Professional Paper SJ94-PP4

PROJECTED AQUIFER DRAWDOWNS
TILLMAN RIDGE WELLFIELD
ST. JOHNS COUNTY, FLORIDA

by

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Seal

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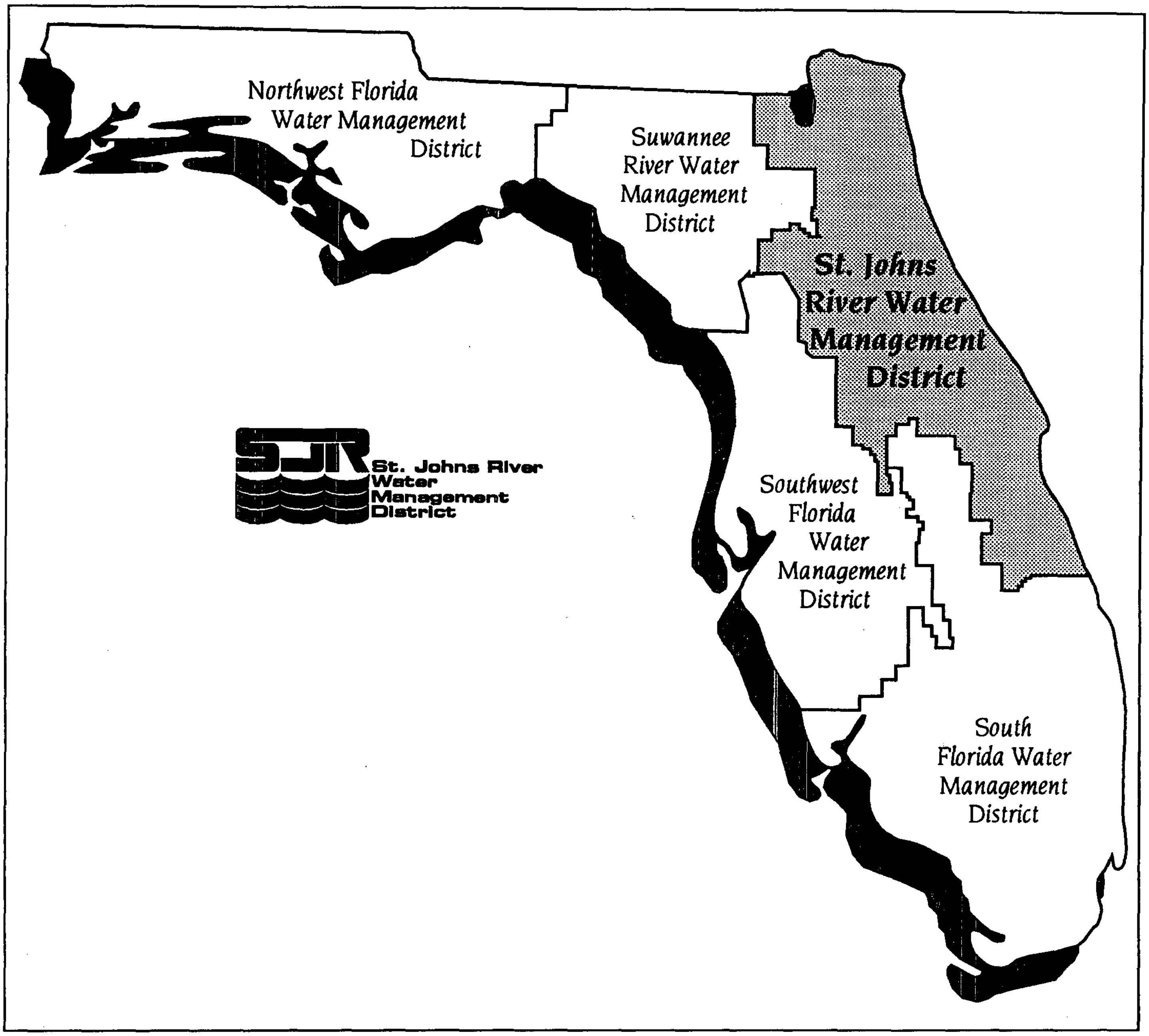
1994



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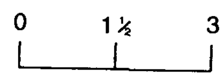
Projected aquifer drawdowns

Tillman Ridge wellfield

St. Johns County, Florida

Errata Sheet

Page 5, Figure 2 replace scale bar with the following



Approximate scale in miles

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) between 1988 and 2010 at the Tillman Ridge wellfield operated by St. Johns County. 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. St. Johns County did not withdraw water from UFA at the Tillman Ridge wellfield in 1988. The change in drawdown at the wells from 1988 to 2010 ranged from 6.60 to 8.48 ft for SAS and is identical to simulated 2010 drawdowns for UFA. An additional 14–18 ft of drawdown at the wells can be expected as a result of new SAS wells added to the wellfield. Increased pumpage is projected also to result in 5 ft of additional drawdown in the water table (unconfined portion of SAS). The simulated drawdowns for projected pumpages at the Tillman Ridge wellfield could have a pronounced effect on the elevation of the water table and the potentiometric surface of SAS and little effect on the potentiometric surface of 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 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 Tillman Ridge wellfield operated by St. Johns County (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 elevation of the water table and elevation of the potentiometric surface of the surficial aquifer and Floridan aquifer systems.

Within the area covered by the Tillman Ridge 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 sands and exists under unconfined conditions (Hayes 1981). 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 (Hayes 1981; Spechler and Hampson 1984). It is referred to in this paper as the confined portion of the surficial aquifer system. These 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.

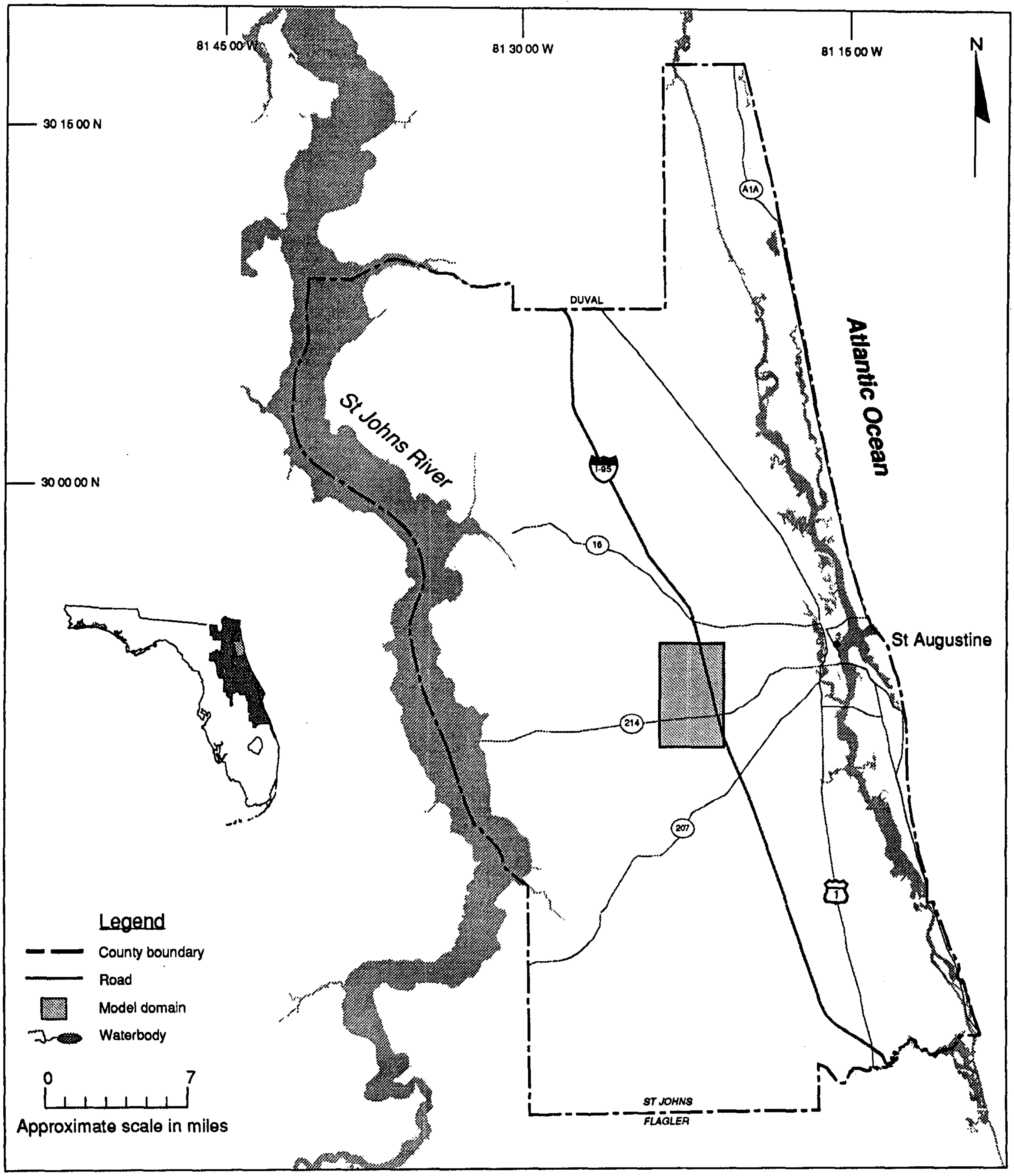


Figure 1. **Location of the model domain for the Tillman Ridge wellfield belonging to St. Johns County**

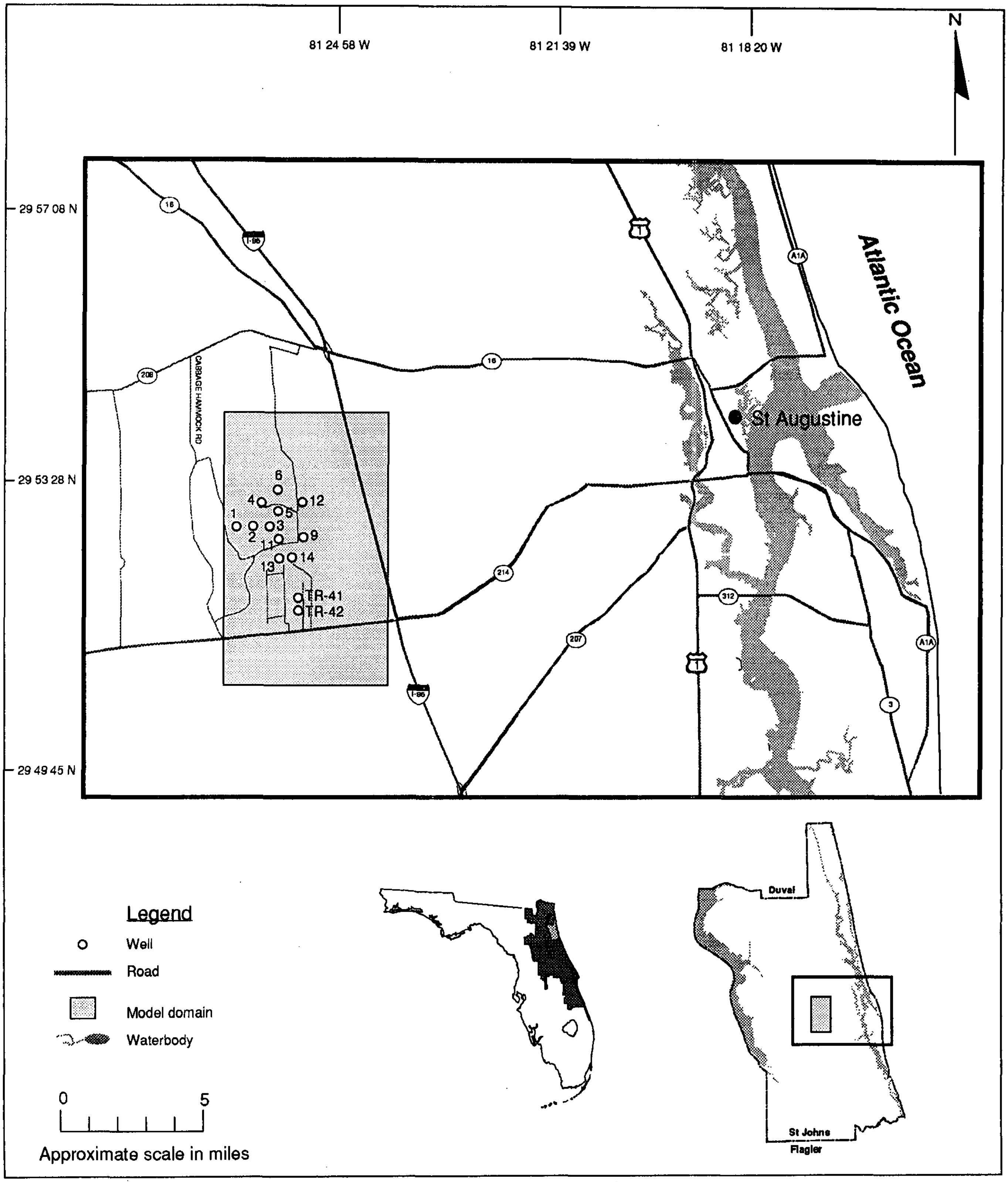


Figure 2. **Model domain and well locations of the Tillman Ridge wellfield, St. Johns County**

St. Johns County operated three wellfields in 1988: one at Tillman Ridge, one on Holmes Boulevard (St. Augustine), and one on Anastasia Island. Combined water use in 1988 was 1.980 million gallons per day (mgd) (Florence 1990). By 1992, only the Tillman Ridge wellfield was operational. In 2010, St. Johns County plans to withdraw 5.08 mgd from the Tillman Ridge wellfield (Young 1993a).

In 1988, St. Johns County withdrew water from five surficial aquifer system wells at the Tillman Ridge wellfield. By 1992, St. Johns County had seven surficial aquifer system and two Floridan aquifer system production wells at the Tillman Ridge wellfield. To satisfy its projected water use for 2010, St. Johns County proposes to add four additional surficial aquifer system wells at the Tillman Ridge wellfield (Young 1993b).

METHODS

Impacts to the ground water flow system resulting from withdrawals at the Tillman Ridge 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 (Motz 1978) in which pumping from an underlying aquifer is balanced by a reduction in evapotranspiration from an overlying aquifer. 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 15,510 feet (ft) wide and 22,110 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 evapotranspiration reduction coefficient (Table 1). The

Table 1. Aquifer characteristics used in the MLTLAY and SURFDOWN models, Tillman Ridge wellfield

Aquifer Characteristic	Value
Evapotranspiration reduction coefficient	0.00043 (ft/day)/ft
Transmissivity—unconfined portion of the surficial aquifer system	748 gpd/ft
Leakance—semiconfining unit of the surficial aquifer system	0.00748 (gpd/ft^2)/ft
Transmissivity—confined portion of the surficial aquifer system	50,490 gpd/ft
Leakance—upper confining unit	0.0000748 (gpd/ft^2)/ft
Transmissivity—Upper Floridan aquifer	119,325 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: Hayes 1981; American Drilling 1990; Hantush 1964; Tibbals 1990

transmissivity of the confined portion of the surficial aquifer system, measured in gallons per day per foot, came from an aquifer performance test by Hayes (1981). The transmissivity of the Upper Floridan aquifer was derived from an average of values obtained from a step drawdown test of Upper Floridan aquifer well TR-42 (American Drilling 1990) and an aquifer performance test using the partial-penetration equation for leaky aquifers (Hantush 1964) for Upper Floridan aquifer well TR-41 (American Drilling 1990). The transmissivity of the unconfined portion of the surficial aquifer system was determined using the following formula.

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

Hayes (1981) indicated that the saturated thickness of the unconfined portion of the surficial aquifer system is 22 ft, based on an estimated depth to water of 8 ft below land surface at the wellfield. Geologic information indicates that it is composed of sands (Hayes 1981). Based on the geologic information and the saturated thickness, an assumed hydraulic conductivity of 34.0 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.

No specific information is available on the leakance of the semiconfining unit of the surficial aquifer system at the Tillman Ridge wellfield. Because the semiconfining unit of the surficial aquifer system is similar geologically to the semiconfining unit of the City of St. Augustine wellfield in St. Johns County, leakance, measured in gallons per day per square foot per foot, was assumed to be identical to a value obtained by CH2M HILL (1982) from an aquifer performance test at the City of St. Augustine wellfield, which is located about 3 miles north of the Tillman Ridge wellfield. Leakance of the upper confining unit came from Durden (1994).

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 8 ft below land surface at the wellfield.

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 1.980 mgd reported by Florence (1990) for all three wellfields and was determined from the reported pumping rates and the percentage of time each well was in service in 1988 (B. Young, St. Johns County Utilities, pers. com. 1992).

The 2010 total projected pumpage at the Tillman Ridge wellfield is estimated to be 5.08 mgd (Young 1993a). The 2010 projected pumpage from the 11 surficial aquifer system wells at the Tillman Ridge wellfield is estimated to be 4.752 mgd (Young 1993b) with each well pumping at the rate of 300 gallons per minute. The 2010 projected pumpage from the Upper Floridan aquifer is estimated to be 0.328 mgd (Young 1993b). Pumpage projections for the year 2010 are based on withdrawals from eight wells more than existed in 1988 (Young 1993b). Four of these wells were in existence in 1992. They include two surficial aquifer system wells and two Upper Floridan aquifer wells. The remaining four surficial aquifer system wells (1, 2, 3, and 6) were not yet constructed in early 1994.

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 of the confined portion of the surficial aquifer system from 1988 to 2010 at the wells ranged from 6.60 to 8.48 ft (Table 3); however, an additional 14–18 ft of drawdown at the wells can be

Table 2. Pumpage values used in the MLTLAY and SURFDOWN models, Tillman Ridge wellfield

Aquifer	Well	Latitude	Longitude	1988 Pumpage (mgd)	Projected 2010 Pumpage (mgd)
Surficial	9	295236	812504	0.283	0.432
	11	295234	812522	0.283	0.432
	12	295304	812505	0.283	0.432
	13	295220	812521	0.283	0.432
	14	295221	812511	0.283	0.432
	4*	295303	812537		0.432
	5*	295300	812524		0.432
	1**	295246	812604		0.432
	2**	295247	812543		0.432
	3**	295247	812527		0.432
	6**	295314	812424		0.432
Upper Floridan	TR-42*	295150	812459		0.164
	TR-41*	295201	812500		0.164

Note: mgd = million gallons per day

*Wells added into service in 1992
**Wells to be installed by 2010

expected as a result of new surficial aquifer system wells added to the wellfield. No Floridan aquifer system withdrawals occurred in 1988 at the Tillman Ridge wellfield; therefore, the simulated 2010 drawdowns at the wells represent the impacts of the withdrawals from the Upper Floridan aquifer. Simulated 1988 drawdowns ranged from 7.96 to 9.68 ft for the confined portion of the surficial aquifer. Simulated 2010 drawdowns ranged from 14.01 to 18.47 ft for the confined portion of the surficial aquifer system and from 3.29 to 3.30 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 Tillman Ridge wellfield were contoured for 1988 and 2010 for the confined and unconfined portions of the surficial aquifer system and the Upper Floridan aquifer (Figures 3–7). Differences between the drawdowns in 1988 and 2010 were contoured for the confined and unconfined portions of the surficial aquifer system (Figures 8 and 9). Figures 3–7 show the localized effect that pumping

Table 3. Simulated drawdowns in the Tillman Ridge wellfield for 1988 and 2010

Aquifer	Well	Simulated 1988 Drawdown (feet)	Simulated 2010 Drawdown (feet)		Drawdown Difference (feet)	
		Confined Portion of the Surficial Aquifer System	Confined Portion of the Surficial Aquifer System	Upper Floridan Aquifer	Confined Portion of the Surficial Aquifer System	Upper Floridan Aquifer
Surficial	9	9.26	16.31		7.05	
	11	9.43	17.91		8.48	
	12	7.96	15.40		7.44	
	13	9.56	16.33		6.77	
	14	9.68	16.28		6.60	
	4*		17.16		NA	
	5*		18.15		NA	
	1**		14.01		NA	
	2**		16.99		NA	
	3**		18.47		NA	
	6**		15.91		NA	
Upper Floridan	TR-42*			3.29	NA	NA
	TR-41*			3.30	NA	NA

Note: NA = not applicable

*Wells added into service in 1992
**Wells to be installed by 2010

of these wells has on the aquifers. In reality, the effect of the pumping extends beyond the model domain.

DISCUSSION

The differences between the drawdowns in 1988 and 2010 for the confined and unconfined portions of the surficial aquifer system and the 2010 drawdowns in the potentiometric surface of the Upper Floridan aquifer are greatest at the wellfield and decrease with radial distance away from the wellfield. The center of the wellfield is approximately in the center of the 1.75-ft contour in Figure 7, the 5-ft contour in Figure 8, and the 8-ft contour in Figure 9. The differences in drawdowns between 1988 and 2010 for the water table of the unconfined portion of the surficial aquifer

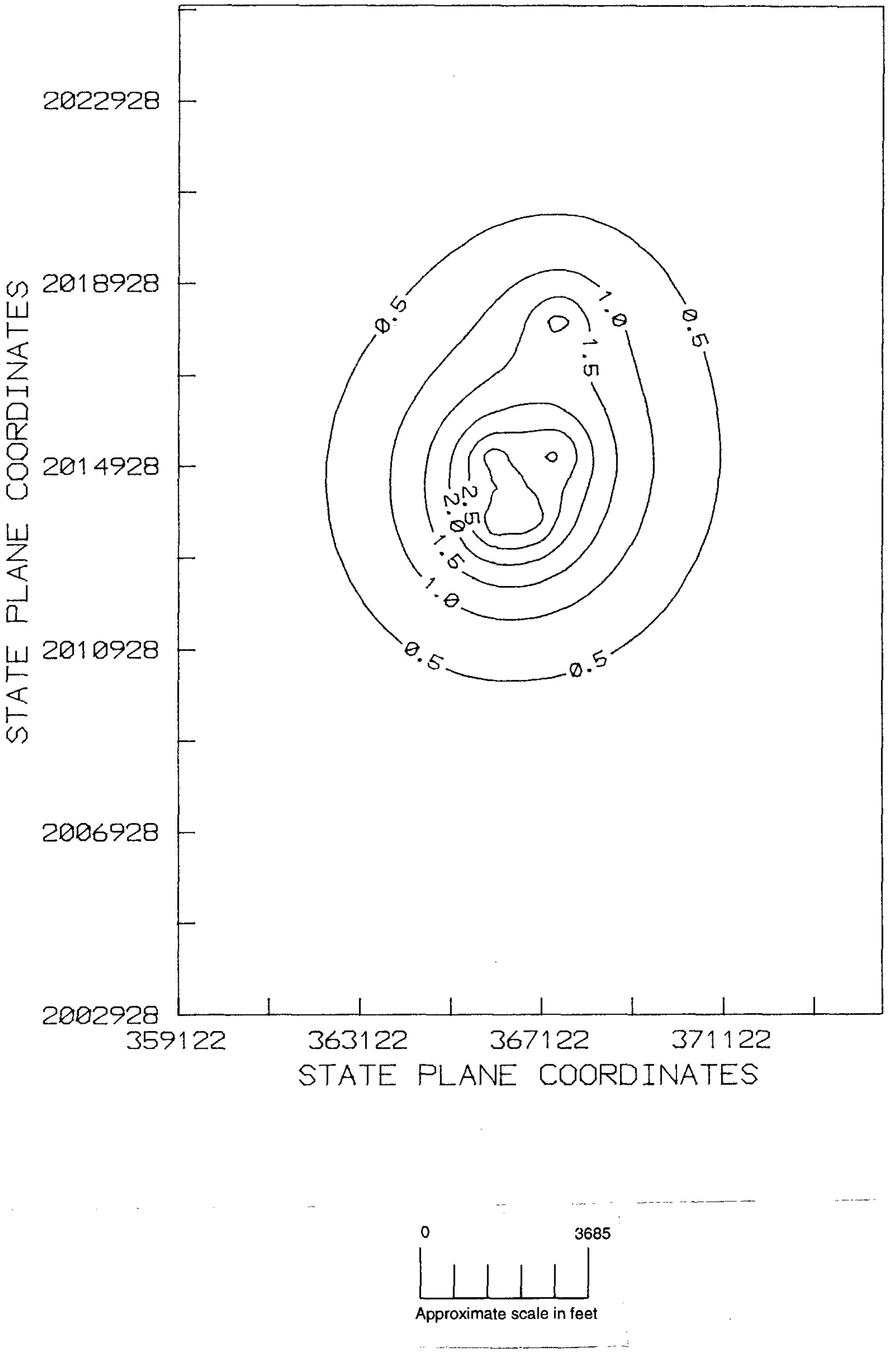


Figure 3. **Simulated 1988 drawdowns in the unconfined portion of the surficial aquifer system at the Tillman Ridge wellfield (measured in feet)**

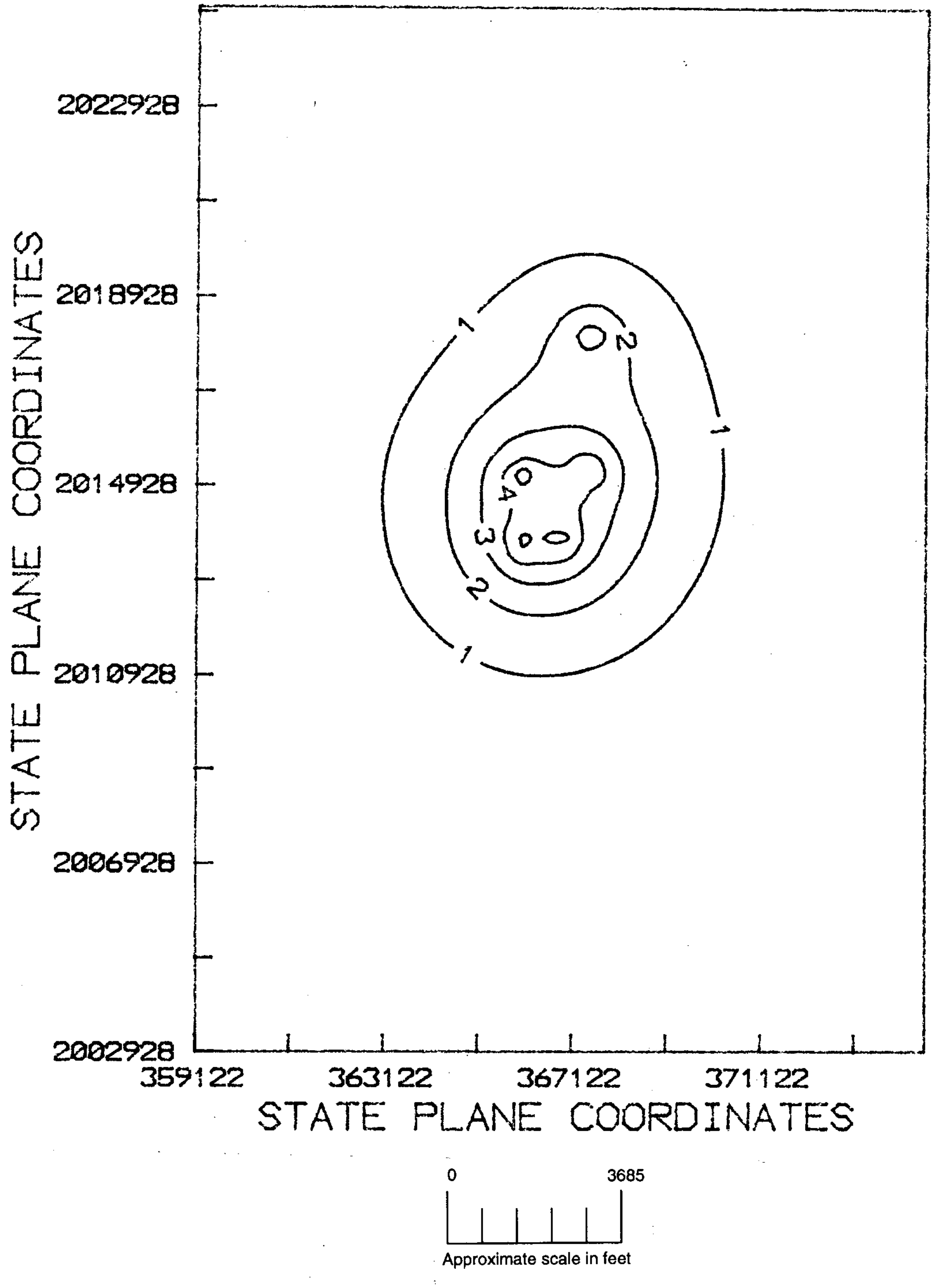


Figure 4. **Simulated 1988 drawdowns in the confined portion of the surficial aquifer system at the Tillman Ridge wellfield (measured in feet)**

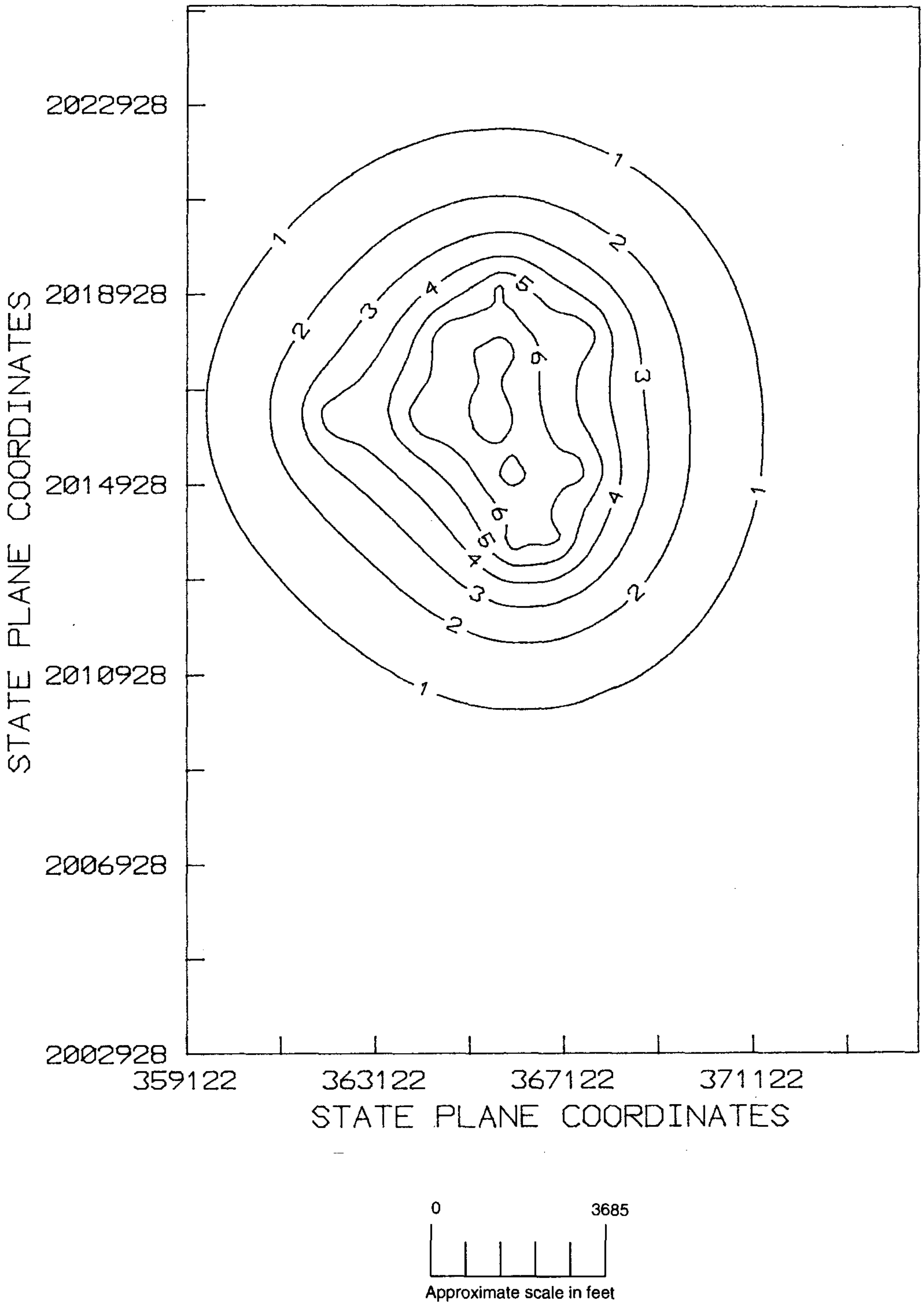


Figure 5. **Simulated 2010 drawdowns in the unconfined portion of the surficial aquifer system at the Tillman Ridge wellfield (measured in feet)**

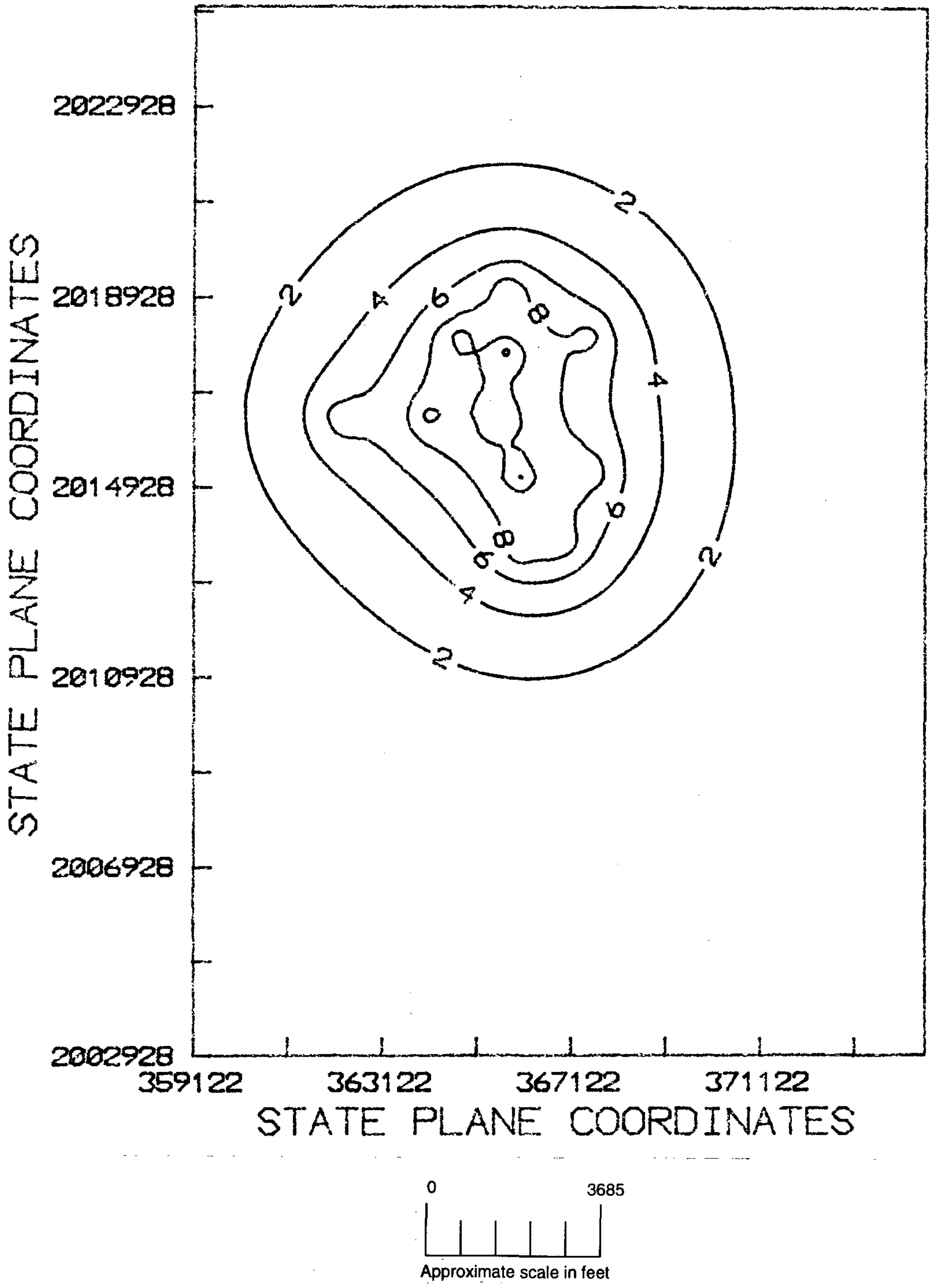


Figure 6. Simulated 2010 drawdowns in the confined portion of the surficial aquifer system at the Tillman Ridge wellfield (measured in feet)

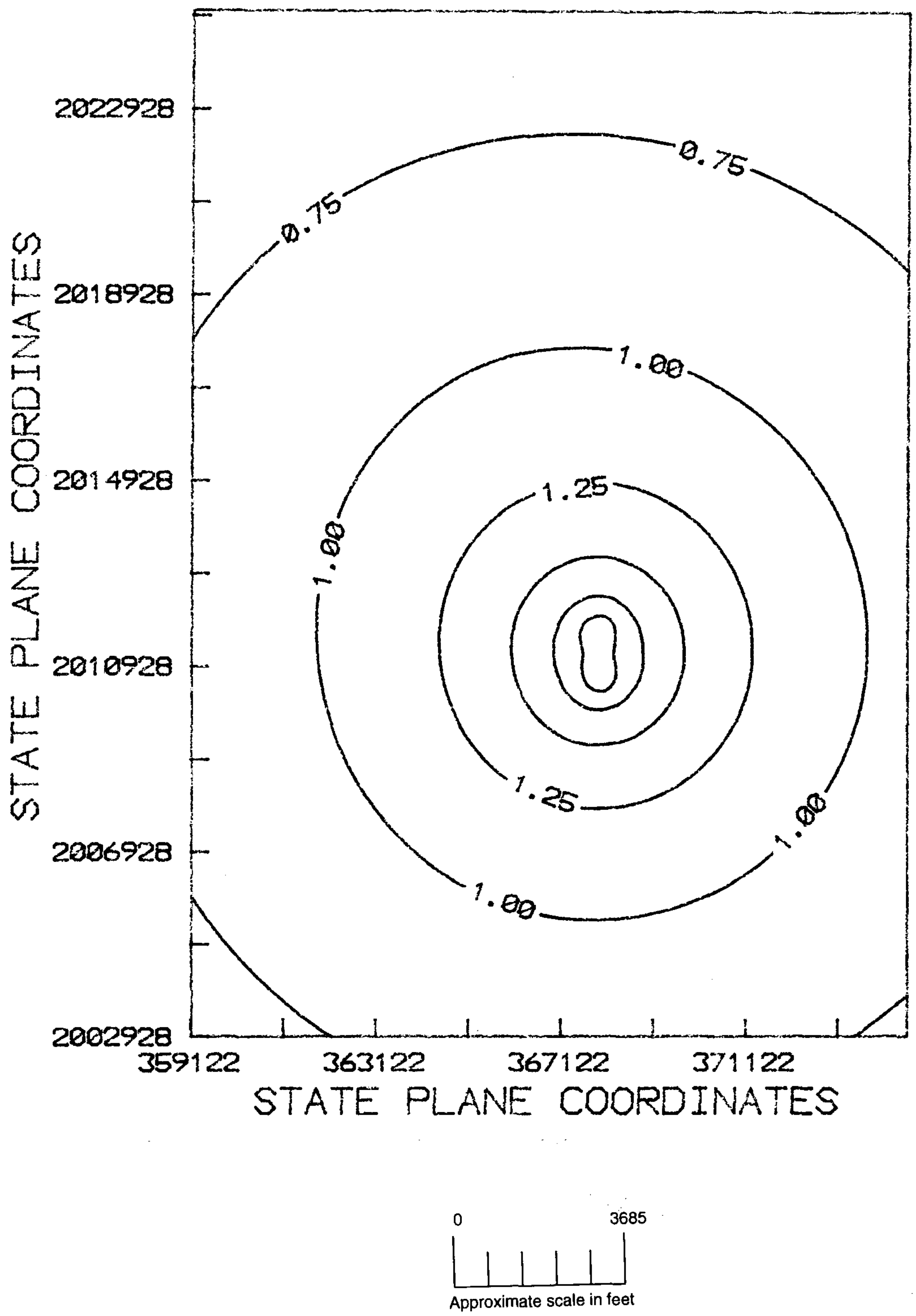


Figure 7. **Simulated 2010 drawdowns in the Upper Floridan aquifer at the Tillman Ridge wellfield (measured in feet)**

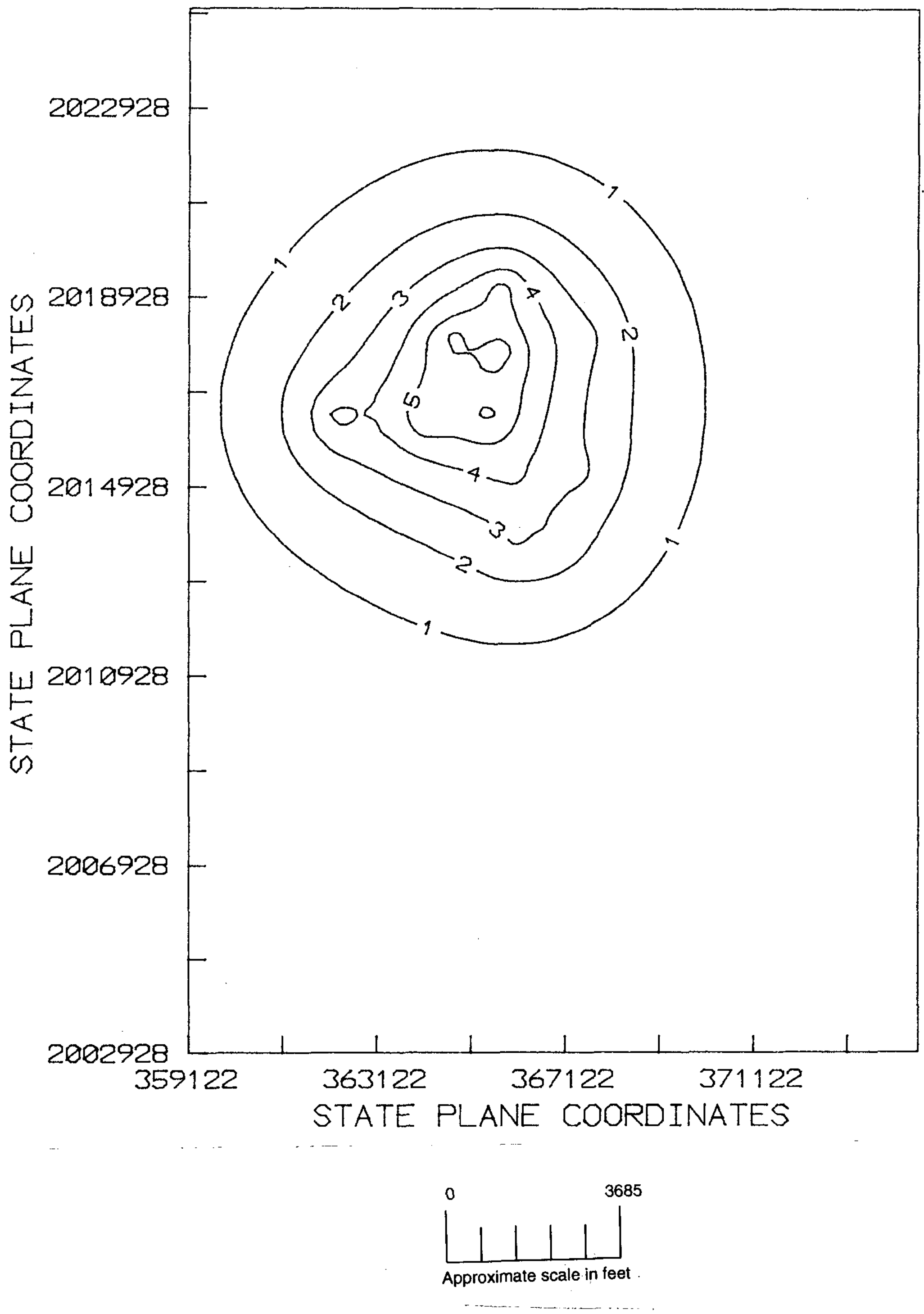


Figure 8. Differences in simulated drawdowns between 1988 and 2010 for the unconfined portion of the surficial aquifer system at the Tillman Ridge wellfield (measured in feet)

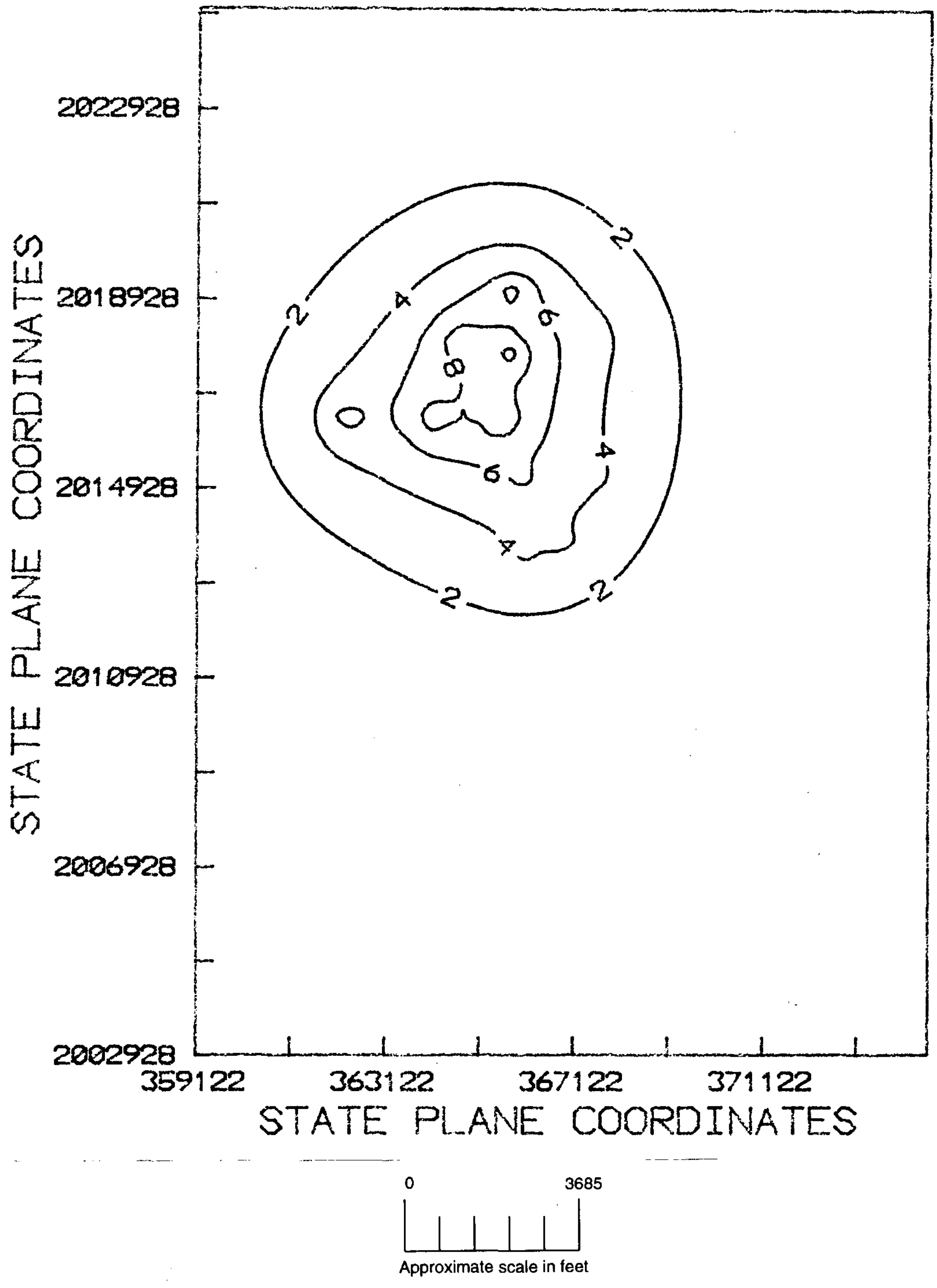


Figure 9. Differences in simulated drawdowns between 1988 and 2010 for the confined portion of the surficial aquifer at the Tillman Ridge wellfield (measured in feet)

system and the potentiometric surface of the confined portion of the surficial aquifer system are less than 7 and 12 ft, respectively (Figures 8 and 9). The elevation of the potentiometric surface of the Upper Floridan aquifer was approximately 24 ft above mean sea level in May 1988 at the Tillman Ridge wellfield (Schiner 1988). The projected pumpage in 2010 may cause this level to be lowered to about 21 ft above mean sea level at the pumping wells.

CONCLUSIONS

Based on the model results, increased pumpage at the Tillman Ridge wellfield between 1988 and 2010 will cause about 3 ft of additional drawdown in the elevation of the potentiometric surface of the Upper Floridan aquifer. The projected increased pumpage potentially could cause about 5 and 8 ft, respectively, of additional drawdown in the elevation of the water table of the unconfined portion of the surficial aquifer system and the potentiometric surface of the confined portion of the surficial aquifer system. The simulated drawdowns for projected pumpages at the Tillman Ridge wellfield indicate that 2010 pumpages may have a pronounced effect on the elevation of the water table and the potentiometric surface of the surficial aquifer system and little effect on the elevation of the potentiometric surface of the Floridan aquifer system.

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———. 1993b. Letter to the author, dated 15 June 1993. Supervisor of Water Utilities, St. Johns County, St. Augustine, Fla.

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)