the City of St. Augustine wellfield have a pronounced effect on the elevation of the potentiometric surface of SAS and UFA at the pumping wells. Away from these wells there is little effect on the elevation of the potentiometric surface of SAS. The projected pumpage has little effect on the elevation of the water table.

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 supply demand. Regional numerical ground water models and local analytical ground water models are used as part of this overall assessment.

The evaluation discussed here is based on the results of two analytical models, which were used to simulate the impacts associated with ground water withdrawals at the City of St. Augustine wellfield (Figures 1 and 2). The evaluation was used as part of the overall assessment of water supply needs and sources to arrive at the projected 2010 districtwide drawdown in the water table and the elevations of the potentiometric surfaces of the surficial aquifer and Floridan aquifer systems.

Within the area covered by the City of St. Augustine wellfield, there are two aquifer systems: the surficial and the Floridan. Two ground water flow systems occur within the surficial aquifer system. The uppermost system consists of water-saturated sand and shell and exists under unconfined conditions (CH2M HILL 1982). It is referred to in this paper as the unconfined portion of the surficial aquifer system. The lower system consists of sand, shell, clay, and limestone and exists under confined conditions (CH2M HILL 1982; Spechler and Hampson 1984). It is referred to in this paper as the confined portion of the surficial aquifer system. The two systems are separated by a confining unit referred to in this paper as the semiconfining unit of the surficial aquifer. The Hawthorn Group acts as the upper confining unit, separating the surficial aquifer system and the Upper Floridan aquifer.

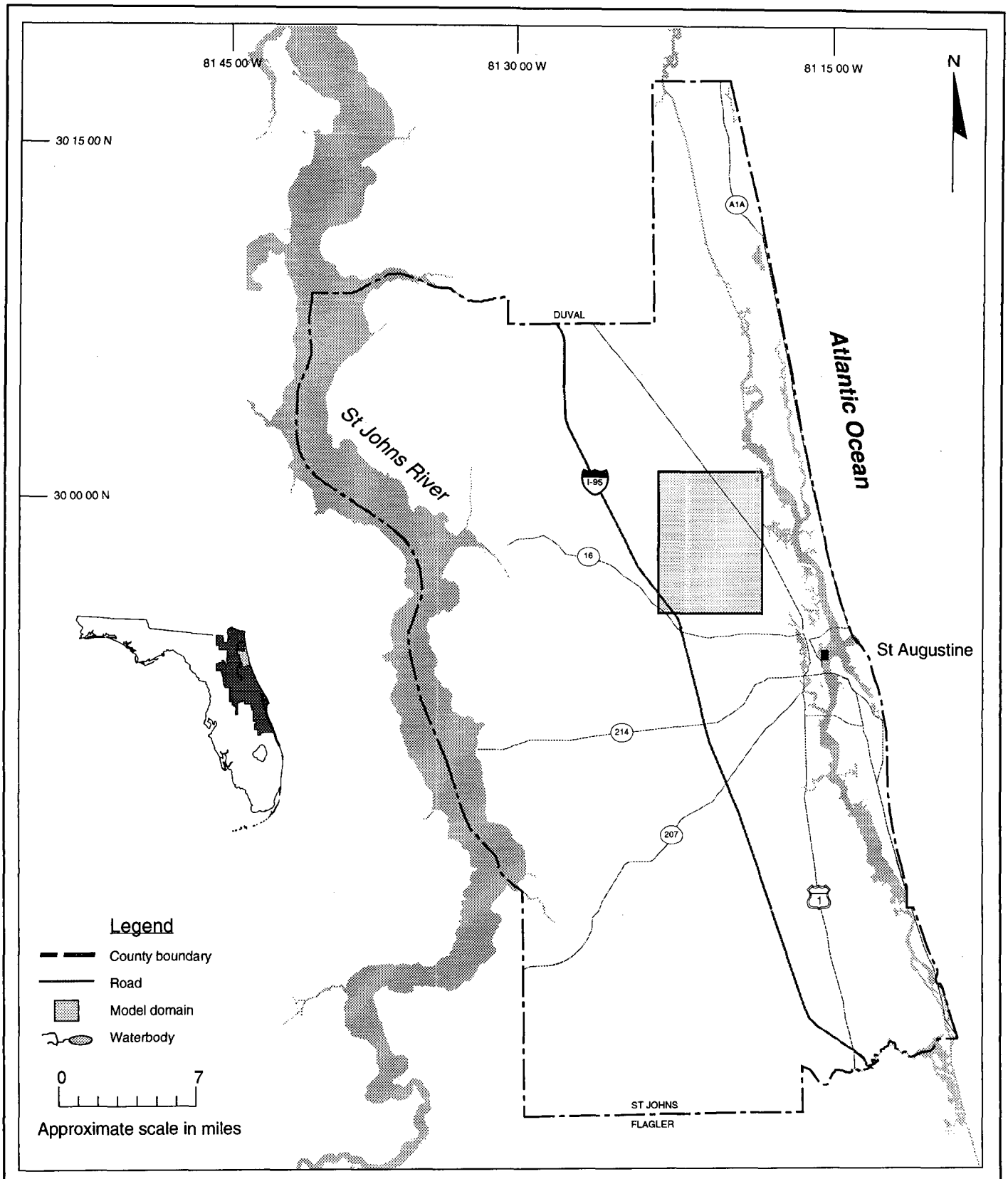

Figure 1. Location of the model domain for the City of St. Augustine wellfield

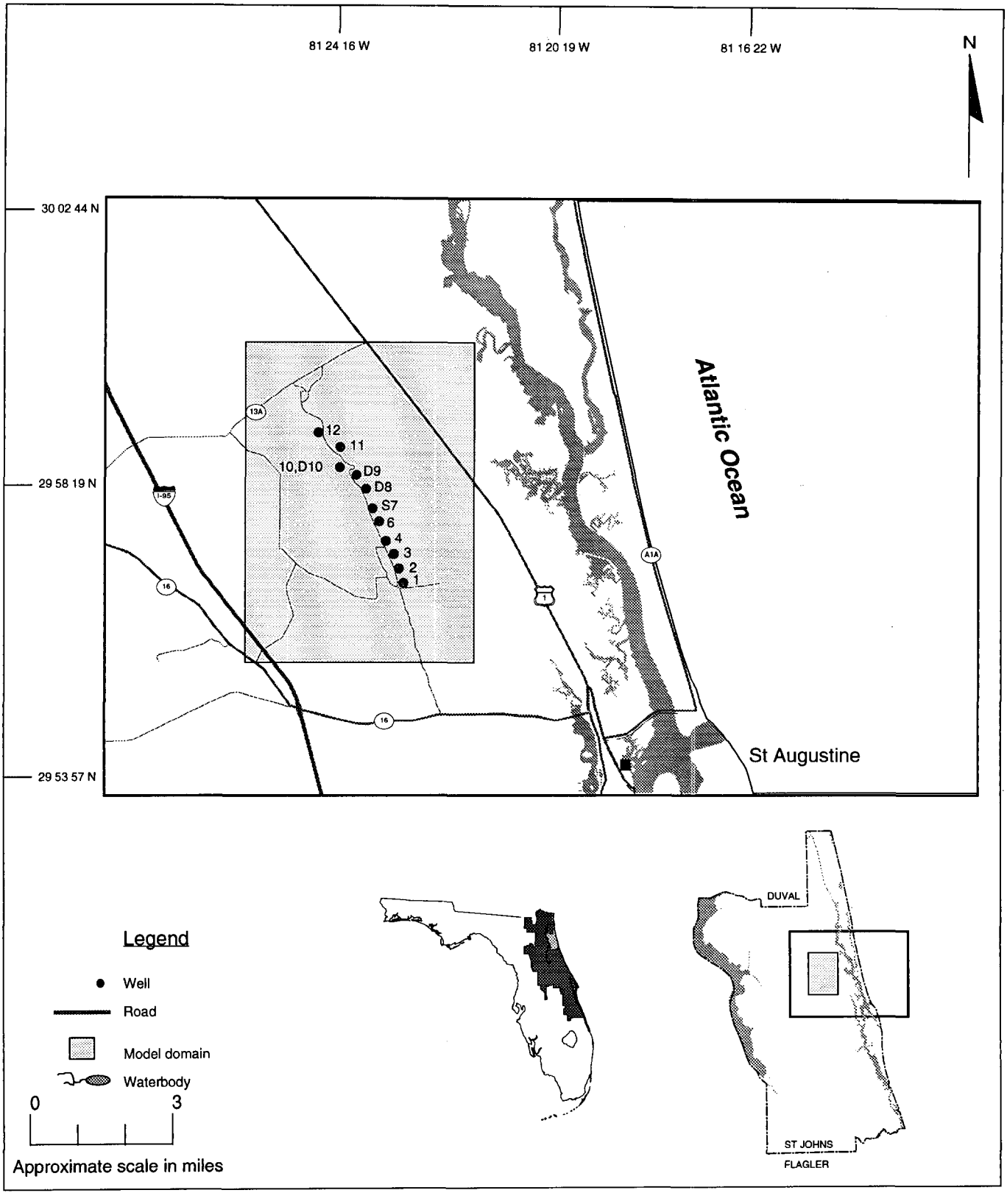

Figure 2. Model domain and well locations of the City of St. Augustine wellfield

The City of St. Augustine withdrew water from nine surficial and three Floridan aquifer wells in 1988. The number of wells in the City of St. Augustine wellfield is not expected to change by the year 2010. Water use in 1988 was 1.687 million gallons per day (mgd) (Florence 1990). Projected 2010 pumpage is 3.82 mgd (Cubbedge 1993a). The City of St. Augustine combines water produced from both its surficial and Floridan aquifer wells before distributing water to its customers. Water is combined in a 70 percent to 30 percent (70:30) ratio (Cubbedge 1993b). This blending is necessary to increase the yield from the wellfield and to improve water quality.

METHODS

Impacts to the ground water flow system resulting from withdrawals from the City of St. Augustine wellfield were evaluated using the MLTLAY (SJRWMD unpublished) and SURFDOWN (Huang 1994, draft) models. The MLTLAY model uses a linear analytical solution for a multilayered, leaky-artesian aquifer system to calculate the amount of drawdown in the surficial aquifer system and the Upper Floridan aquifer. The method assumes that homogeneous and isotropic conditions prevail in the surficial aquifer and Floridan aquifer systems. The model simulated steady-state conditions. The model considers the flow of water through multiple aquifers separated by semipervious leaky layers. The model has the capability of simulating the withdrawal of water from either the surficial aquifer system or the Upper Floridan aquifer or from both simultaneously.

The SURFDOWN model is based on an analytical solution for a coupled two-aquifer system in which pumping from an underlying aquifer is balanced by a reduction in evapotranspiration from an overlying aquifer (Motz 1978). SURFDOWN is used to solve for drawdowns in the water table of the unconfined portion of the surficial aquifer system as a function of drawdowns in the potentiometric surface of the confined portion of the surficial aquifer system. SURFDOWN is an analytical, steady-state, two-layered flow model. The analysis is based on the assumption that homogeneous and isotropic conditions prevail in both the unconfined and confined portions of the surficial aquifer system.

The model domain was chosen to be large enough to include the most significant drawdown in the area around the wellfield. Drawdowns actually occur beyond the extent of the model domain. The dimensions of the model domain are 22,110 feet (ft) wide and 30,030 ft long.

Aquifer characteristics used in the models include transmissivity of the confined and unconfined portions of the surficial aquifer system and the Upper Floridan aquifer, leakance of the semiconfining unit of the surficial aquifer system and of the upper confining unit, and the evapotranspiration reduction coefficient (Table 1). The transmissivity of the surficial aquifer system and the Upper Floridan aquifer,

Table 1. Aquifer characteristics used in the MLTLAY and SURFDOWN models, City of St. Augustine wellfield

Aquifer Characteristic	Wells	Value
Evapotranspiration reduction coefficient		0.00046 (ft/day)/ft
Transmissivity—unconfined portion of the surficial aquifer system		748 gpd/ft
Leakance—semiconfining unit of the surficial aquifer system	1–7	0.0075 $(gpd/ft^2)/ft$
	10–12	0.0075 $(gpd/ft^2)/ft$
Transmissivity—confined portion of the surficial aquifer system	1–7	17,000 gpd/ft
	10–12	128,000 gpd/ft
Leakance—upper confining unit	D8–D10	7.48×10^{-7} $(gpd/ft^2)/ft$
Transmissivity—Upper Floridan aquifer	D8–D10	165,000 gpd/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

Source: CH2M HILL 1982; Tibbals 1990

measured in gallons per day per foot, came from pump tests (CH2M HILL 1982). The transmissivity of the unconfined portion of the surficial aquifer system was determined using the following formula.

Transmissivity = aquifer thickness · hydraulic conductivity

CH2M HILL (1982) indicated that the saturated thickness of the unconfined portion of the surficial aquifer system is 15 ft, based on an estimated depth to water of 7 ft below land surface at the wellfield. Geologic information indicates that it is composed of sand and shell (CH2M HILL 1982). Based on this information and the saturated thickness, an assumed hydraulic conductivity of 50.0 gallons per day per square foot was used to determine the transmissivity of the unconfined portion of the surficial aquifer system. This value is consistent with values reported by Fetter (1980) for this lithology.

Leakance of the semiconfining unit of the surficial aquifer system and leakance of the upper confining unit, measured in gallons per day per square foot per foot, came from CH2M HILL (1982).

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 7 ft below land surface at the wellfield.

Because the transmissivity of the surficial aquifer system differs between the north and south parts of the wellfield, the MLTLAY and SURFDOWN models were run twice. In the first run, drawdowns were calculated for surficial aquifer wells 1–7. In the second run, drawdowns were calculated for surficial aquifer wells 10–12 and the Upper Floridan aquifer wells. Total drawdown was obtained by adding the drawdowns from the two runs.

Well pumpage rates for 1988 and 2010, measured in million gallons per day, were used in the model (Table 2). Pumpage for each well in 1988 was based on a total metered water use of 1.687 mgd reported by Florence (1990) and was determined based on the recommended pumping rate of each well (CH2M HILL 1982) and the percentage of time each well was operated in 1988 (Cubbedge 1991). The calculated

Table 2. Pumpage values used in the MLTLAY and SURFDOWN models of the City of St. Augustine wellfield

Aquifer	Well	Latitude	Longitude	1988 Pumpage (mgd)	Projected 2010 Pumpage (mgd)
Surficial	1	295656	802301	0.062	0.180
	2	295710	812305	0.027	0.144
	3	295725	812310	0.032	0.072
	4	295738	812316	0.031	0.072
	6	295805	812329	0.028	0.072
	7	295814	812333	0.019	0.108
	10	295856	812400	0.433	0.540
	11	295909	812409	0.238	0.504
	12	295921	812415	0.292	0.576
Upper Floridan	D8	295827	812342	0.136	0.517
	D9	295841	812351	0.189	0.517
	D10	295856	812400	0.199	0.517

Note: mgd = million gallons per day

pumpage produces a surficial/Floridan aquifer water blend of 69 percent to 31 percent, which closely agrees with Cubbedge's 70:30 ratio.

The 2010 total projected pumpage at the City of St. Augustine wellfield is estimated to be 3.82 mgd (City of St. Augustine 1987, Table 4-1, p. 69). Pumpage for the Upper Floridan aquifer wells was obtained by subtracting the total withdrawals from the surficial aquifer wells (2.27 mgd) from the projected 2010 pumpage and equally dividing the withdrawals among the Upper Floridan aquifer wells. The resulting withdrawals produced a projected 60:40 blend of surficial and Floridan aquifer water for 2010.

RESULTS

Drawdowns calculated by the model are based on the assumption that all wells were pumping 100 percent of the time (a worst-case scenario). However, the wells are actually pumped on a rotated basis. The purpose of using the model was to examine the long-term regional impacts of the wellfield.

The change in simulated drawdowns in the potentiometric surface from 1988 to 2010 at the wells ranged from 1.77 to 8.77 ft for the confined portion of the surficial aquifer system and from 7.72 to 8.20 ft for the Upper Floridan aquifer (Table 3). Simulated 1988 drawdowns ranged from 1.54 to 5.13 ft for the confined portion of the surficial aquifer system and from 3.75 to 4.26 ft for the Upper Floridan aquifer. Simulated 2010 drawdowns ranged from 5.69 to 13.24 ft for the confined portion of the surficial aquifer system and from 11.95 to 12.30 ft for the Upper Floridan aquifer. SURFDOWN does not calculate drawdowns at the wells for the unconfined portion of the surficial aquifer system; however, it does calculate drawdowns at the nodes of a grid.

Simulated drawdowns in the City of St. Augustine wellfield were contoured for 1988 and 2010 for the confined and unconfined portions of the surficial aquifer system and the Upper Floridan aquifer (Figures 3–8). Differences between the drawdowns in 1988 and in 2010 were contoured for the confined and unconfined portions of the surficial aquifer system and the Upper Floridan aquifer (Figures 9–11). Figures 3–8 show the localized effect that pumping these wells has on the aquifer. In reality, the effect of the pumping extends beyond the model domain.

DISCUSSION

The differences in drawdowns between 1988 and 2010 for the water table are generally less than 1.75 ft (Figure 9). The cone of depression is steeper in the southern part of the wellfield than in the northern part. The differences between the

Table 3. Simulated drawdowns in the City of St. Augustine wellfield for 1988 and 2010

Aquifer	Well	1988 Simulated Drawdown (feet)		2010 Simulated Drawdown (feet)		Drawdown Difference (feet)	
		Confined Portion of the Surficial Aquifer System	Upper Floridan Aquifer	Confined Portion of the Surficial Aquifer System	Upper Floridan Aquifer	Confined Portion of the Surficial Aquifer System	Upper Floridan Aquifer
Surficial	1	4.47		13.24		8.77	
	2	2.30		11.13		8.83	
	3	2.54		6.10		3.56	
	4	2.39		5.69		3.30	
	6	2.13		5.87		3.74	
	7	1.54		8.06		6.52	
	10	5.13		6.90		1.77	
	11	3.61		7.02		3.41	
	12	3.80		7.30		3.50	
Upper Floridan	D8		3.75		11.95		8.20
	D9		4.26		12.30		8.04
	D10		4.24		11.96		7.72

drawdowns at the wells in 1988 and 2010 for the confined portion of the surficial aquifer system are greater than 8 ft in the southern part of the modeled area where wells 1 and 2 are located. Differences between 3 and 4 ft in the confined portion of the surficial aquifer system occur near wells 11 and 12 in the northern part of the wellfield (Table 3).

The cone of depression is much steeper for surficial aquifer wells 1–7 than for surficial aquifer wells 10-12 because the transmissivity of the surficial aquifer at wells 1–7 is approximately an order of magnitude smaller than for wells 10-12 .

The differences between the drawdowns in 1988 and 2010 for the Upper Floridan aquifer are about 8.0 ft (Table 3). The 4-ft differences in drawdowns occur at approximate distances of 10,000 ft and 8,400 ft east and west, respectively, of well D10 (Figure 8). The potentiometric surface of the Upper Floridan aquifer was approximately 32 ft above mean sea level in May 1988 at the City of St. Augustine

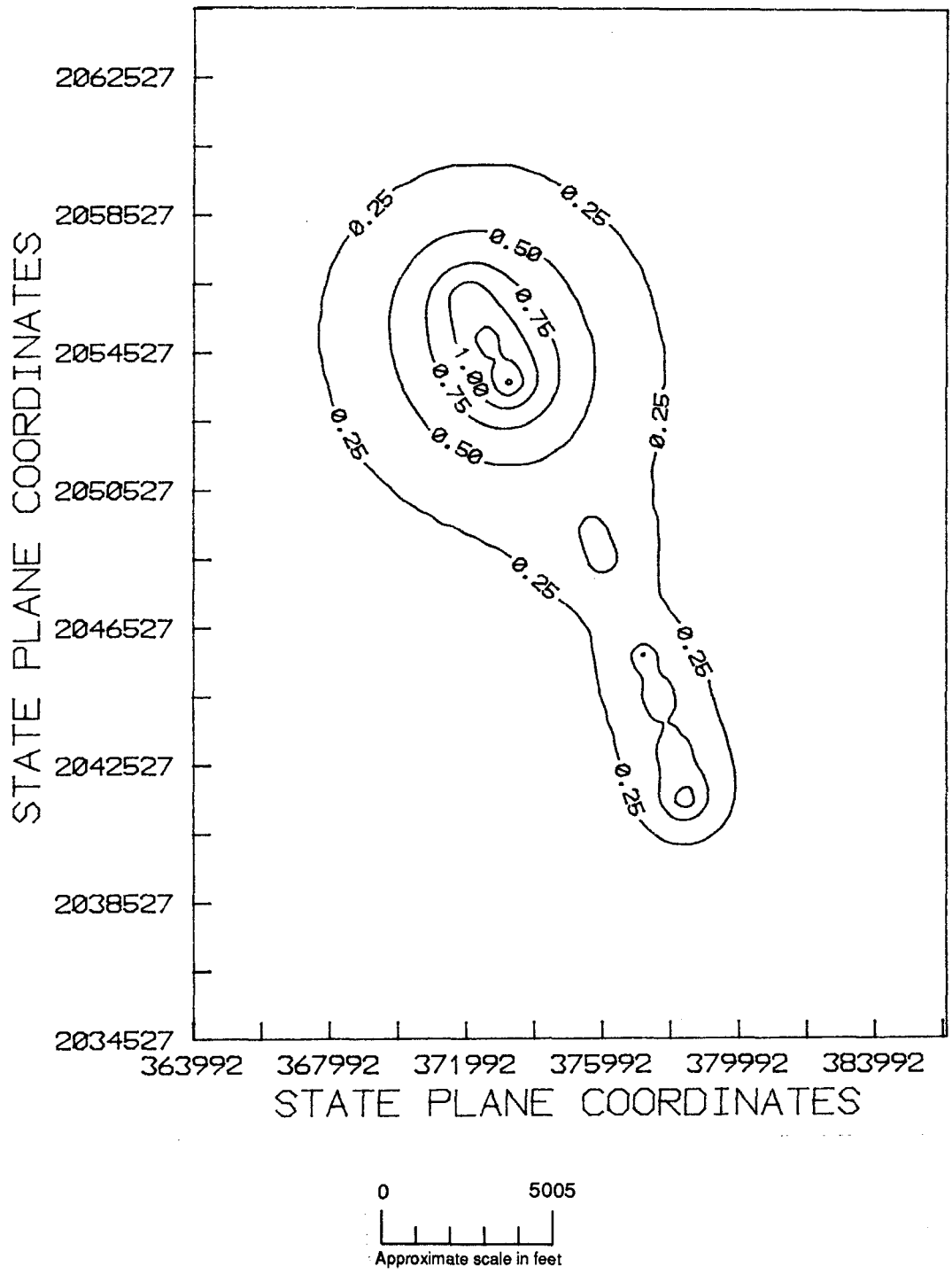

Figure 3. Simulated 1988 drawdowns in the unconfined portion of the surficial aquifer system at the St. Augustine wellfield (measured in feet)

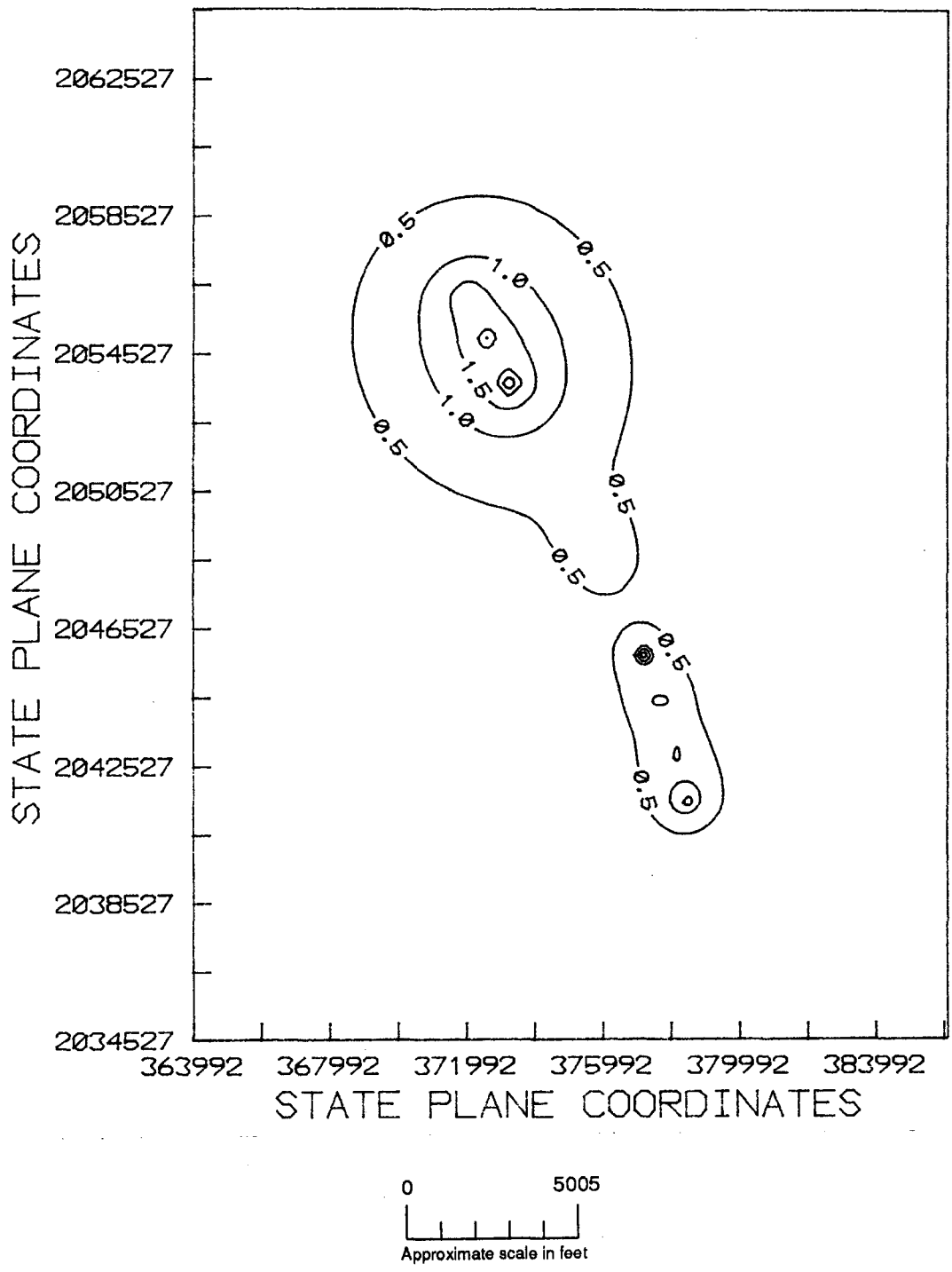

Figure 4. Simulated 1988 drawdowns in the confined portion of the surficial aquifer system at the St. Augustine wellfield (measured in feet)

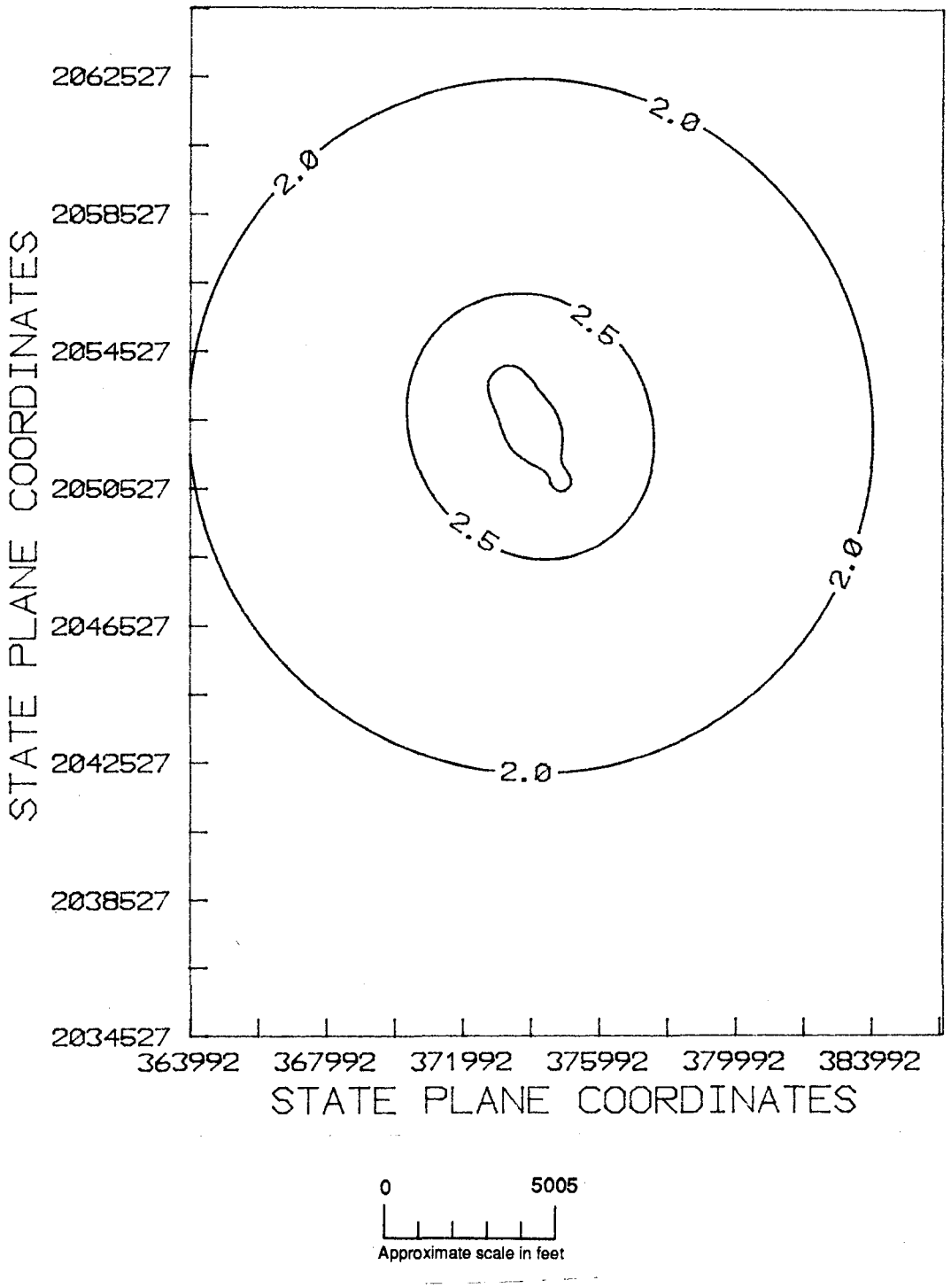

Figure 5. Simulated 1988 drawdowns in the Upper Floridan aquifer at the St. Augustine wellfield (measured in feet)

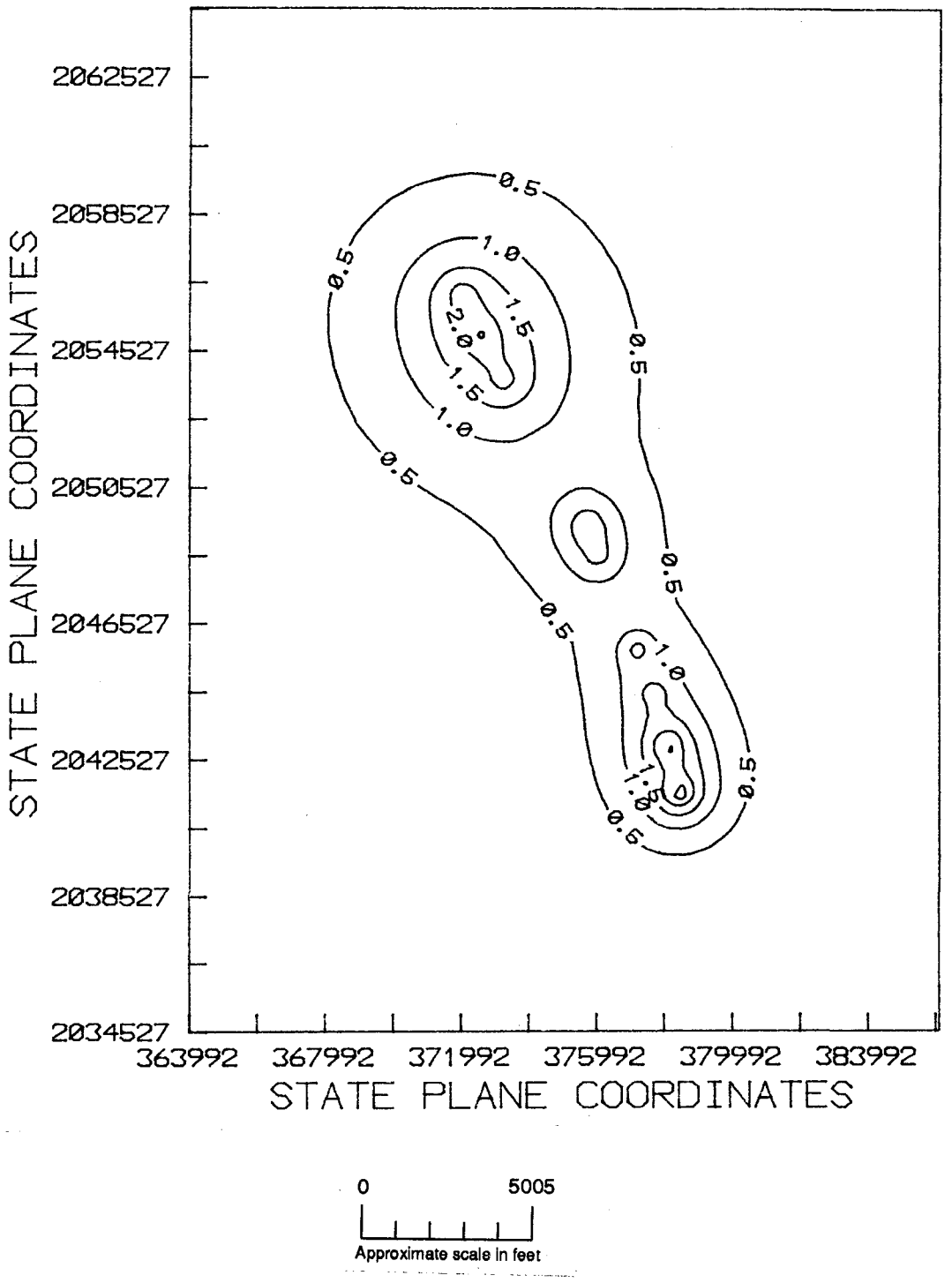

Figure 6. Simulated 2010 drawdowns in the unconfined portion of the surficial aquifer system at the St. Augustine wellfield (measured in feet)

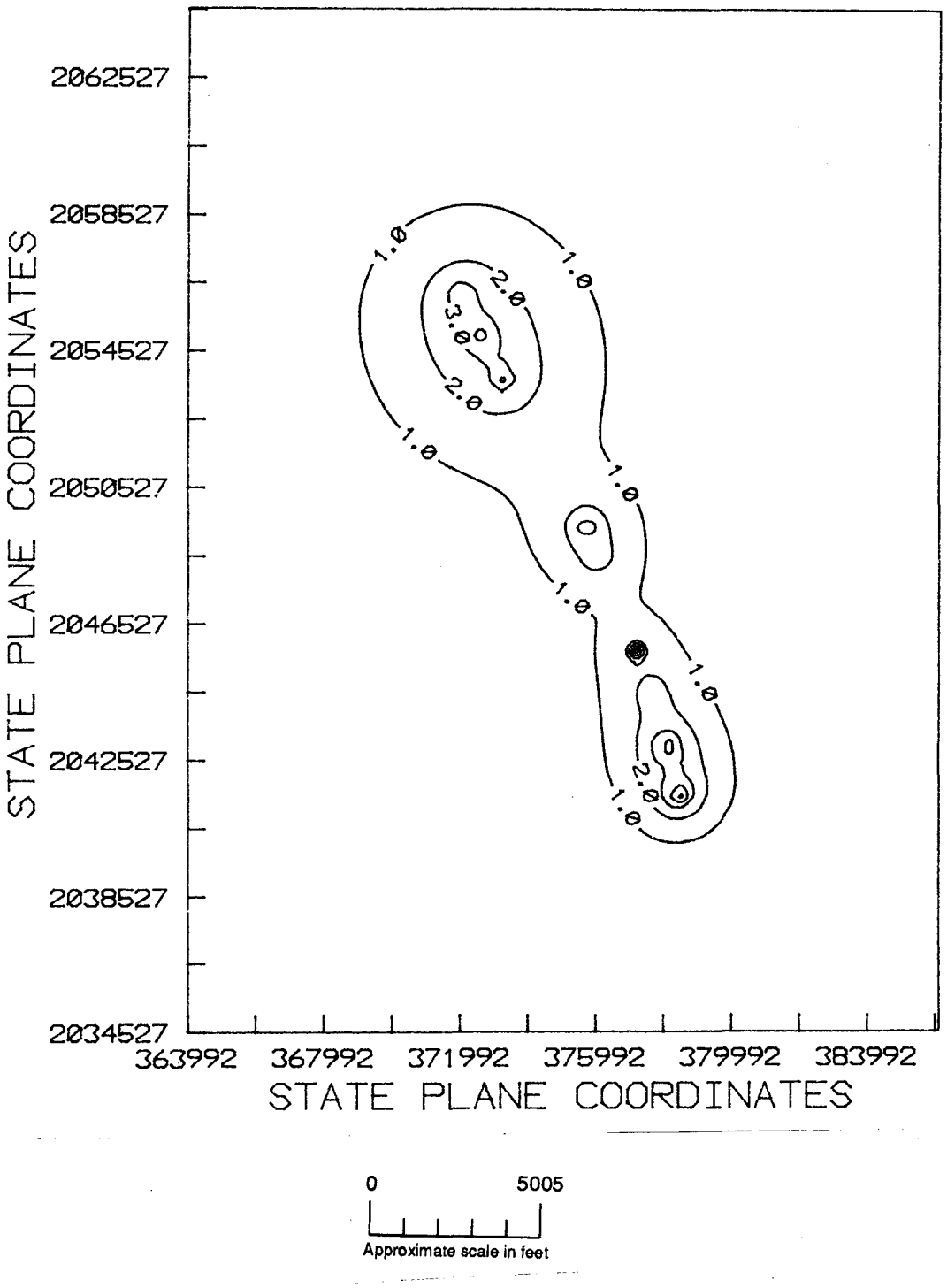

Figure 7. Simulated 2010 drawdowns in the confined portion of the surficial aquifer system at the St. Augustine wellfield (measured in feet)

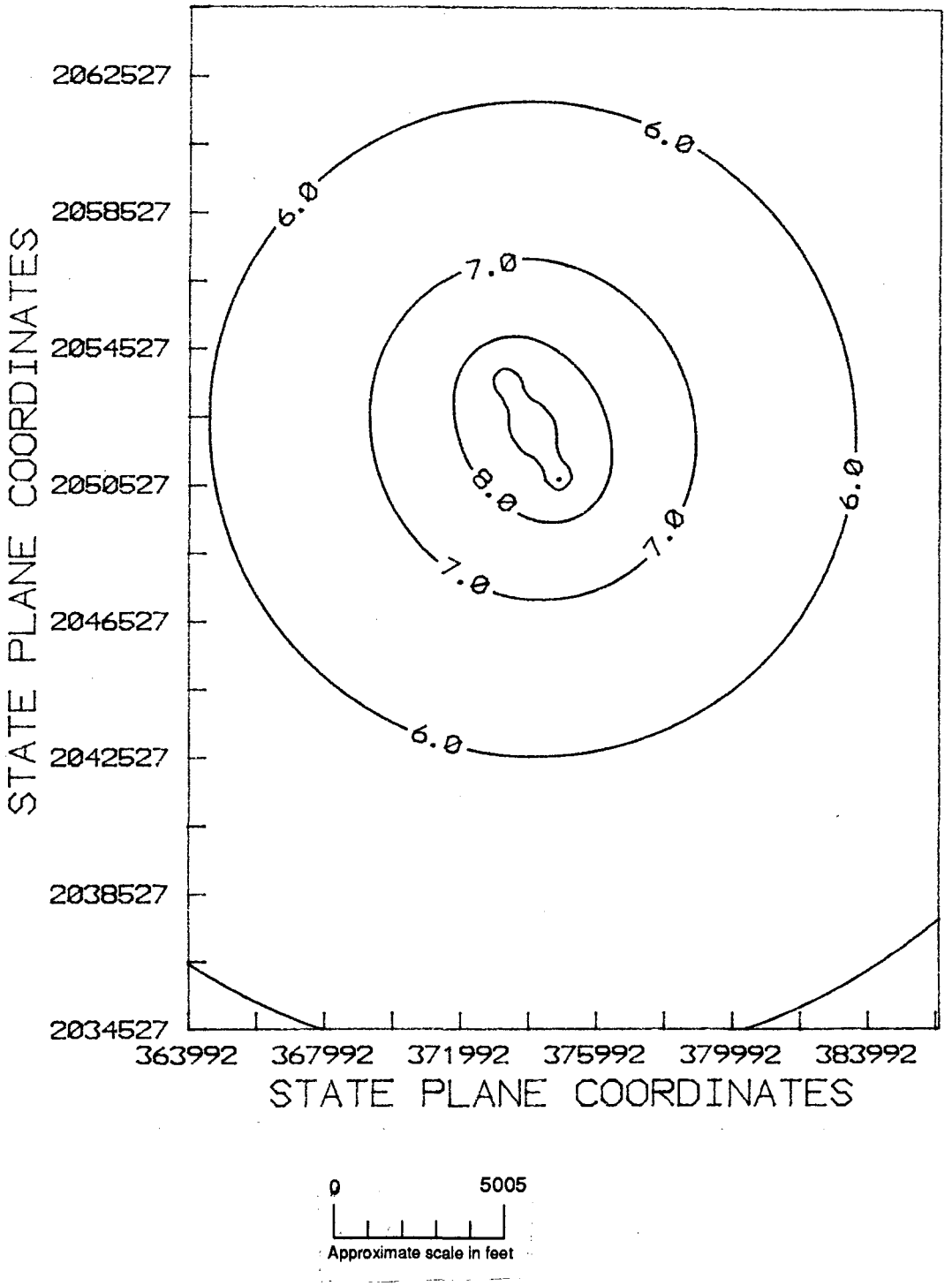

Figure 8. Simulated 2010 drawdowns in the Upper Floridan aquifer at the St. Augustine wellfield (measured in feet)

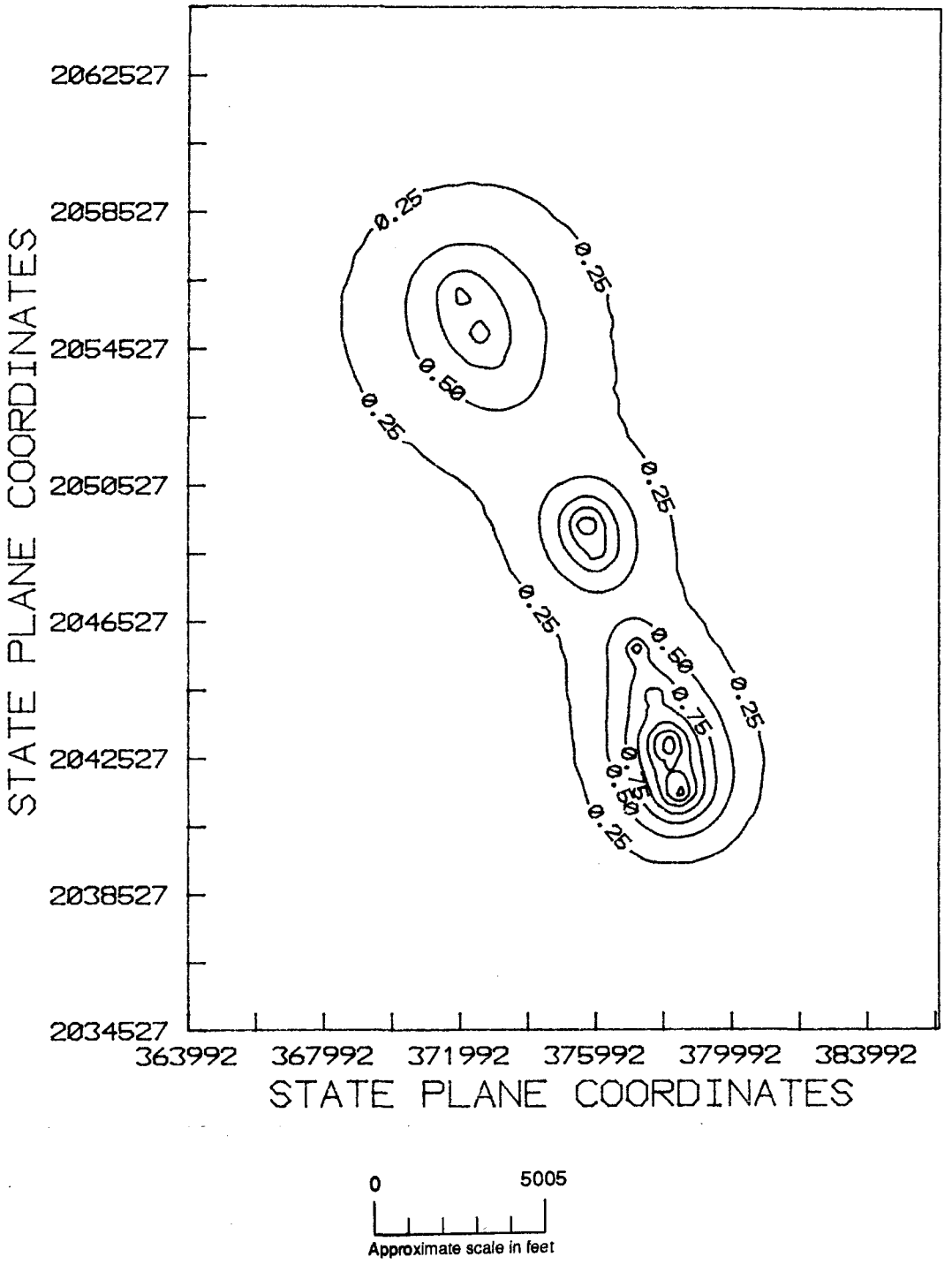

Figure 9. Differences in simulated drawdowns between 1988 and 2010 for the unconfined portion of the surficial aquifer system at the St. Augustine wellfield (measured in feet)

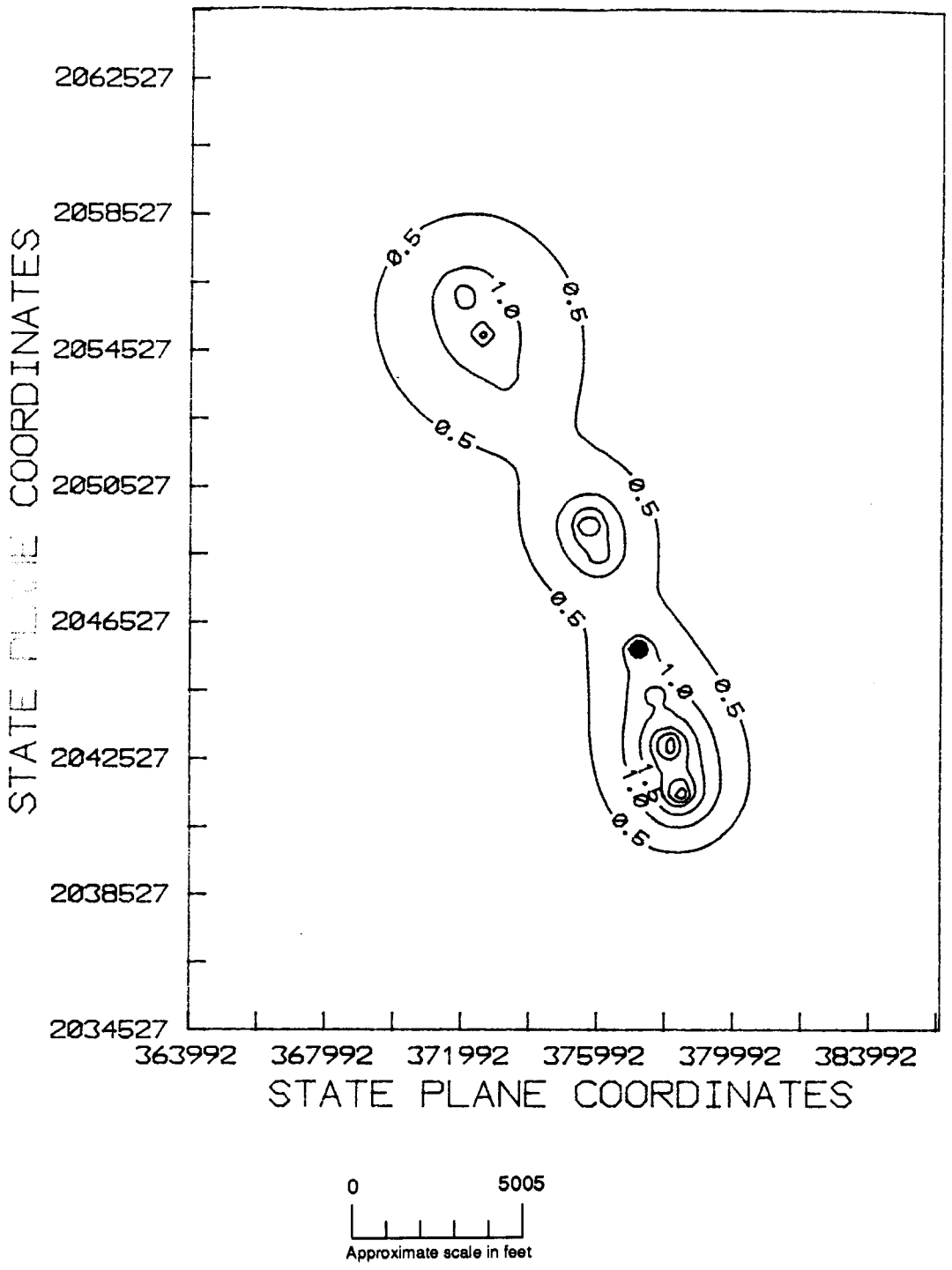

Figure 10. Differences in simulated drawdowns between 1988 and 2010 for the confined portion of the surficial aquifer system at the St. Augustine wellfield (measured in feet)

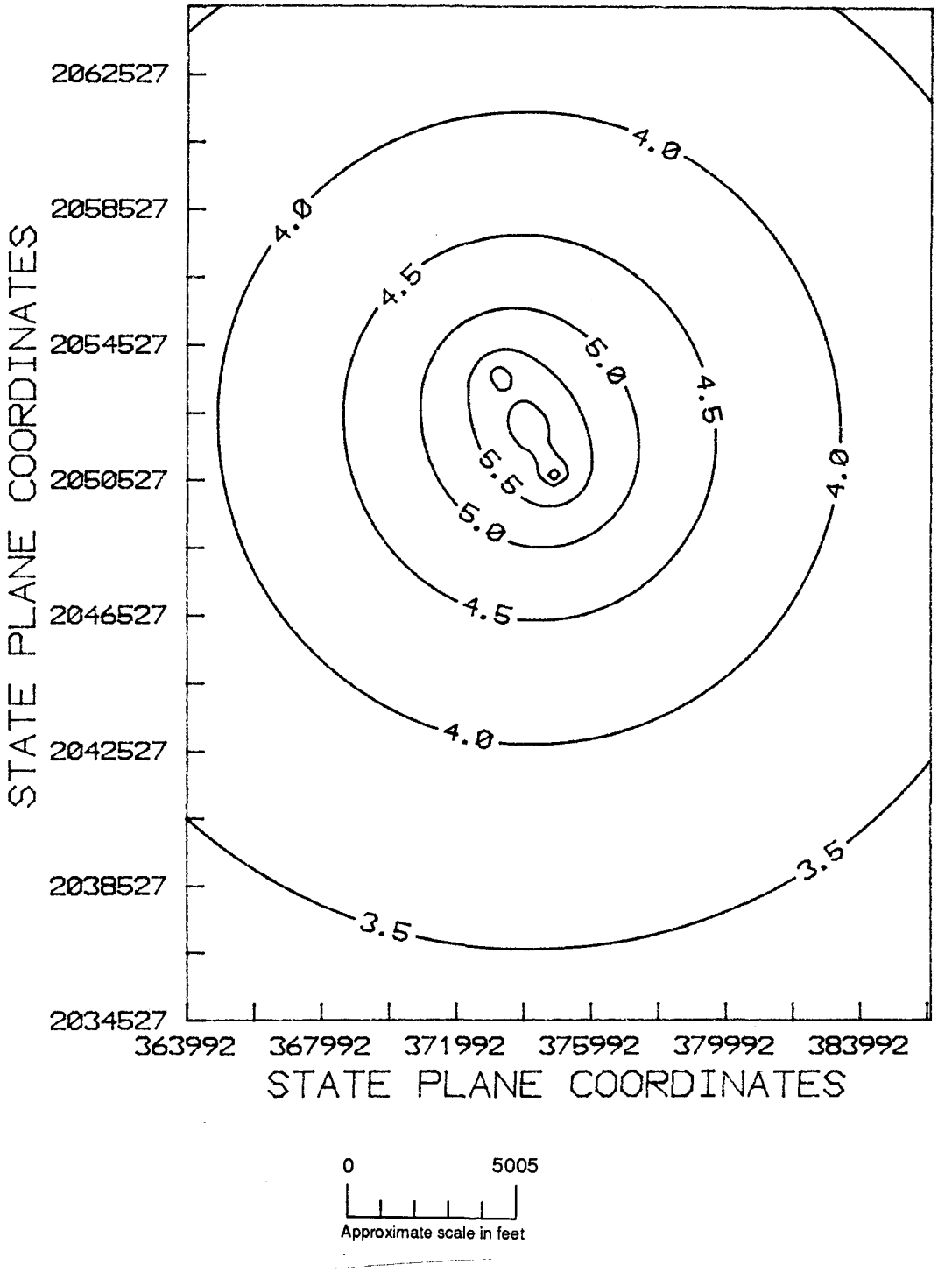

Figure 11. Differences in simulated drawdowns between 1988 and 2010 for the Upper Floridan aquifer at the St. Augustine wellfield (measured in feet)

wellfield (Schiner 1988). The projected pumpage in 2010 will lower this level to about 24 ft above mean sea level at the pumping wells.

CONCLUSIONS

Based on the results of the model, increased pumpage at the City of St. Augustine wellfield between 1988 and 2010 will cause about 2 and 9 ft, respectively, of additional drawdown in the elevation of the water table and the potentiometric surface of the surficial aquifer system at the pumping wells. The increased pumpage also will cause about 8 ft of additional drawdown at the pumping wells in the elevation of the potentiometric surface of the Upper Floridan aquifer. The simulated drawdowns for projected pumpages at the City of St. Augustine wellfield have a pronounced effect on the elevation of the potentiometric surface of both the surficial aquifer and Floridan aquifer systems at the pumping wells. Away from the wells, there is little effect on the elevation of the potentiometric surface of the surficial aquifer system and a small effect (2 to 5 ft) on the elevation of the potentiometric surface of the Floridan aquifer system. The projected pumpage has little effect on the elevation of the water table.

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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)