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PROJECTED AQUIFER DRAWDOWNS
PALM COAST UTILITY CORPORATION WELLFIELDS
FLAGLER COUNTY, FLORIDA

by

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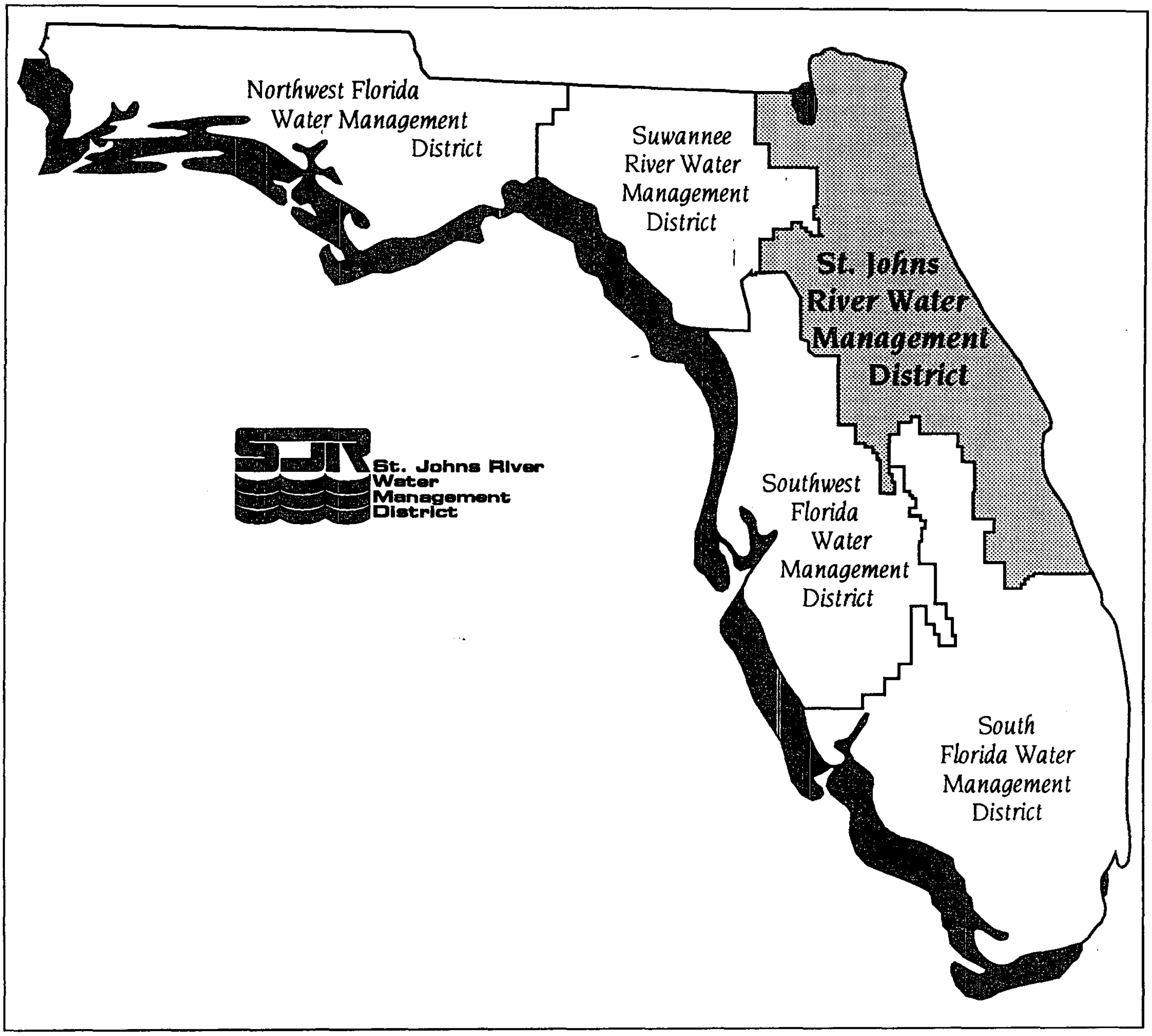

The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued 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. Three linear analytical ground water models, DRAWDOWN, MLTLAY, and SURFDOWN, were used in this study. The DRAWDOWN model calculated changes in the potentiometric surfaces of the water table in the surficial aquifer system (SAS) and of the intermediate aquifer system (IAS) based on 1988 pumpage values and 2010 projected pumpages at the SW wellfield of Palm Coast Utility Corporation. The MLTLAY model calculated changes in the potentiometric surfaces of IAS and the Floridan aquifer system (FAS) based on 1993 pumpage values and 2010 projected pumpages at the LW wellfield; the SURFDOWN model then calculated the drawdown of the water table in SAS for the LW wellfield. The SW wellfield pumps ground water from IAS. The LW wellfield, completed in 1993, pumps ground water from FAS. The calculated 1988 drawdowns at the SW wellfield ranged from 1.31 to 1.94 feet (ft) in SAS and from 5.79 to 16.43 ft in IAS. The calculated 2010 drawdowns at the SW wellfield ranged from 0.38 to 3.84 ft in SAS and from 4.70 to 15.90 ft in IAS. The calculated 1993 drawdowns at the LW wellfield ranged from 0.02 to 0.03 ft in SAS, from 0.24 to 0.29 ft in IAS, and from 1.00 to 3.11 ft in FAS. The calculated 2010 drawdowns at the LW wellfield ranged from 0.25 to 0.49 ft in SAS, from 2.73 to 3.76 ft in IAS, and from 10.32 to 17.23 ft in FAS. Projected 2010 pumpages will affect SAS, IAS, and FAS at both the SW and LW wellfields.

Section 62-40.520, *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 calculate the impacts associated with ground water withdrawals at two wellfields (SW and LW) operated by Palm Coast Utility Corporation (PCUC) in Flagler County (Figures 1–3). This evaluation was used as part of the overall assessment of water supply needs and sources to predict the 2010 elevation of the potentiometric surface of the Floridan aquifer system and the change in the elevation of the water table in the surficial aquifer system in SJRWMD.

Within the area covered by the two wellfields, the ground water system consists of three aquifers: the surficial, the intermediate, and the Floridan. At the SW wellfield site, the surficial aquifer system contains an unconfined water table aquifer that overlies the upper confining unit of the Hawthorn Group (Bermes et al. 1963a). The intermediate aquifer system is a confined aquifer composed of thin, discontinuous lenses of sand, shell, and limestone. The intermediate aquifer is located within the confining Hawthorn Group (Bermes et al. 1963b). The Hawthorn Group typically consists of sandy clay and marl, interbedded with lenses of phosphatic pebbles, sand, and sandy limestone. In most parts of north Florida, the Hawthorn Group is located above the Ocala Limestone. The Floridan aquifer system in this area is composed generally of Ocala Limestone (Tibbals 1990). At the SW wellfield, the intermediate aquifer system is the main source

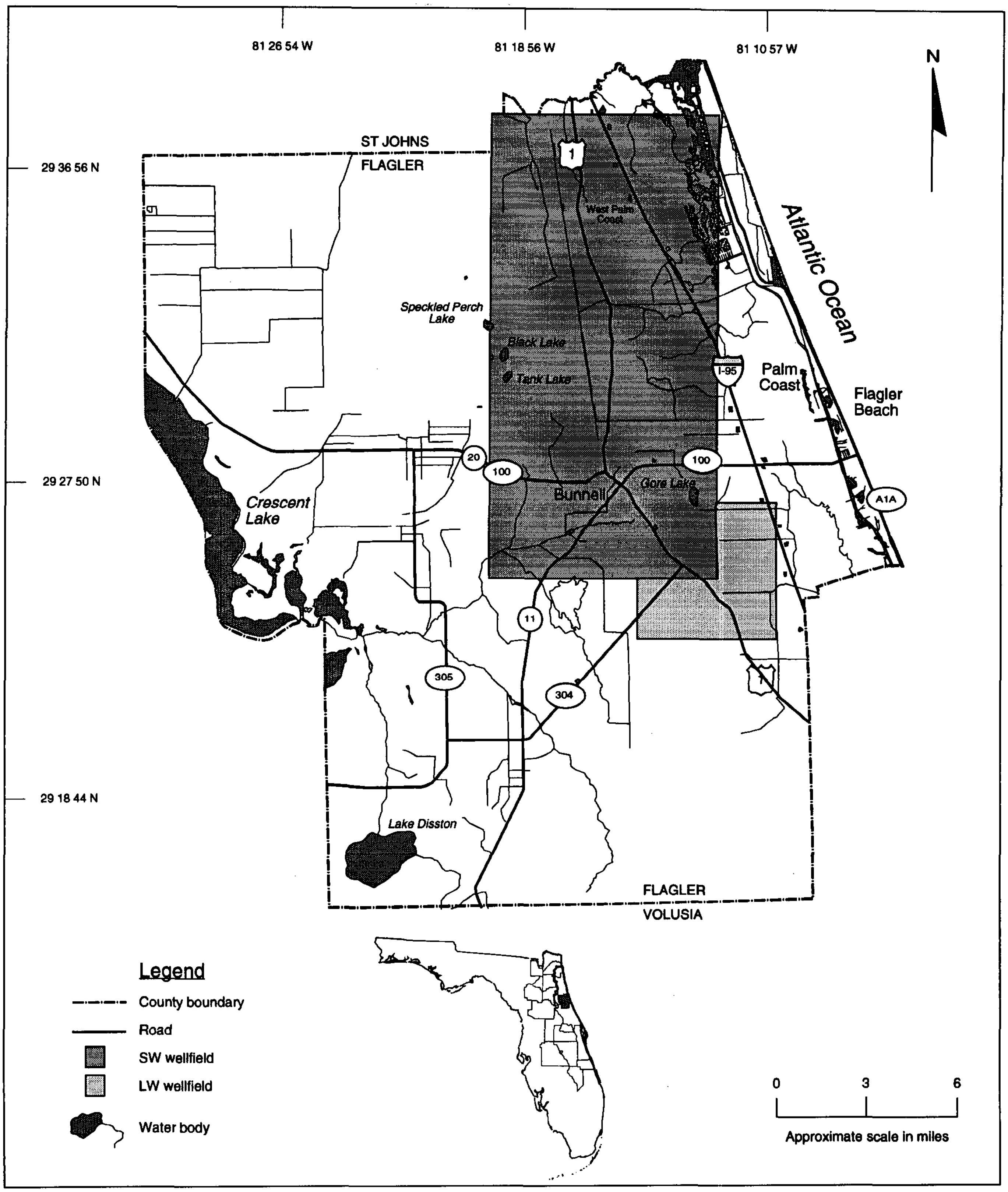
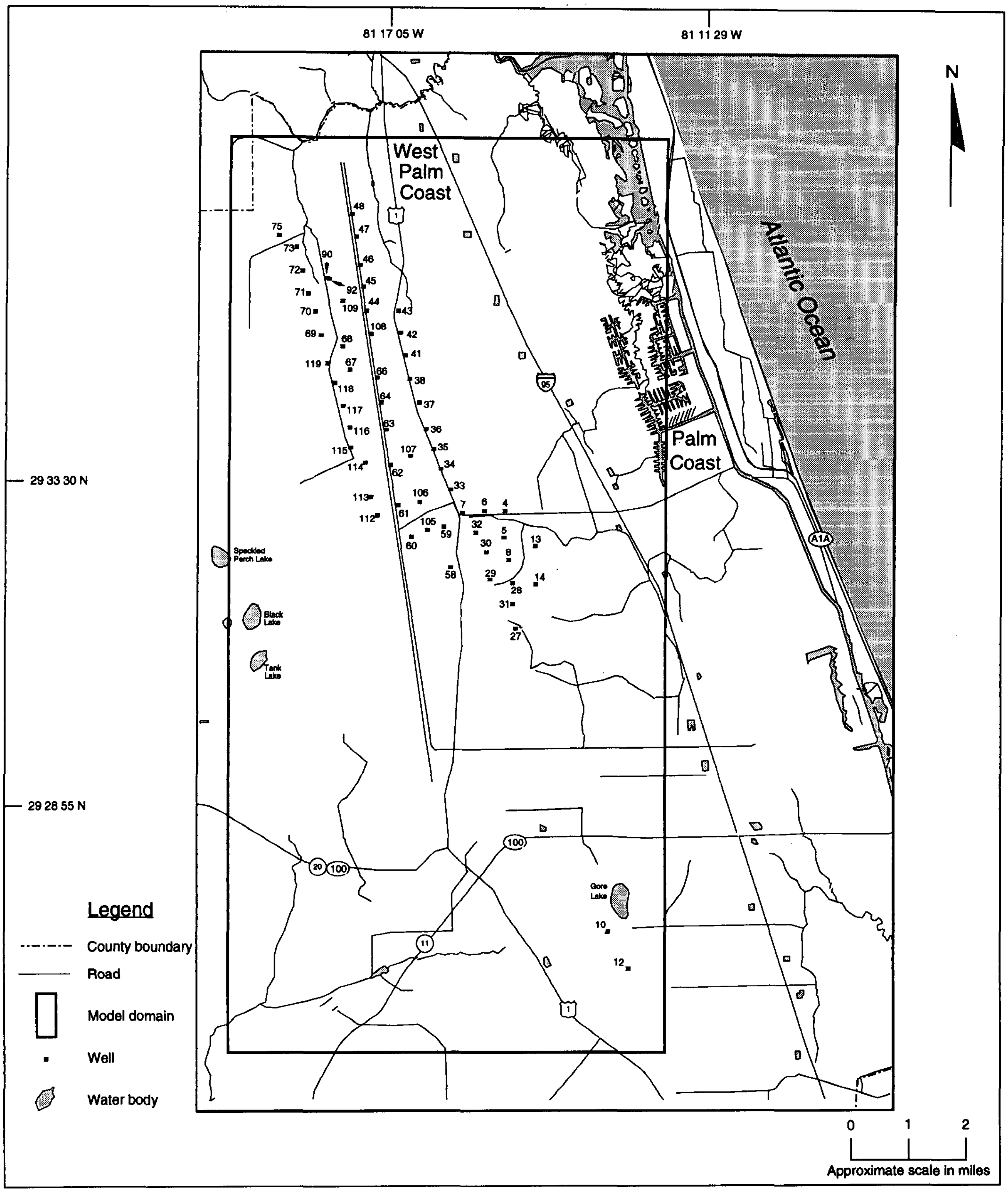


Figure 1. Locations of the SW and LW wellfields of Palm Coast Utility Corporation



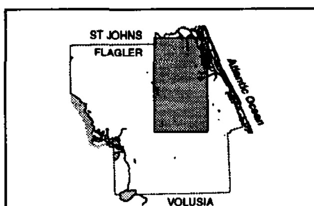


Figure 2. Model domain and well locations for the SW wellfield of Palm Coast Utility Corporation

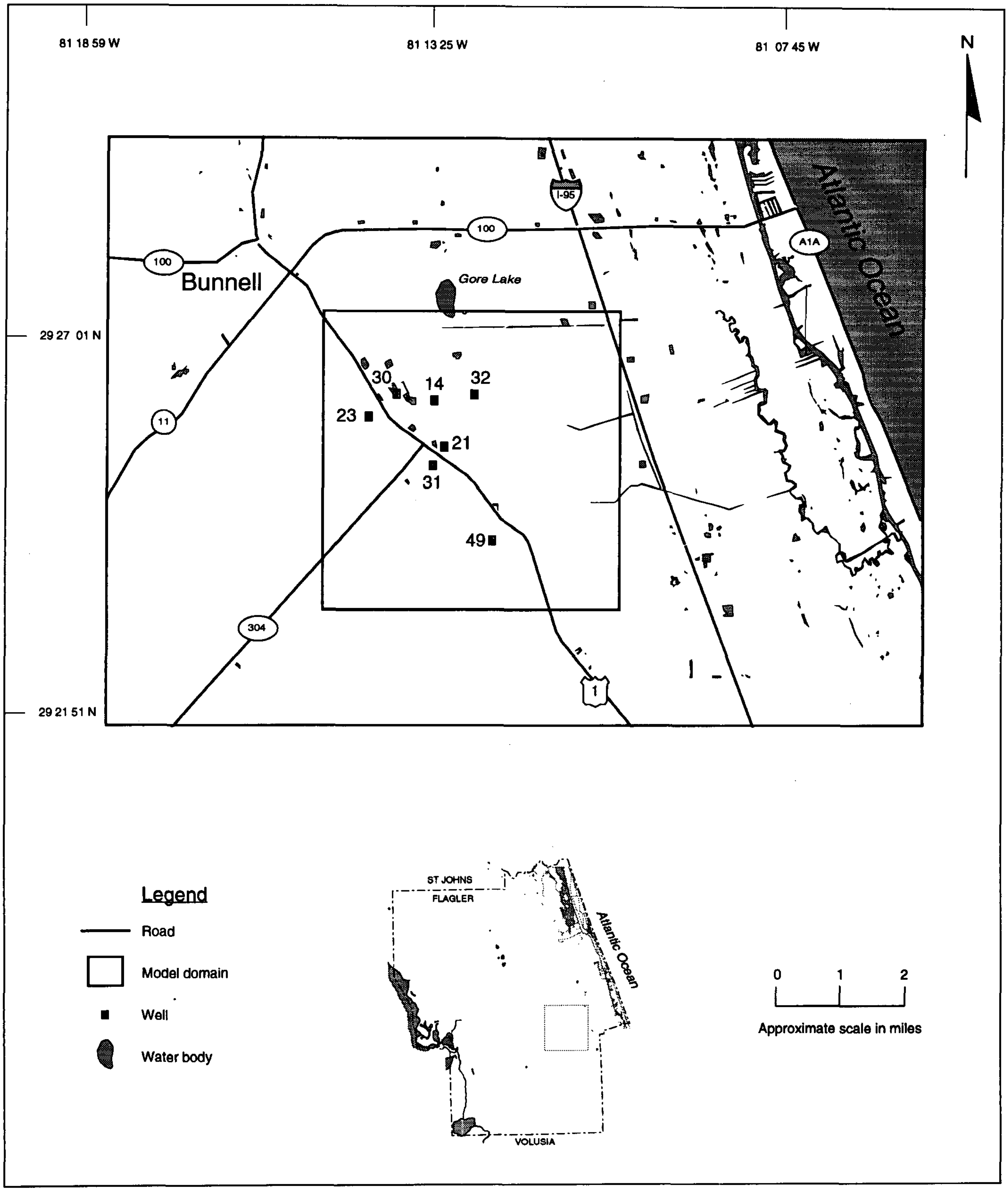


Figure 3. Model domain and well locations for the LW wellfield of Palm Coast Utility Corporation

of water supply. At the LW wellfield, the Floridan aquifer system is separated from the surficial aquifer system by the confining Hawthorn Group. The Hawthorn Group under the LW wellfield contains the intermediate aquifer system. The separation between the intermediate and the Floridan aquifer systems is due to the lower confining unit that exists at the bottom of the Hawthorn Group. At the LW wellfield, the Floridan aquifer system is the main source of water supply.

In 1988, PCUC operated only the SW wellfield; the LW wellfield began operation in 1993. The SW wellfield has 27 wells, and the LW wellfield has 3 wells. PCUC plans to add 33 wells (intermediate aquifer system) at the SW wellfield and 4 wells (Floridan aquifer system) at the LW wellfield before 2010. The locations of the existing and additional wells were identified on a map furnished by PCUC in 1993.

METHODS

The SW and LW wellfields at PCUC were evaluated using the DRAWDOWN and MLTLAY models, respectively (SJRWMD unpublished). The DRAWDOWN model uses a linear analytical solution to calculate the amount of drawdown in a coupled, two-layered (unconfined and confined), leaky-artesian aquifer (Motz 1981). The DRAWDOWN model calculates the decline in the potentiometric surface in the intermediate aquifer system and the resultant, induced drawdowns in the surficial aquifer system caused by pumping water from the intermediate aquifer system at the SW wellfield. The MLTLAY model also uses a linear analytical solution to calculate the amount of drawdown in a coupled, confined multi-layered, leaky-artesian aquifer (Bear 1979). The MLTLAY model calculates the decline in the potentiometric surface in the Floridan aquifer system and the changes of the potentiometric surface in the intermediate aquifer system caused by pumping water from the Floridan aquifer system at the LW wellfield. Both methods assume that homogeneous and isotropic conditions prevail in the aquifer systems. Horizontal flow of water is assumed for the surficial, intermediate, and Floridan aquifer systems at the SW and LW wellfields. The vertical flow between the surficial and the intermediate aquifer systems at the SW wellfield and between the intermediate and the Floridan aquifer systems at the LW wellfield is represented by the leakance coefficients and the head difference between the two aquifers through the confining bed. The lateral model boundaries for the DRAWDOWN and MLTLAY analytical models are assumed to be infinite. The models were run under a steady-state flow condition.

Aquifer characteristics used in the DRAWDOWN model include the evapotranspiration reduction coefficient, the transmissivity of the surficial and the intermediate aquifer systems, and the leakance coefficients of the confining unit between the surficial and the intermediate aquifer systems (Table 1).

Table 1. Aquifer characteristics used in the DRAWDOWN and MLTLAY models at the SW and LW wellfields, Palm Coast Utility Corporation

Aquifer Characteristic	Value
Evapotranspiration reduction coefficient (SW wellfield)	0.0002 (ft/day)/ft
Transmissivity—Surficial aquifer system (SW wellfield)	9,350 gpd/ft
Transmissivity—Intermediate aquifer system (SW and LW wellfields)	35,000 gpd/ft
Transmissivity—Floridan aquifer system (LW wellfield)	213,600 gpd/ft
Leakance—Surficial aquifer system to intermediate aquifer system (SW wellfield)	0.0007 (gpd/ft^2)/ft
Leakance—Intermediate aquifer system to Floridan aquifer system (LW wellfield)	0.0007 (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 feet per foot

The evapotranspiration reduction coefficient, measured in feet per day per foot ([ft/day]/ft), 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, for depths of 15 feet (ft) or less below land surface. For depths greater than 15 ft below land surface, a minimum evapotranspiration rate of 30 inches per year is assumed. This hydrologic parameter is used to calculate the reduction of evapotranspiration loss in response to the decline in the water table of the surficial aquifer system. An evapotranspiration reduction coefficient of 0.0002 (ft/day)/ft was used in the DRAWDOWN model.

The transmissivity of the surficial aquifer system was determined by multiplying the saturated aquifer thickness by the hydraulic conductivity. Black, Crow, and Eidsness/CH2M HILL (1977) indicated that the thickness of the surficial sediments was about 40–60 ft. A saturated thickness of 50 ft for the surficial aquifer system was used in the DRAWDOWN model. Geologic information indicates that the surficial sediments are composed of sands and clayey sands (Bermes et al. 1963a, 1963b; Black, Crow, and Eidsness/CH2M HILL 1977). Based on the composition and thickness of the surficial sediments, a horizontal hydraulic conductivity of 187 gallons per day per square foot (or 25 feet per day) was used to estimate the transmissivity of the surficial aquifer system (Freeze and Cherry 1979, p. 29). A transmissivity of 9,350 gallons per day per foot (gpd/ft) was used in the DRAWDOWN model.

The transmissivity of the intermediate aquifer system came from Blasland, Bouck, and Lee (1990). The transmissivity ranged from 1,500 gpd/ft to 60,000 gpd/ft. A transmissivity of 35,000 gpd/ft was used for the intermediate aquifer system in the DRAWDOWN model.

The leakance coefficient of the confining bed came from Blasland, Bouck, and Lee (1990). A leakance coefficient of 0.0007 gallons per day per square feet per foot ([gpd/ft^2]/ft) was used in the DRAWDOWN model for the confining unit between the surficial and the intermediate aquifer systems. The confining unit is the top portion of the Hawthorn Group, which separates the surficial and the intermediate aquifer systems.

The aquifer systems considered in the MLTLAY model include the intermediate and the Floridan aquifer systems separated by a leaky semiconfining unit. The MLTLAY model is capable of handling three pumping scenarios. The first scenario is pumping water from the intermediate aquifer system. The second scenario is pumping water from the Floridan aquifer system. The third pumping scenario is simultaneously pumping water from both aquifer systems. At the LW wellfield, water is pumped from the Floridan aquifer system only.

Aquifer characteristics used in the MLTLAY model include the transmissivity of the intermediate and the Floridan aquifer systems, and the leakance coefficient of the confining layer between the intermediate and the Floridan aquifer systems (Table 1). The transmissivity value used in the DRAWDOWN model for the intermediate aquifer system also was used in the MLTLAY model—35,000 gpd/ft. The transmissivity of the Floridan aquifer system was obtained from various U.S. Geological Survey publications and from pump tests of wells in the area at the LW wellfield (Bentley 1977; Navoy and Bradner 1987; Tibbals 1981). A transmissivity of the Floridan aquifer system of 213,600 gpd/ft was used. The confining unit between the intermediate and the Floridan aquifer systems is the lower portion of the Hawthorn Group. A leakance coefficient of 0.0007 (gpd/ft^2)/ft for the Hawthorn Group was used to represent the confining unit between the intermediate and the Floridan aquifer systems.

At the LW wellfield, the MLTLAY model calculates the drawdown distributions in the intermediate and the Floridan aquifer systems and at the pumping wells, but the impact on the surficial aquifer system is not calculated. Therefore, the induced change in the elevation of the water table in the surficial aquifer system caused by withdrawing water from the Floridan aquifer system was calculated using the SURFDOWN model (Huang and Williams 1996, draft). The SURFDOWN model is an analytical, two-aquifer, steady-state model. It calculates the induced drawdown of the elevation of the water table in the surficial aquifer system as a result of pumping from the intermediate or the Floridan aquifer systems.

Actual well pumpage for 1988 and estimated pumpage for 2010, measured in gallons per day (gpd), were used in the models (Tables 2–5). Pumpage for each well was calculated using pump capacity and the percentage of time each pump was in operation. Pump capacities, the percentage of operation time, and pumping rates for

1988 were derived from Blasland, Bouck, and Lee (1990, 1991), Glace & Radcliffe (1989), and Florence (1990).

Table 2. Pumpage and calculated drawdowns (1988) in the surficial and the intermediate aquifer systems at the SW wellfield of Palm Coast Utility Corporation

Well Number	State Plane Coordinate X (feet)	State Plane Coordinate Y (feet)	Pumpage (gpd)	Calculated Drawdown Surficial Aquifer System (feet)	Calculated Drawdown Intermediate Aquifer System (feet)
SW4	420,159	1,897,606	33,868	1.70	6.88
SW5	420,066	1,895,283	149,018	1.86	11.34
SW6	418,304	1,897,610	101,603	1.88	9.70
SW7	416,273	1,897,413	33,868	1.94	7.64
SW8	420,503	1,893,363	62,091	1.81	8.44
SW13	422,891	1,894,570	27,094	1.48	5.79
SW14	422,972	1,891,237	39,512	1.44	6.19
SW27	421,197	1,887,402	164,541	1.31	9.93
SW28	420,852	1,891,342	81,283	1.70	8.70
SW29	418,821	1,891,650	88,056	1.77	8.98
SW30	418,473	1,893,974	28,223	1.90	7.51
SW31	420,848	1,889,524	86,669	1.56	8.37
SW32	417,505	1,895,693	27,094	1.93	7.48
SW33	415,217	1,899,435	71,122	1.94	8.90
SW34	414,338	1,901,256	149,018	1.91	11.47
SW35	413,636	1,902,974	76,767	1.79	8.76
SW36	412,934	1,904,693	101,603	1.59	8.70
SW58	415,202	1,892,668	67,735	1.65	7.55
SW59	414,592	1,896,204	18,063	1.87	6.77
SW60	411,675	1,895,302	50,802	1.61	6.87
SW61	410,445	1,898,032	36,126	1.73	6.79
SW62	409,747	1,901,570	73,380	1.86	8.76
SW105	413,089	1,895,905	35,560	1.77	7.00
SW106	412,389	1,898,331	30,581	1.87	7.19
SW107	411,515	1,902,373	27,094	1.85	7.21
SW114	407,451	1,901,777	155,227	1.78	11.62
SW115	406,130	1,903,094	316,099	1.65	16.43
Total			2,132,097		

Note: gpd = gallons per day

Table 3. Pumpage and calculated drawdowns (2010) in the surficial and the intermediate aquifer systems at the SW wellfield of Palm Coast Utility Corporation

Well Number	State Plane Coordinate		Pumpage (gpd)*	Calculated Drawdown	
	X (feet)	Y (feet)		Surficial Aquifer System (feet)	Intermediate Aquifer System (feet)
SW4	420,159	1,897,606	100,000	2.97	13.24
SW5	420,066	1,895,283	100,000	3.01	13.52
SW6	418,304	1,897,610	100,000	3.32	14.48
SW7	416,273	1,897,413	100,000	3.59	15.43
SW8	420,503	1,893,363	100,000	2.90	13.27
SW10	429,565	1,860,945	100,000	0.39	4.74
SW12	431,438	1,857,757	100,000	0.38	4.70
SW13	422,891	1,894,570	100,000	2.46	11.37
SW14	422,972	1,891,237	100,000	2.23	10.81
SW27	421,197	1,887,402	100,000	1.85	9.43
SW28	420,852	1,891,342	100,000	2.61	12.32
SW29	418,821	1,891,650	100,000	2.79	12.66
SW30	418,473	1,893,974	100,000	3.19	14.12
SW31	420,848	1,889,524	100,000	2.25	10.96
SW32	417,505	1,895,693	100,000	3.44	15.01
SW33	415,217	1,899,435	100,000	3.61	15.30
SW34	414,338	1,901,256	100,000	3.60	15.12
SW35	413,636	1,902,974	100,000	3.57	14.92
SW36	412,934	1,904,693	100,000	3.55	14.88
SW37	412,331	1,907,032	100,000	3.52	14.78
SW38	411,444	1,909,129	100,000	3.52	14.80
SW41	411,038	1,911,184	100,000	3.42	14.50
SW42	410,578	1,913,156	100,000	3.30	14.19
SW43	410,396	1,915,039	100,000	3.07	13.33
SW44	407,502	1,915,046	100,000	3.50	15.04
SW45	407,178	1,917,163	100,000	3.27	14.16
SW46	406,833	1,919,026	100,000	2.90	12.98
SW47	406,550	1,921,493	100,000	2.36	11.10
SW48	406,099	1,923,455	100,000	1.93	9.59
SW58	415,202	1,892,668	100,000	3.14	13.72
SW59	414,592	1,896,204	100,000	3.46	15.02
SW60	411,675	1,895,302	100,000	3.17	13.73
SW61	410,445	1,898,032	100,000	3.49	14.89
SW62	409,747	1,901,570	100,000	3.73	15.58
SW63	409,305	1,904,642	100,000	3.82	15.81
SW64	408,847	1,907,034	100,000	3.84	15.90
SW66	408,489	1,909,203	100,000	3.83	15.88
SW67	406,025	1,909,912	100,000	3.75	15.87
SW68	405,365	1,911,960	100,000	3.68	15.62
SW69	403,423	1,912,931	100,000	3.37	14.47

Table 3—*Continued*

Well Number	State Plane Coordinate		Pumpage (gpd)*	Calculated Drawdown	
	X (feet)	Y (feet)		Surficial Aquifer System (feet)	Intermediate Aquifer System (feet)
SW70	402,912	1,915,011	100,000	3.25	14.25
SW71	402,181	1,916,539	100,000	3.03	13.65
SW72	401,675	1,918,481	100,000	2.73	12.58
SW73	401,118	1,920,555	100,000	2.30	11.01
SW75	399,548	1,921,572	100,000	1.87	9.45
SW90	403,930	1,917,914	100,000	3.15	15.27
SW92	403,964	1,917,818	100,000	3.17	15.34
SW105	413,089	1,895,905	100,000	3.46	14.94
SW106	412,389	1,898,331	100,000	3.70	15.52
SW107	411,515	1,902,373	100,000	3.80	15.78
SW108	407,947	1,913,030	100,000	3.66	15.45
SW109	405,328	1,915,876	100,000	3.47	15.11
SW112	408,586	1,897,158	100,000	3.05	13.35
SW113	407,970	1,898,772	100,000	3.20	13.82
SW114	407,451	1,901,777	100,000	3.42	14.49
SW115	406,130	1,903,094	100,000	3.19	13.57
SW116	406,033	1,904,813	100,000	3.50	14.80
SW117	405,428	1,906,717	100,000	3.52	14.87
SW118	404,671	1,908,741	100,000	3.50	14.97
SW119	404,009	1,910,478	100,000	3.45	14.81
Total			6,000,000		

Note: gpd = gallons per day

*Source: PCUC, pers. com. 1994

Table 4. Difference in drawdowns from 1988 to 2010 at the SW wellfield of Palm Coast Utility Corporation

Well Number	Drawdown Difference (feet)	
	Surficial Aquifer System	Intermediate Aquifer System
SW4	1.27	6.36
SW5	1.15	2.18
SW6	1.44	4.78
SW7	1.65	7.79
SW8	1.09	4.83
SW10	0.36*	4.66*
SW12	0.36*	4.65*
SW13	0.98	5.58
SW14	0.79	4.62
SW27	0.54	–0.50
SW28	0.91	3.62
SW29	1.02	3.68
SW30	1.29	6.61

Table 4—*Continued*

Well Number	Drawdown Difference (feet)	
	Surficial Aquifer System	Intermediate Aquifer System
SW31	0.69	2.59
SW32	1.51	7.53
SW33	1.67	6.40
SW34	1.69	3.65
SW35	1.78	6.16
SW36	1.96	6.18
SW37	2.34*	11.05*
SW38	2.62*	12.05*
SW41	2.73*	12.42*
SW42	2.78*	12.66*
SW43	2.68*	12.17*
SW44	3.13*	13.93*
SW45	2.99*	13.32*
SW46	2.69*	12.34*
SW47	2.20*	10.63*
SW48	1.81*	9.23*
SW58	1.49	6.17
SW59	1.59	8.25
SW60	1.56	6.86
SW61	1.76	8.10
SW62	1.87	6.82
SW63	2.24*	10.52*
SW64	2.66*	12.21*
SW66	2.96*	13.22*
SW67	3.00*	13.61*
SW68	3.12*	13.94*
SW69	2.87*	12.97*
SW70	2.91*	13.24*
SW71	2.74*	12.77*
SW72	2.50*	11.91*
SW73	2.13*	10.49*
SW75	1.72*	9.00*
SW90	2.89*	14.51*
SW92	2.91*	14.58*
SW105	1.69	7.94
SW106	1.83	8.33
SW107	1.95	8.57
SW108	3.15*	13.92*
SW109	3.14*	14.13*
SW112	1.56*	8.62*
SW113	1.65*	8.80*
SW114	1.64	2.87
SW115	1.54	–2.86
SW116	2.07*	9.54*
SW117	2.42*	11.33*
SW118	2.66*	12.39*
SW119	2.79*	12.83*

*Interpolated value

Table 5. Pumpage and calculated drawdowns (1993) in the surficial, intermediate, and Floridan aquifer systems at the LW wellfield of Palm Coast Utility Corporation

Well Number	State Plane Coordinate X (feet)	State Plane Coordinate Y (feet)	Pumpage (gpd)	Calculated Drawdown: Surficial Aquifer System (feet)	Calculated Drawdown: Intermediate Aquifer System (feet)	Calculated Drawdown: Floridan Aquifer System (feet)
LW21	430,584	1,851,627	20,600	0.03	0.28	1.05
LW30	426,612	1,855,977	72,000	0.02	0.24	1.00
LW31	429,608	1,850,214	394,600	0.03	0.29	3.11
Total			487,200			

Note: gpd = gallons per day

In general, the pumping capacities of the 27 production wells (SW wellfield) in 1988, obtained through various sources, were consistent with the pump capacities reported in the wellhead protection area questionnaire (SJRWMD unpublished). The 1988 calculated pumpage for the 27 production wells at the SW wellfield was 2.132 million gallons per day (mgd) (Table 2). The 1988 average daily pumpage at the SW wellfield ranged from 18,063 gpd to 316,099 gpd (Table 2). The 2010 projected pumpage for the 60 production wells at the SW wellfield was 6.0 mgd (Table 3) (PCUC, pers. com. 1994), or 100,000 gpd per well.

At the LW wellfield, the 1993 calculated pumpage of water from the Floridan aquifer system for the existing three wells was 0.487 mgd (Table 5). The 1993 average daily pumping rates of the three Floridan aquifer wells at the LW wellfield ranged from 20,600 gpd to 394,600 gpd (Table 5). The 2010 projected pumpage at the seven production wells at the LW wellfield was 7.296 mgd (Table 6) (PCUC, pers. com. 1994).

Table 6. Pumpage and calculated drawdowns (2010) in the surficial, intermediate, and Floridan aquifer systems at the LW wellfield of Palm Coast Utility Corporation

Well Number	State Plane Coordinate X (feet)	State Plane Coordinate Y (feet)	Pumpage (gpd)*	Calculated Drawdown: Surficial Aquifer System (feet)	Calculated Drawdown: Intermediate Aquifer System (feet)	Calculated Drawdown: Floridan Aquifer System (feet)
LW14	429,708	1,855,365	576,000	0.49	3.73	13.33
LW21	430,584	1,851,627	1,200,000	0.49	3.76	17.23
LW23	424,398	1,854,063	1,200,000	0.41	3.48	15.87
LW30	426,612	1,855,977	1,200,000	0.46	3.61	16.44
LW31	429,608	1,850,214	1,200,000	0.47	3.68	16.85
LW32	432,978	1,856,066	1,200,000	0.42	3.47	15.67
LW49	434,372	1,843,943	720,000	0.25	2.73	10.32
Total			7,296,000			

Note: gpd = gallons per day

*Source: PCUC, pers. com. 1994

The average pumping rate for each well at each wellfield was used in either the DRAWDOWN or MLTLAY model to determine the drawdown in each aquifer system.

RESULTS

Drawdowns calculated by the DRAWDOWN and MLTLAY models are based on the assumption that all wells were pumping on a 24-hour schedule for a long period of time, at an average pumping rate. In reality, however, the wells are actually operated at pumping capacity on an alternating schedule to prevent an overdraft of water from the aquifers and to achieve optimal operation. By using the long-term average pumping rates for each production well, the change in the elevation of the potentiometric surface in each aquifer can be evaluated in response to an integrated pumping stress on the ground water system under a steady-state pumping condition. In reality, the elevation of the potentiometric surface of an aquifer system fluctuates in response to the pumping stress based on the pumping schedule of the production well. The long-term average pumping assumption presented a conservative impact analysis on the ground water system.

At the SW wellfield, the DRAWDOWN model calculated the drawdowns in the surficial and the intermediate aquifer systems for 1988 and 2010. The calculated 1988 drawdowns at the SW wellfield ranged from 1.31 to 1.94 ft in the surficial aquifer system and from 5.79 to 16.43 ft in the intermediate aquifer system (Table 2). Based on the 2010 projected pumping rate of 100,000 gpd for each of the 60 wells (provided by PCUC), the calculated 2010 drawdowns at the SW wellfield ranged from 0.38 to 3.84 ft in the surficial aquifer system and from 4.70 to 15.90 ft in the intermediate aquifer system (Table 3). For the 27 wells in existence in 1988 and expected to be in existence in 2010, the changes in drawdown ranged from 0.54 to 1.96 ft in the surficial aquifer system and from a rise of 2.86 ft to a decline of 8.57 ft in the intermediate aquifer system (Table 4). However, the change in calculated drawdowns from 1988 to 2010 at the pumping wells when interpolated values were included ranged from 0.36 to 3.15 ft in the surficial aquifer system and from a rise of 2.86 ft to a decline of 14.58 ft in the intermediate aquifer system (Table 4).

At the LW wellfield, the MLTLAY model (using SURFDOWN) calculated the drawdowns in the surficial, intermediate, and Floridan aquifer systems for 1993 and 2010. The calculated 1993 drawdowns at the LW wellfield ranged from 0.02 to 0.03 ft in the surficial aquifer system, from 0.24 to 0.29 ft in the intermediate aquifer system, and from 1.00 to 3.11 ft in the Floridan aquifer system (Table 5). The 2010 average daily pumping rates of the proposed seven wells at the LW wellfield ranged from 576,000 gpd to 1,200,000 gpd. The calculated 2010 drawdowns at the LW wellfield ranged from 0.25 to 0.49 ft in the surficial aquifer system, from 2.73 to 3.76 ft in the intermediate aquifer system, and from 10.32 to 17.23 ft in the Floridan aquifer system (Table 6). For the three wells in existence in 1993 and expected to be in existence in 2010, the changes in drawdown ranged from 0.44 to 0.46 ft in the surficial aquifer system, from 3.37 to 3.48 ft in the intermediate aquifer system, and from 13.74 to 16.18 ft in the Floridan aquifer system (Table 7). However, the change in calculated drawdowns from 1993 to 2010 at the pumping wells when interpolated values were included ranged from 0.23 to 0.47 ft in the surficial aquifer system and from 2.49 to 3.49 ft in the intermediate aquifer system (Table 7).

Table 7. Difference in drawdowns from 1993 to 2010 at the LW wellfield of Palm Coast Utility Corporation

Well Number	Drawdown Difference (feet)		
	Surficial Aquifer System	Intermediate Aquifer System	Floridan Aquifer System
LW14	0.47*	3.49*	NA
LW21	0.46	3.48	16.18
LW23	0.39*	3.25*	NA
LW30	0.44	3.37	15.44
LW31	0.44	3.39	13.74
LW32	0.40*	3.22*	NA
LW49	0.23*	2.49*	NA

*Interpolated value

Note: NA = not applicable

Calculated drawdowns for each wellfield were contoured. The calculated drawdowns at the SW wellfield were contoured for the surficial and the intermediate aquifer systems for 1988 (Figures 4 and 5) and 2010 (Figures 6 and 7). The change in calculated drawdowns in the surficial aquifer system at the SW wellfield from 1988 to 2010 also was contoured (Figure 8). The calculated drawdowns at the LW wellfield were contoured for the surficial aquifer system, the intermediate aquifer system, and the Floridan aquifer system for 1993 (Figures 9–11) and 2010 (Figures 12–14). The change in calculated drawdowns in the surficial aquifer system at the LW wellfield from 1993 to 2010 also was contoured (Figure 15).

DISCUSSION

When water is pumped from the intermediate aquifer system at the SW wellfield, the potentiometric surface in the intermediate aquifer system declines. The water in the surficial aquifer system moves into the intermediate aquifer system by means of leakage through the upper confining unit of the intermediate aquifer system. A response to this downward leakage is the decline in the elevation of the water table in the surficial

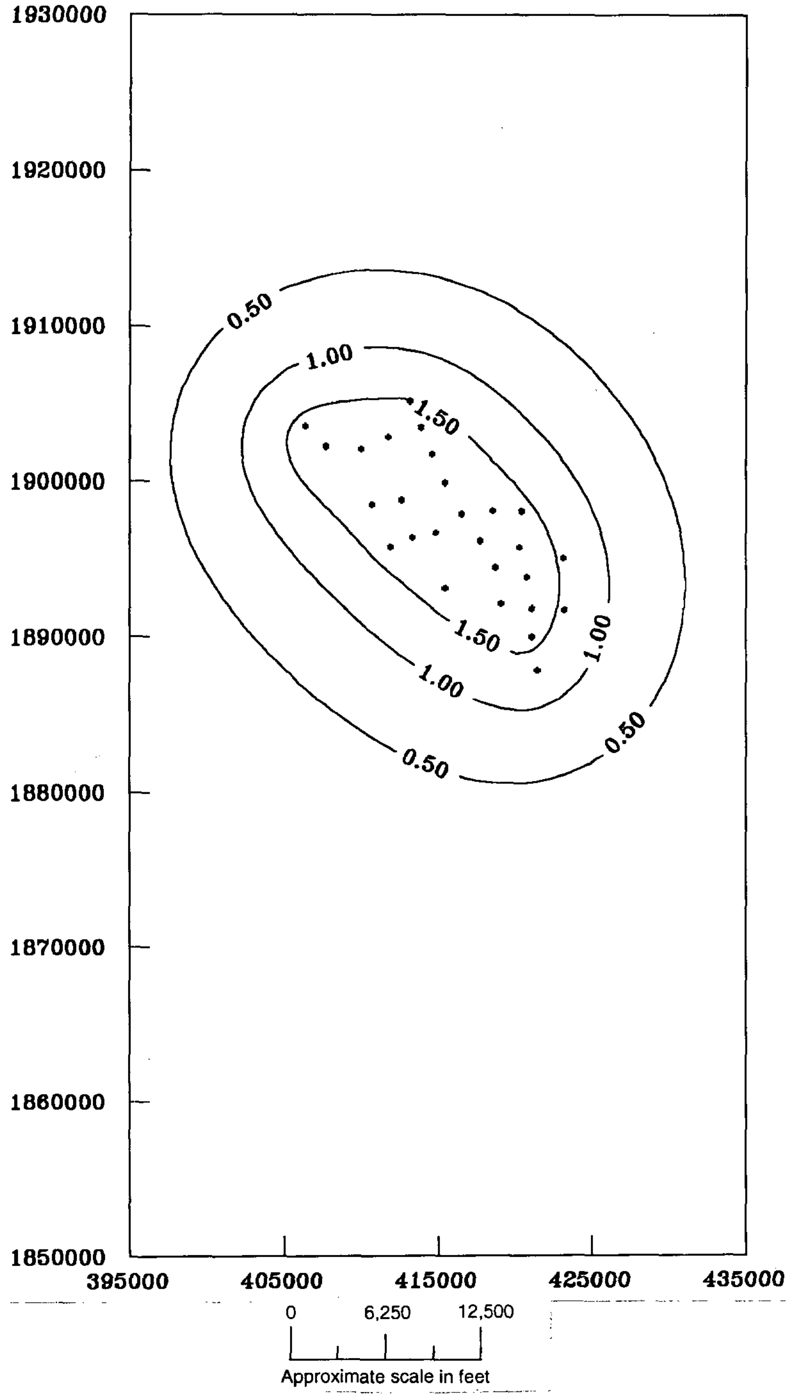


Figure 4. Calculated 1988 drawdowns in the surficial aquifer system at the SW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

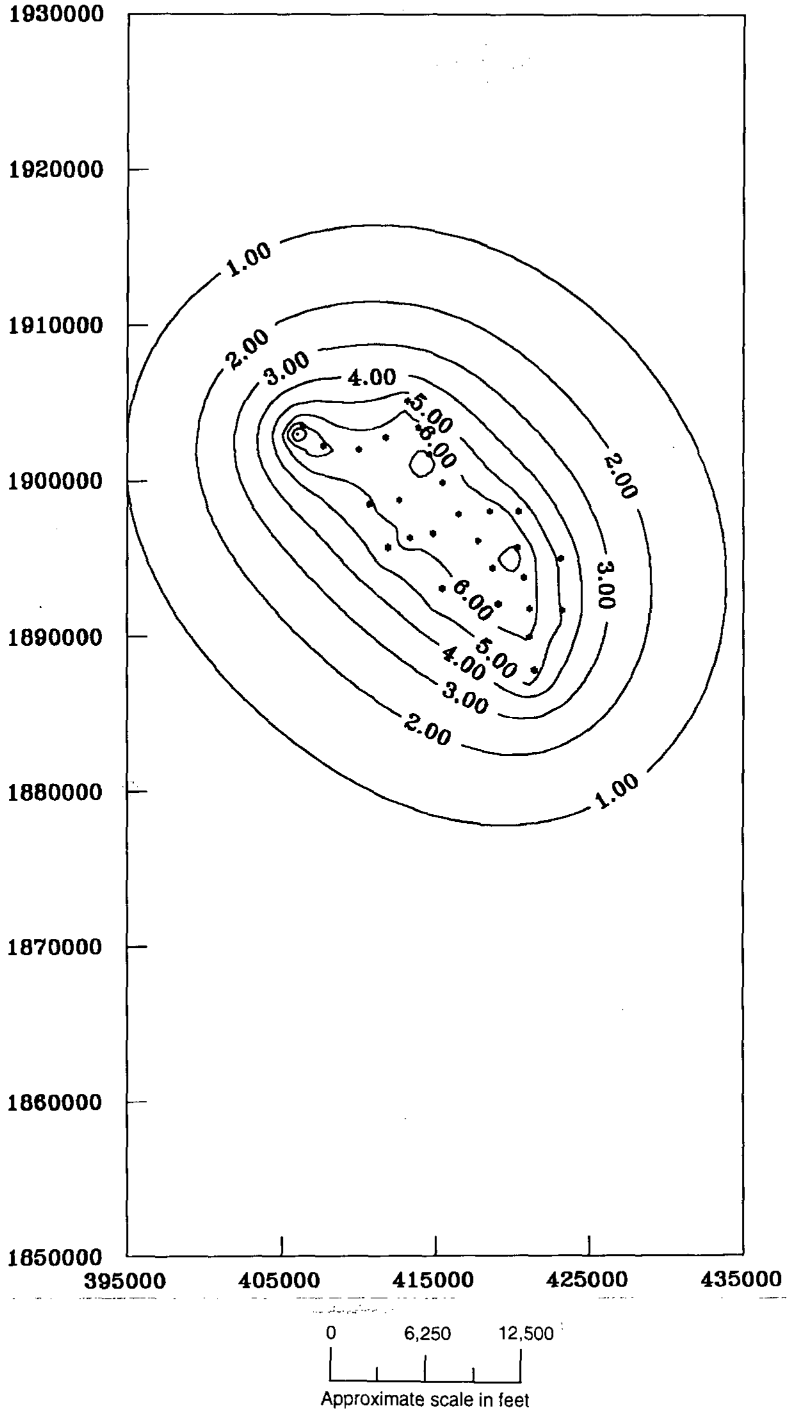


Figure 5. Calculated 1988 drawdowns in the intermediate aquifer system at the SW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

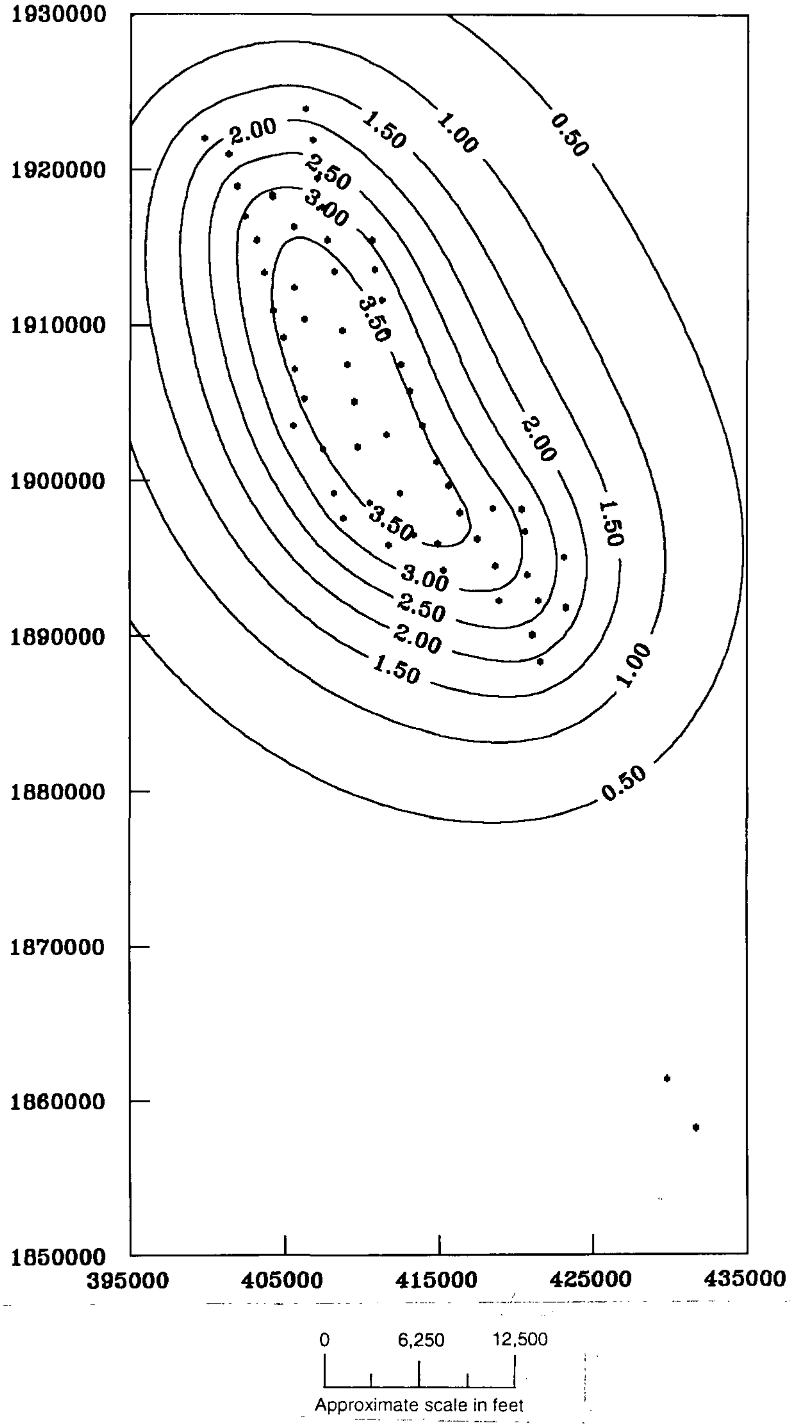


Figure 6. Calculated 2010 drawdowns in the surficial aquifer system at the SW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

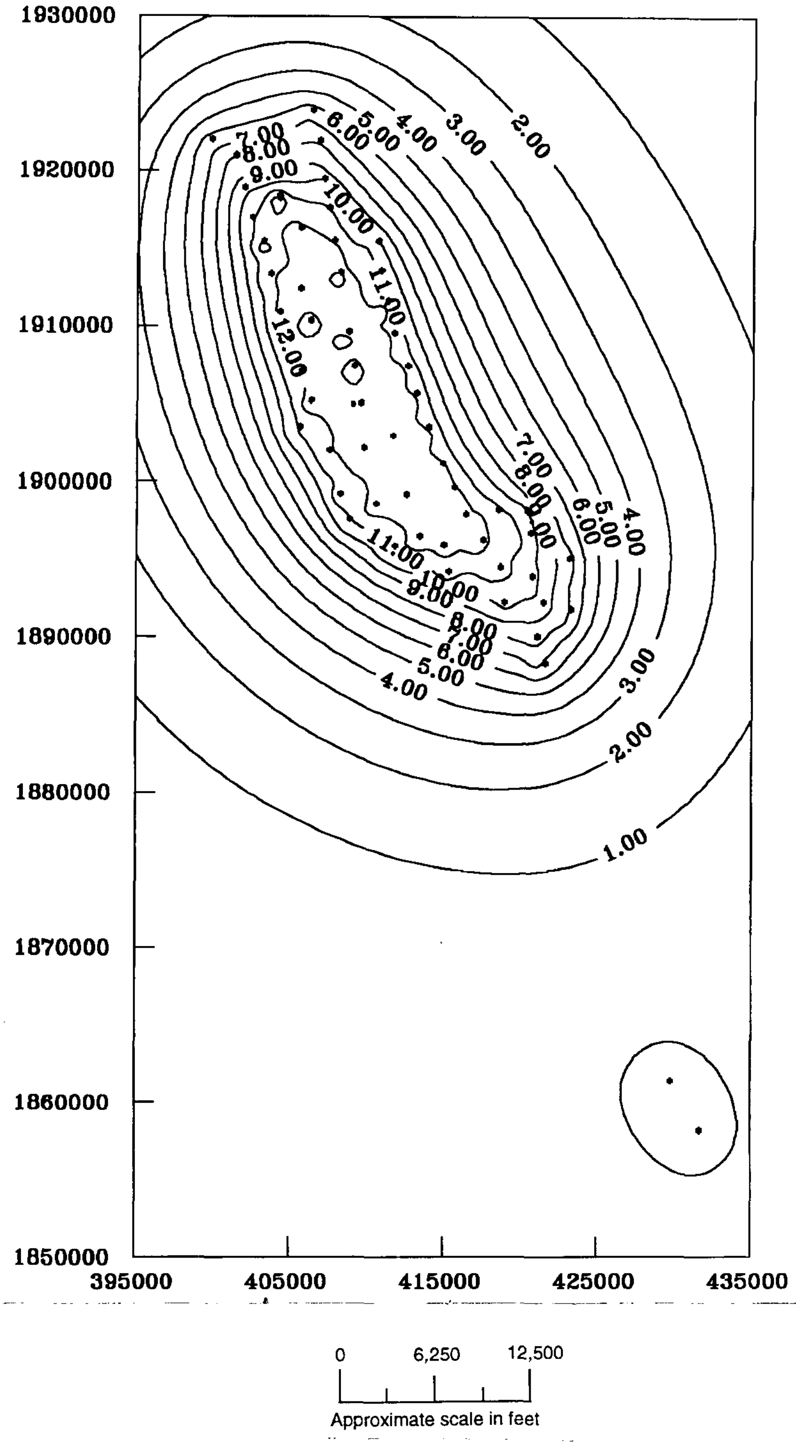


Figure 7. Calculated 2010 drawdowns in the intermediate aquifer system at the SW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

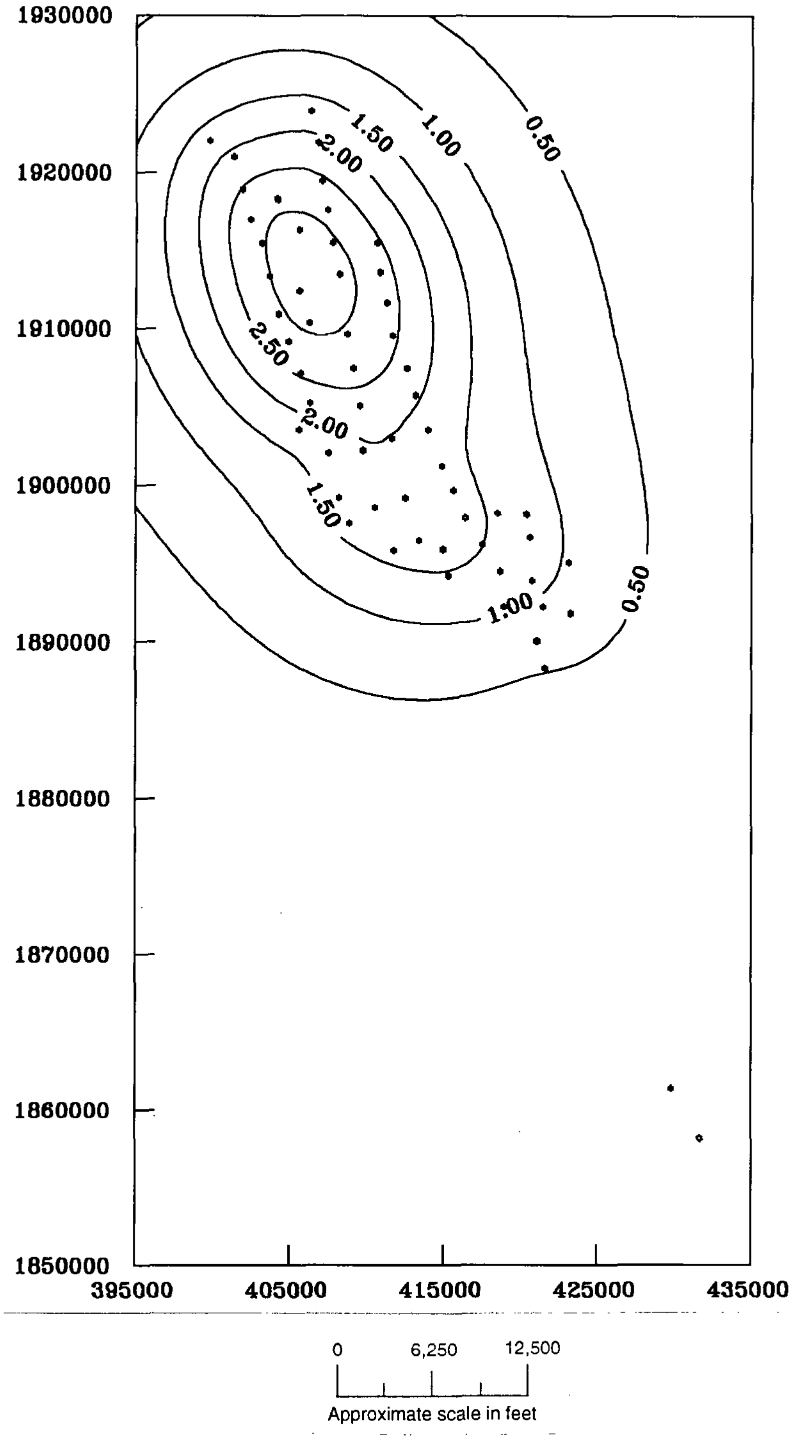


Figure 8. Differences in calculated drawdowns between 1988 and 2010 in the surficial aquifer system at the SW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

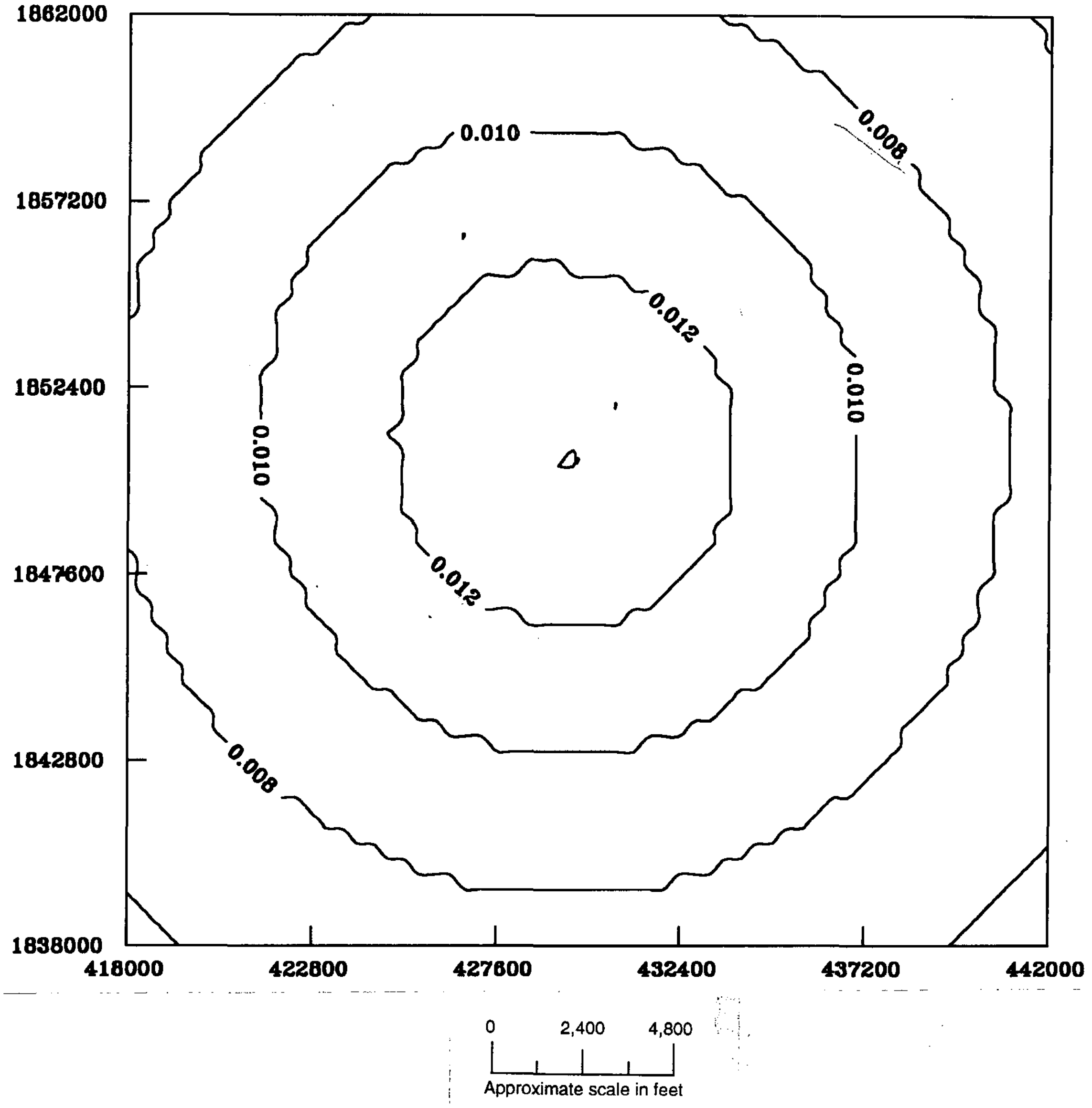


Figure 9. Calculated 1993 drawdowns in the surficial aquifer system at the LW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

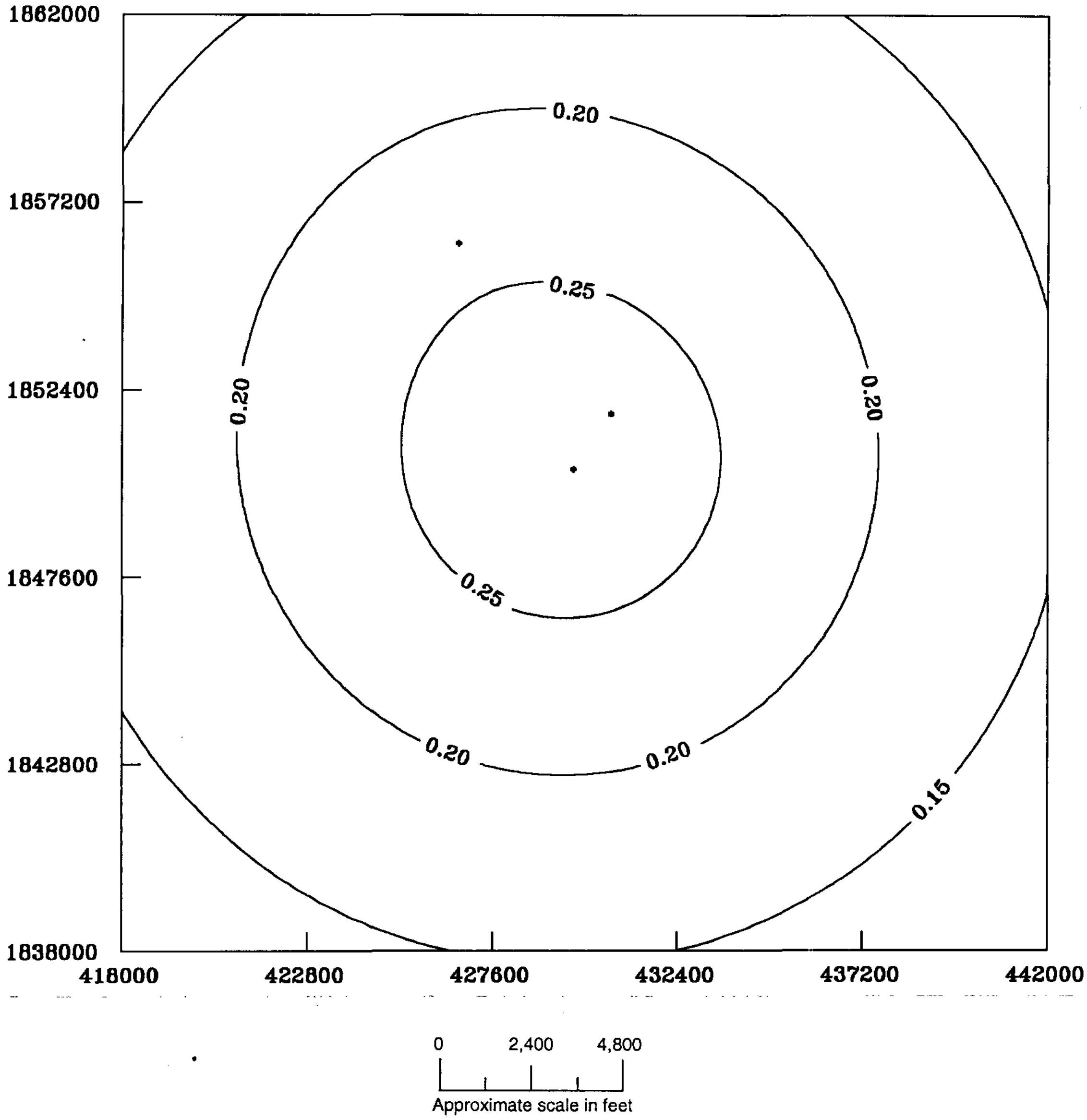


Figure 10. Calculated 1993 drawdowns in the intermediate aquifer system at the LW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

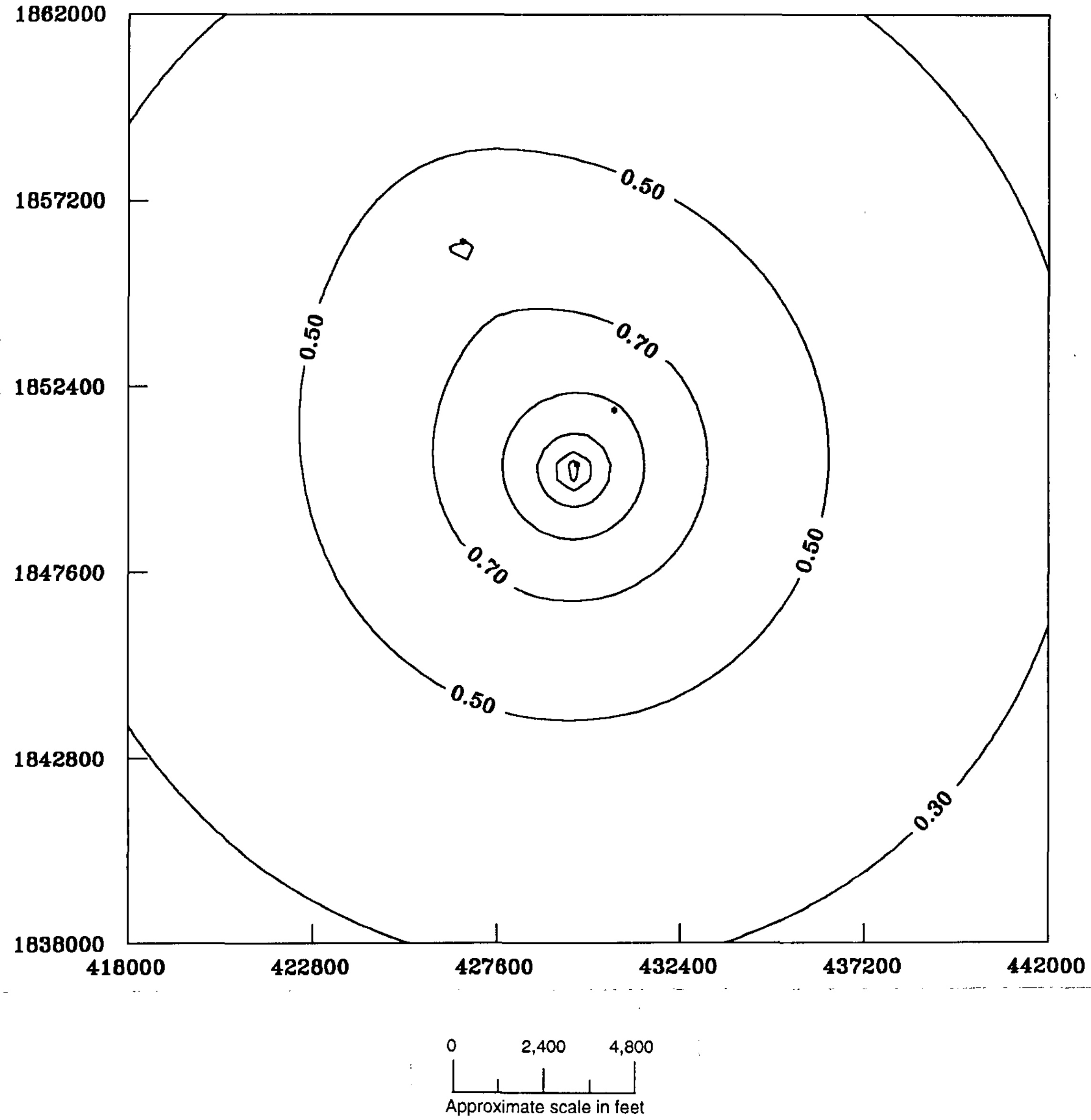


Figure 11. Calculated 1993 drawdowns in the Floridan aquifer system at the LW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

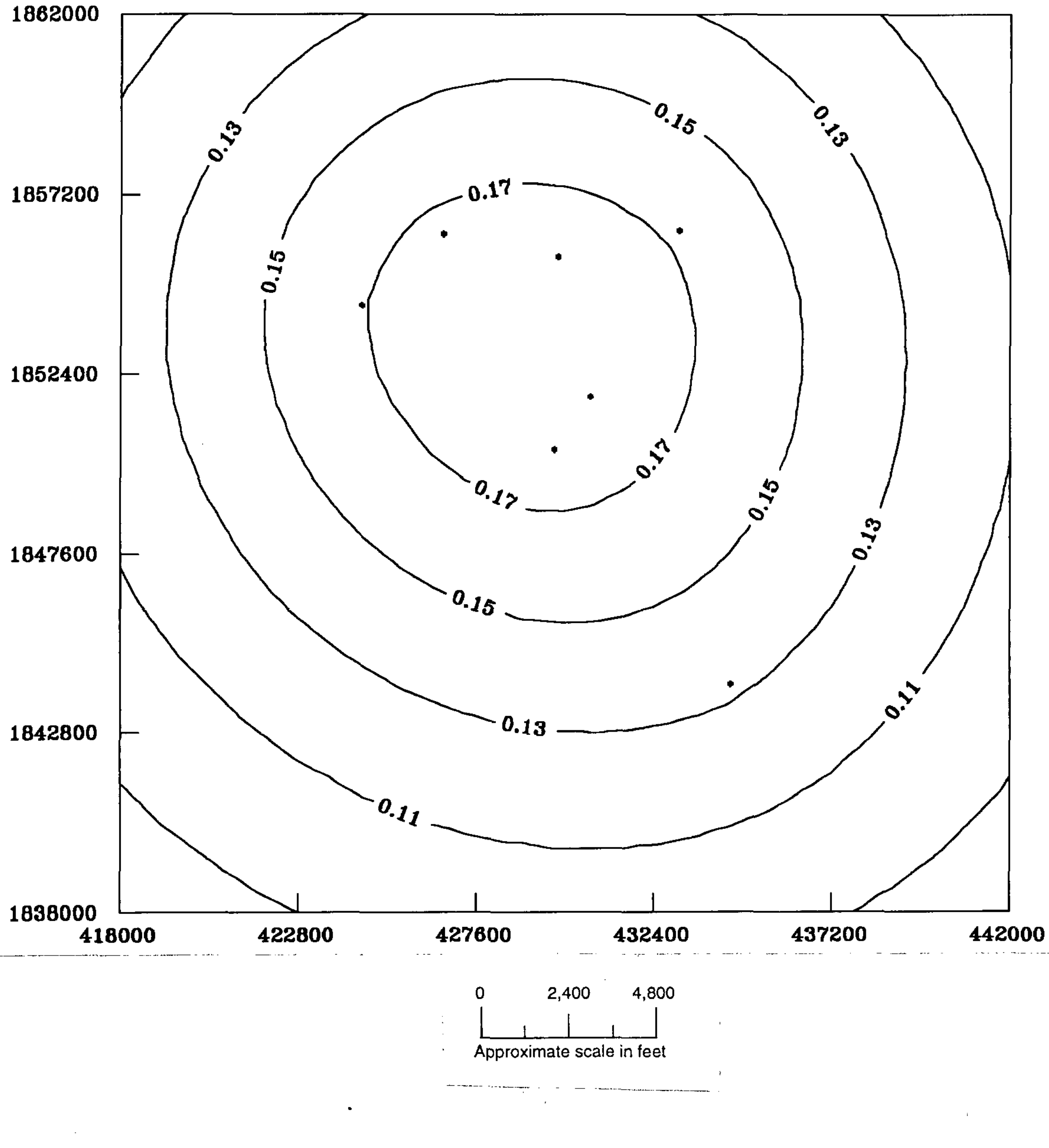


Figure 12. Calculated 2010 drawdowns in the surficial aquifer system at the LW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

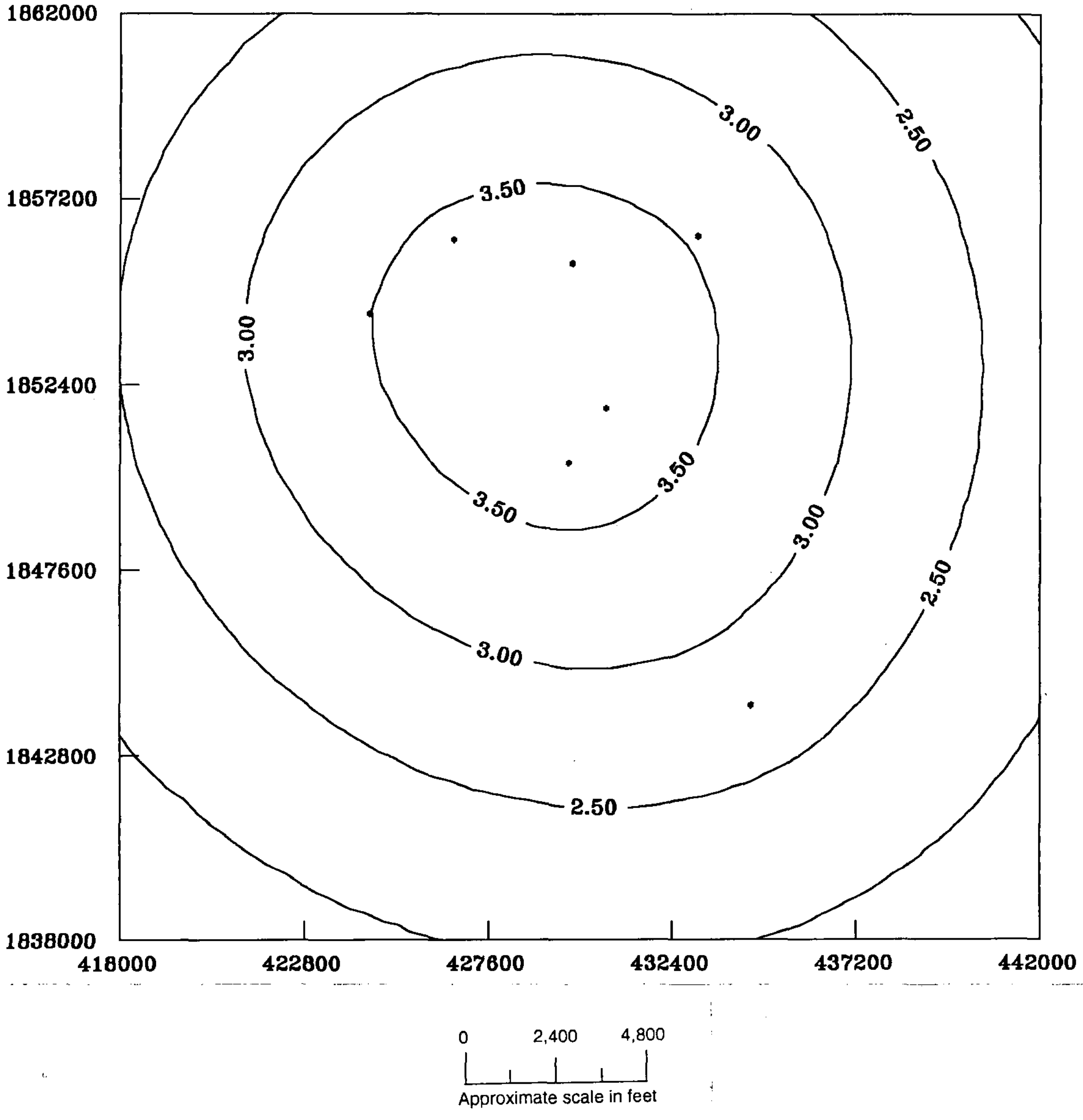


Figure 13. Calculated 2010 drawdowns in the intermediate aquifer system at the LW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

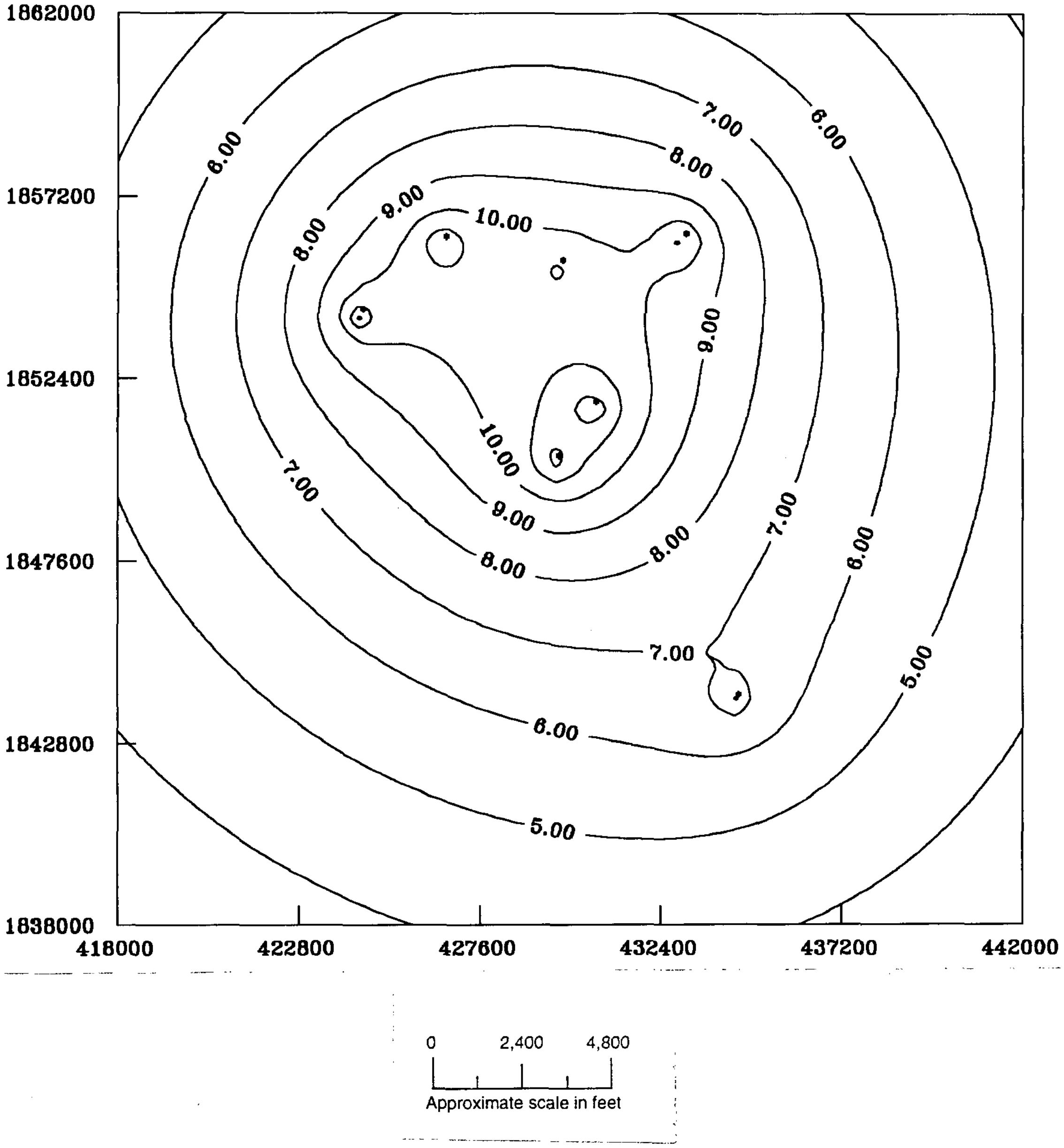


Figure 14. Calculated 2010 drawdowns in the Floridan aquifer system at the LW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

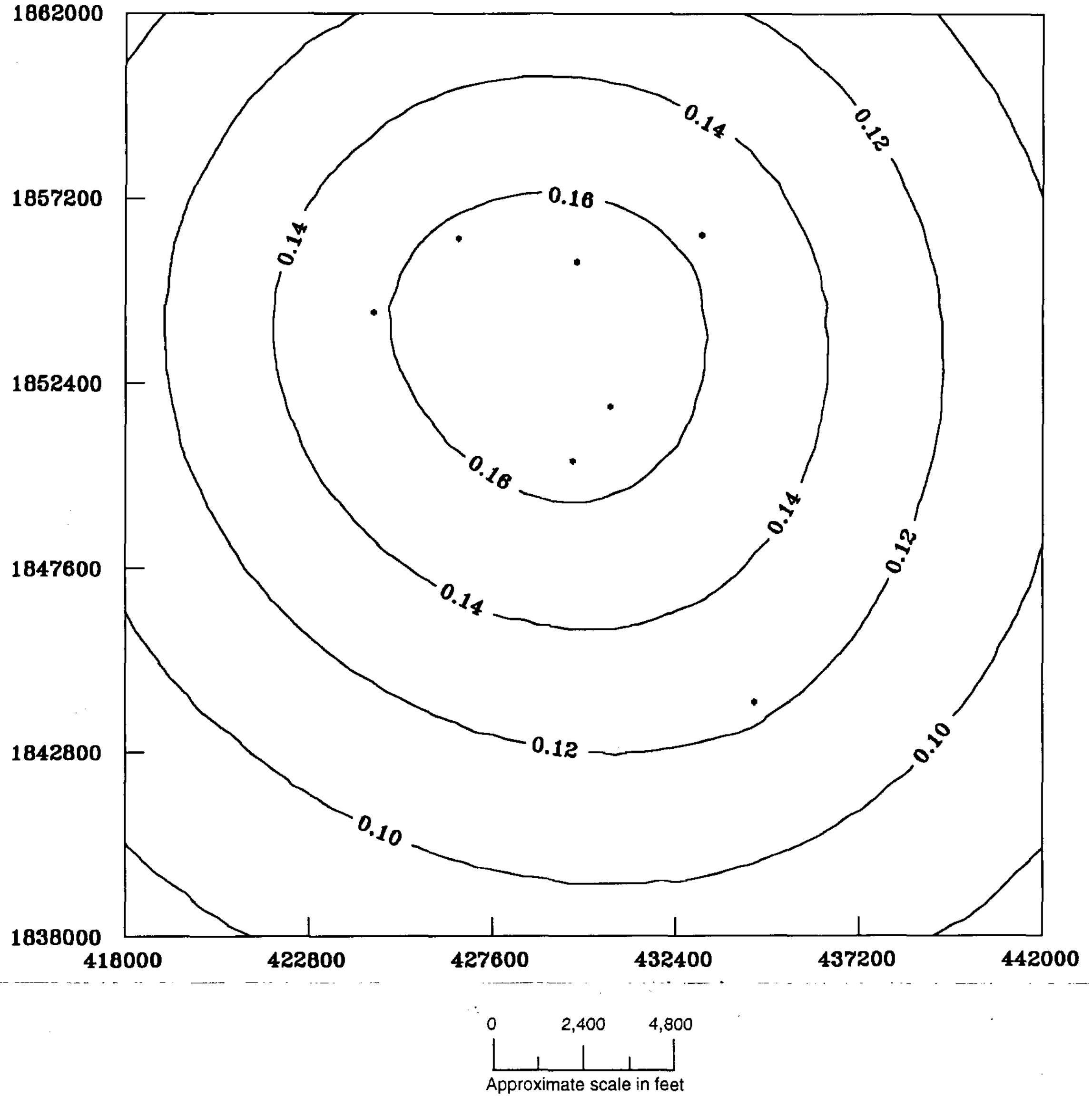


Figure 15. Differences in calculated drawdowns between 1993 and 2010 in the surficial aquifer system at the LW wellfield of Palm Coast Utility Corporation (State Plane Coordinates, measured in feet)

aquifer system. A lower water table reduces the loss of water through evapotranspiration. If pumping continues long enough for a new equilibrium to be established, the water pumped from the underlying intermediate aquifer system will be balanced by the reduction of evapotranspiration loss and less surface water runoff loss. The amount of decline in the water table for the surficial aquifer system will depend on the leakance coefficient of the confining unit and the hydraulic head differences between the surficial and the intermediate aquifer systems and the pumping rates at the production wells.

At the LW wellfield, the hydrologic units consist of a surficial aquifer system, an intermediate aquifer system within the Hawthorn Group, and the Floridan aquifer system separated from the intermediate aquifer system by a lower confining unit. The hydraulic connection between the intermediate and the Floridan aquifer systems was represented in the MLTLAY model by a leakance coefficient of the lower confining unit that separates these two aquifers. The effect of pumping water from the Floridan aquifer system will cause declines in the elevation of the potentiometric surfaces of the Floridan aquifer system and the intermediate aquifer system. Transmissivities, pumping rates, and the leakance coefficient are the main factors causing the declines of the potentiometric surfaces in both aquifers. If pumping water from the Floridan aquifer system continues long enough for a new equilibrium to be established, the water pumped from the Floridan aquifer system will be balanced by the increase in leakage and the lowering of the potentiometric surface in the intermediate aquifer system. The water table in the surficial aquifer system also will be affected.

The DRAWDOWN and MLTLAY models were used as tools to calculate the drawdowns caused by withdrawal of water from the intermediate and the Floridan aquifer systems. The DRAWDOWN model calculated the drawdowns in the surficial aquifer system and the intermediate aquifer system at the SW wellfield. The MLTLAY model calculated the drawdowns in both the intermediate and the Floridan aquifer systems, and the induced water table drawdown in the surficial aquifer system at the LW wellfield.

The DRAWDOWN and MLTLAY models were used primarily as mathematical tools to calculate drawdown in the aquifer system based on prescribed hydraulic and hydrologic parameters. However, the 1988 calculated drawdowns using the DRAWDOWN model were used to verify the reliability of model computation by comparing the model results with the 1990 observed data at some selected wells at the SW wellfield. For example, the 1988 drawdown at well SW8, based on an average pumping rate of 62,091 gpd, was calculated at 8.44 ft for the intermediate aquifer system at the well. The specific capacity of SW8, based on model calculation, is 5.10 gallons per minute per foot (gpm/ft). The 1990 monitoring drawdown data at well SW8 ranged from 9.0 to 18.0 ft in response to the pumping rates of 115,200 to 172,800 gpd, respectively (Blasland, Bouck, and Lee 1991). The average specific capacity, based on observed data, is about 4.44 gpm/ft. The specific capacity comparison between the model analysis and the observed data demonstrated that the DRAWDOWN model is capable of providing reasonable predictions. No data were available in the surficial aquifer system to compare the results of the induced drawdowns in that aquifer; such data, if available, would allow SJRWMD to determine the accuracy of the calculated drawdowns.

No water level data for the Floridan aquifer system were available at the LW wellfield for comparison to the results of the MLTLAY model. However, a test case using a three-layer aquifer system model developed by Walton (1984) was conducted to verify the MLTLAY model results. Aquifer characteristics that were applied to the MLTLAY model also were applied to the Walton model. The results of the Walton and MLTLAY models indicated a drawdown in the intermediate aquifer system of 2.81 ft and 1.15 ft, respectively, and in the Floridan aquifer system of 16.23 ft and 15.16 ft, respectively, at a pumping rate of 360,000 gpd. The variations in drawdown results were due primarily to different model assumptions and definitions used in these models. This comparison between the MLTLAY and Walton models demonstrated that the MLTLAY model can be used to calculate reasonable drawdown results for the LW wellfield.

CONCLUSIONS

Based on the results of the DRAWDOWN model, the calculated drawdowns for the projected 2010 pumpage at the SW wellfield could have an impact on the surficial aquifer system. The maximum drawdown in the surficial aquifer system changed from 1.94 ft at SW33 and SW7 in 1988 (Table 2) to 3.84 ft at SW64 in 2010 (Table 3). This increase in drawdown is the result of the new configuration of the proposed 2010 production wells at the SW wellfield. The proposed new wells are to be added to the northwest of the existing wells. The total average daily pumping rate for the proposed 60 wells at the SW wellfield is 6.0 mgd. Due to the impact of accumulated pumping, the production wells located in the center of the proposed 2010 SW wellfield (e.g., SW63, SW64, and SW66) will experience more decline in ground water levels in both the surficial and the intermediate aquifer systems. In order to reduce the cumulative drawdown effect, consideration should be given to the optimized design of well locations at the SW wellfield.

Based on the results of the DRAWDOWN model, the calculated drawdowns for the projected 2010 pumpage at the SW wellfield could have little effect on the intermediate aquifer system. The maximum drawdown in the intermediate aquifer system changed from 16.43 ft at SW115 in 1988 (Table 2) to 15.90 ft at SW64 in 2010. This change in drawdown in the intermediate aquifer system is due to the difference in pumping rates between 1988 and 2010.

Based on the results of the MLTLAY model, the calculated drawdowns for the projected 2010 pumpages at the LW wellfield could have an impact on the surficial, intermediate, and Floridan aquifer systems. However, the impact on the surficial aquifer system due to withdrawing water from the Floridan aquifer system will result in an insignificant decline in the surficial aquifer system. The maximum drawdown in the surficial aquifer system changed from 0.03 ft at LW21 and LW31 in 1993 (Table 5) to 0.49 ft at LW14 and LW21 in 2010 (Table 6). The maximum drawdown in the intermediate aquifer system changed from 0.29 ft at LW31 in 1993 (Table 5) to 3.76 ft at LW21 in 2010 (Table 6). The maximum drawdown in the Floridan aquifer system changed from 3.11 ft at LW31 in 1993 to 17.23 ft at LW21 in 2010 (Table 6). The difference in drawdown in the surficial aquifer system at the LW wellfield between 1993 and 2010 is due to a projected increase in pumpage from the Floridan aquifer system of 7.296 mgd from 0.487 mgd.

The results of this study have been incorporated with regional ground water flow model results 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 are important for future evaluations and to the definition of monitoring needs. The development of a program to monitor the surficial aquifer system could provide much-needed data that, in time, could support the development of an expanded, more comprehensive model.

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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	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 minute per foot (gpm/ft)	1.242×10^{-2}	square meters per minute (m^2/min)
gallons per day per square feet 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)