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PROJECTED 2020 AQUIFER DRAWDOWNS AT THE CITY OF ST. AUGUSTINE WELLFIELD, ST. JOHNS COUNTY, FLORIDA

by

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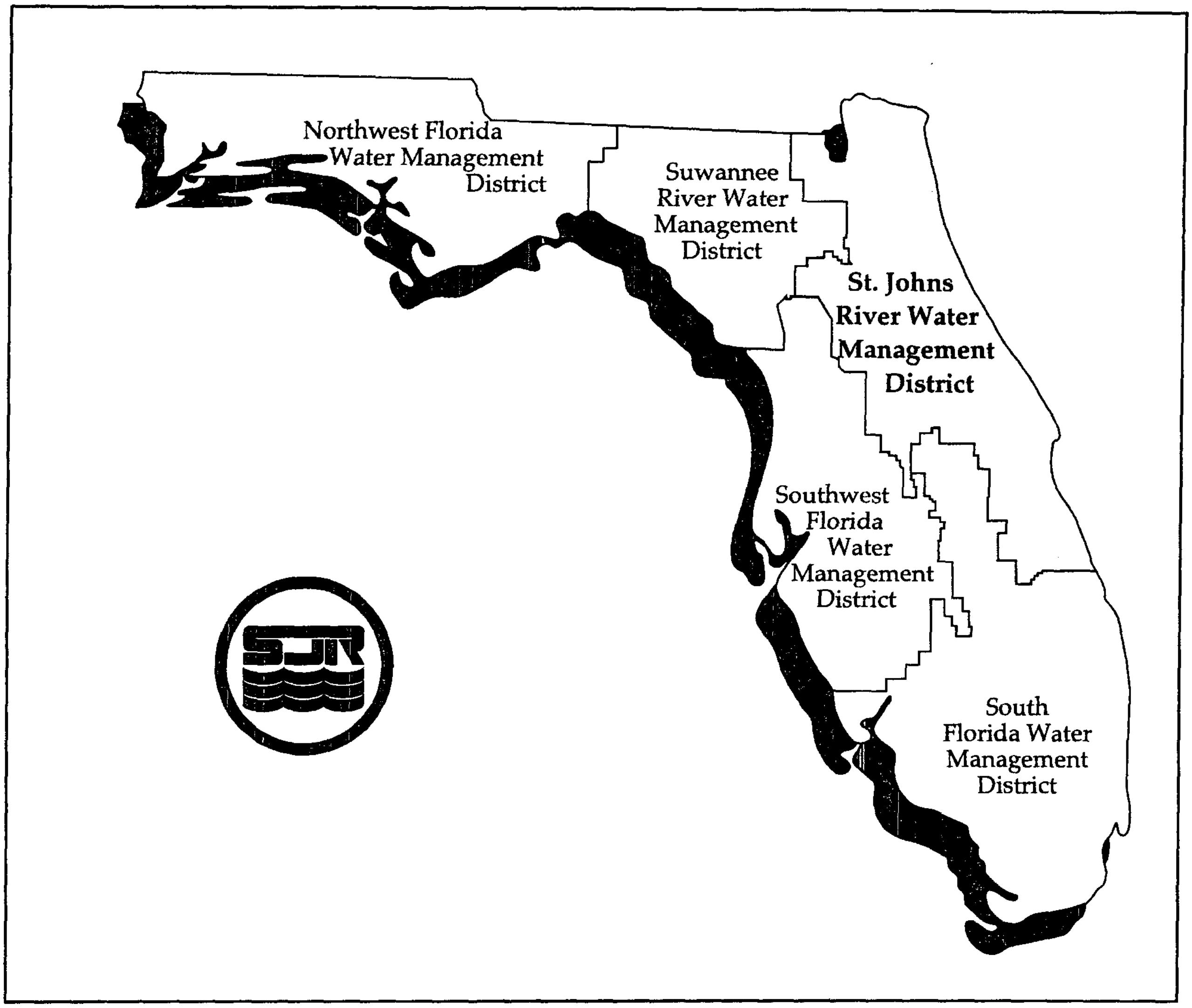

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Projected 2020 Aquifer Drawdowns at the City of St. Augustine Wellfield, St. Johns County, Florida

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ABSTRACT

This paper supports a water supply assessment performed by the St. Johns River Water Management District pursuant to the requirements of Subparagraph 373.036(2)(b)4, *Florida Statutes.* 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, 2015, and 2020 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 the models assume homogeneous, isotropic, and steady-state conditions. Simulated drawdowns for 1995 pumpage at the wells ranged from 3.39 to 10.96 feet (ft) for SAS and from 4.55 to 4.99 ft for UFA. Simulated drawdowns for 2020 pumpage ranged from 5.95 to 13.61 ft for SAS and from 12.24 to 12.62 ft for UFA. Projected drawdowns as a result of 2020 pumpage in SAS and UFA at the wells are as much as 4.1 and 7.7 ft greater than calculated drawdowns resulting from 1995 pumpage. The simulated drawdowns for projected pumpages at this wellfield have a pronounced effect on the elevation of the water table and the potentiometric surfaces 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. Maximum drawdowns in the unconfined surficial aquifer (water table) due to 1995 and 2020 withdrawals are projected to be greater than 0.9 and 1.1 ft, respectively. Many isolated wetlands in the city of St. Augustine wellfield may have been impacted in 1995, and this potential impact may continue as a result of the proposed 2020 withdrawals.

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) performs water supply assessments pursuant to the requirements of Subparagraph 373.036(2)(b)4, *Florida Statutes (FS).* As part of this assessment process, SJRWMD identifies priority water resource caution areas, which are areas where existing and reasonably anticipated sources of water and water conservation efforts are not adequate to supply water for all existing legal uses and reasonably anticipated future needs and to sustain the water resources and related natural systems during a 20-year planning horizon. Regional numerical groundwater models and local analytical groundwater models are used as part of this overall assessment.

The objectives of the evaluation presented in this professional paper are (1) to use geohydrologic data collected since Toth 1994 to better calibrate the city of St. Augustine wellfield model; (2) to provide an analysis of the projected 2010, 2015, and 2020 pumping impacts to the surficial aquifer system and the Upper Floridan aquifer at the city of St. Augustine wellfield; and (3) to use projected water table drawdowns to evaluate the potential for wetland impacts.

A review of Toth 1994 indicated a need to acquire better information on the transmissivity of the unconfined surficial aquifer at the city of St. Augustine wellfield. This review also indicated an absence of water level monitoring data needed for calibrating model-simulated drawdowns in the various aquifer systems. Because of this need to acquire better information and to verify projected drawdowns, SJRWMD entered into a cooperative agreement with the city of St. Augustine in February 1997. Emphasis in the agreement was placed on acquiring hydrogeologic data that would improve the predicted impacts to the surficial aquifer system. In October 1997, Huss Drilling, SJRWMD's well drilling contractor, constructed three unconfined surficial aquifer monitor wells (SJ0291, SJ0292, and SJ0293) at the city of St. Augustine wellfield (Appendix A). The monitor wells were located adjacent to surficial aquifer production wells which are located on a sandy ridge. The monitor wells were installed to verify that a difference exists between the elevation of the water table and the confined surficial aquifer; monitor wells SJ0291 and SJ0293 bore this out. These three monitor wells were also constructed to determine the transmissivity of the water table. Huss Drilling also conducted a step-drawdown test on each of the three unconfined surficial aquifer wells at the city of St. Augustine wellfield in October 1997 (Appendix A). In March 1998, the cooperative agreement between SJRWMD and the city of St. Augustine was extended for another year because of a problem in obtaining permission from property owners to install monitor wells. In October 1998, Huss Drilling constructed four unconfined surficial aquifer monitor wells in the northern portion of the wellfield (Appendix B). Two of these wells, SJ0311 and SJ0314, border on St. Marks Pond and one of these wells, SJ0313, borders on Twelve Mile Swamp (Figure 1). In November and December 1998, the city of St. Augustine, with the cooperation of Connect Consulting, conducted a stress test of its wellfield. Surficial aquifer production wells in the wellfield were grouped into two zones. Wells 1–7 were grouped in the south zone and wells 10–12 were grouped in the north zone. The south zone wells were pumped continuously for 3 days while the north zone wells were idle. Because the south zone wells yield inadequate amounts of water for the city's needs, it was necessary to turn wells 11 and 12 on during the south zone test. The north zone wells were pumped continually for 14 days; no south zone wells were on during the north zone test. In March 1999, Connect Consulting provided information to SJRWMD on the measured drawdowns in the confined and unconfined surficial aquifer monitor wells (Eichler 1999) (Appendix C).

WATER USE

The city of St. Augustine blends water withdrawn from surficial and Floridan aquifer wells before distribution to its customers. The city's wellfield was specifically designed to produce water from both the confined surficial aquifer and the Floridan aquifer primarily to produce a blend of water that is of higher quality than the water from either aquifer alone. Blending is a quality, not a quantity, issue. In 1995, water was blended in a 72.3% surficial aquifer to 27.7% Floridan aquifer ratio (72.3:27.7). In 1998, the ratio was approximately 60:40 (Regan 1998). The ratio for withdrawals for 2010–2020 is projected to remain at approximately 60:40.

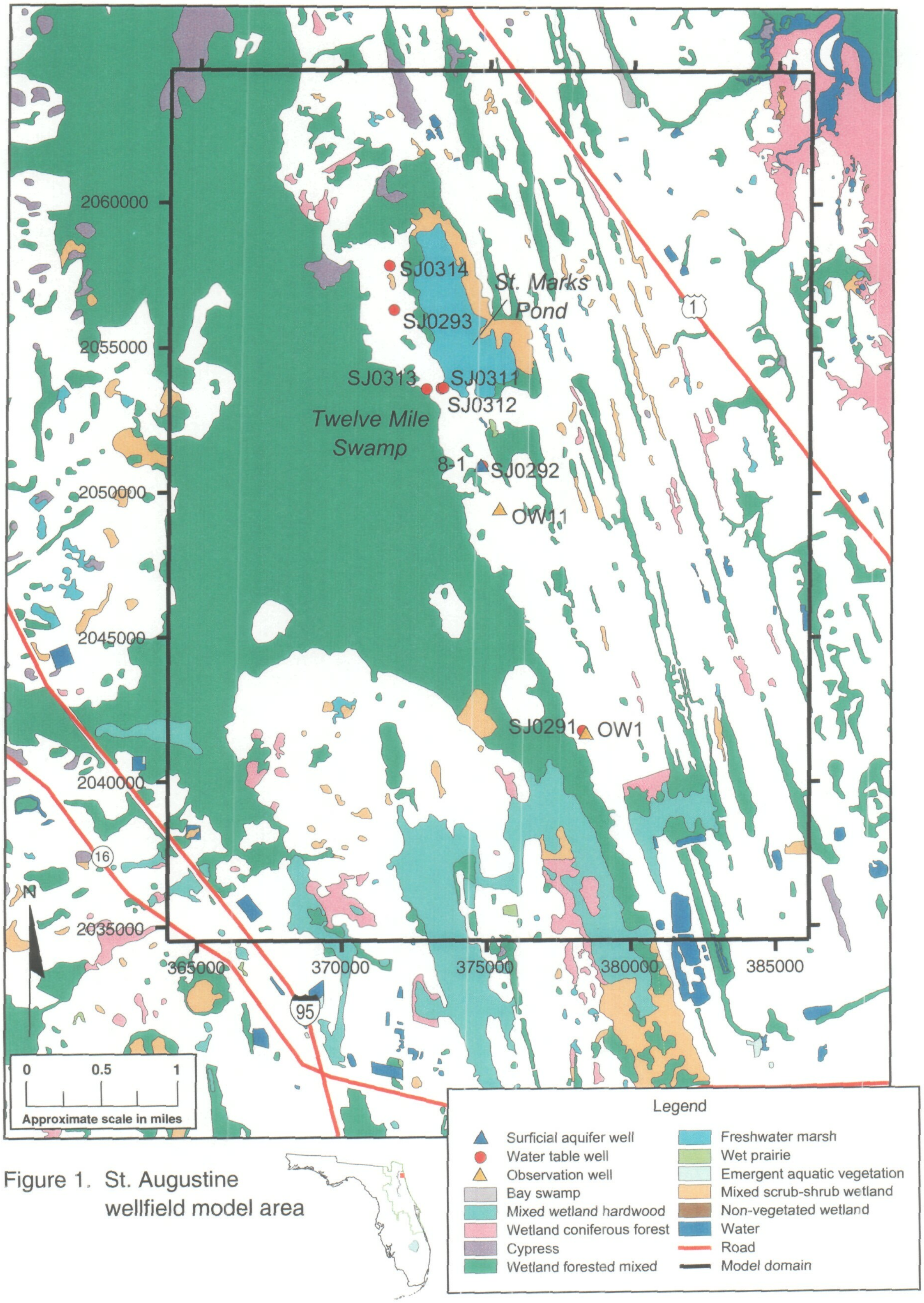

Figure 1. St. Augustine wellfield model area

In 2010, 2015, and 2020, the city of St. Augustine plans to withdraw 3.71, 3.81, and 3.91 million gallons per day (mgd), respectively. The city of St. Augustine withdraws water from both the surficial aquifer and the Upper Floridan aquifer (Preuss 1998; Regan 1999). The projections are based on historical water use and projected growth and are consistent with projections in Vergara 1998.

City of St. Augustine Wellfield

In 1995, the city of St. Augustine withdrew water from nine surficial aquifer system wells and three Upper Floridan aquifer wells (Figure 2). Pumpage for each well (Table 1) was based on metered water use reported by the city to SJRWMD. The total metered water use for 1995 was 2.24 mgd. The city has purchased an additional well site suitable for the development of a confined surficial aquifer and Floridan aquifer well. However, in 1999, the city had not made a commitment to install any additional wells.

For the purpose of this evaluation, the number of wells in the city's wellfield does not change between 1995 and 2020. Individual well pumpages for the 2010, 2015, and 2020 projections are proportioned as in Toth 1994. These proportions are from City of St. Augustine 1987, Table 4-1, p. 69.

The 2010, 2015, and 2020 individual well pumpages from the surficial aquifer were estimated to range between 49 and 410 gallons per minute (gpm) (0.07 and 0.59 mgd, respectively). The 2010, 2015, and 2020 projected pumpages from the three Upper Floridan aquifer wells are estimated to range between 347 and 368 gpm (0.50 and 0.53 mgd, respectively) (Table 1).

METHODS

The methods used in this study were

1. Use of the MLTLAY (SJRWMD 1993) and SURFDOWN (Huang and Williams 1996) models to predict drawdowns in the surficial and Floridan aquifer systems. MLTLAY was used to calculate drawdowns in the confined surficial and Floridan aquifers. SURFDOWN was used to calculate induced water table drawdowns resulting from drawdowns in the confined surficial aquifer. The surficial and Floridan aquifer systems are separated by a thick layer of low-permeability clay, and withdrawals from one aquifer do not appreciably affect the other. Drawdowns calculated by the models are based on the assumption that all wells pump 100% of the time, which is a worst-case scenario.

2. Use of aquifer characteristics determined from three step-drawdown tests to improve projected, model-calculated drawdowns for the surficial aquifer system.

3. Comparison of model-calculated drawdowns in the confined surficial aquifer with drawdowns measured in monitor wells during the stress test to verify the approach of superposition of drawdowns and to adjust aquifer parameters for calibration.

4. Comparison of model-calculated drawdowns in the unconfined surficial aquifer with drawdowns measured in monitor wells during the stress test to calibrate the water table drawdowns.

5. Comparison of projected water table drawdowns with a generalized 0.5-ft planning-level threshold established for wetlands (CH2M HILL 1998) to determine the potential for wetlands to be impacted by the projected withdrawals.

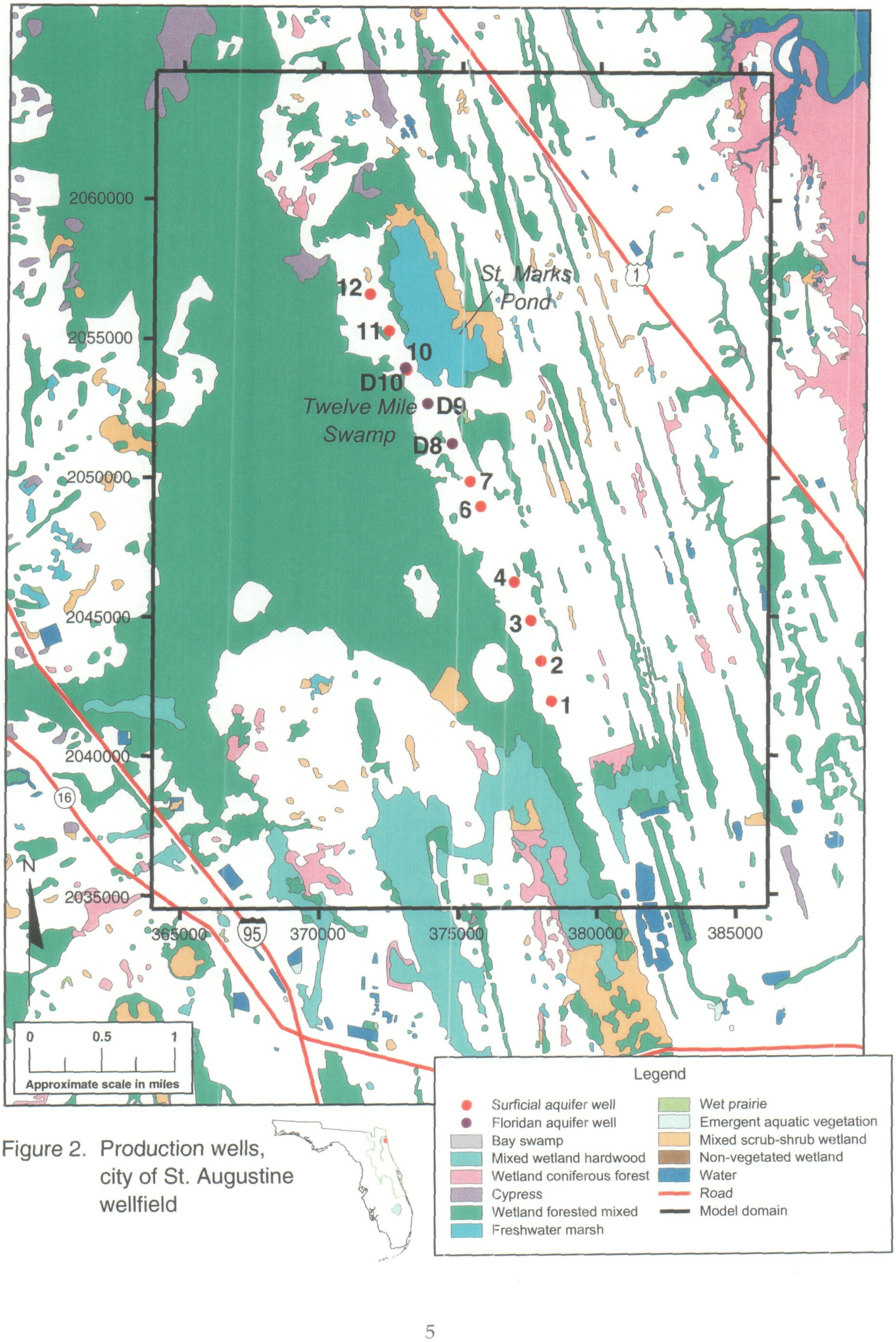

Figure 2. Production wells, city of St. Augustine wellfield

Table 1. Well locations and pumpage values used in the MLTLAY and SURFDOWN models, city of St. Augustine wellfield

Well	Latitude	Longitude	Pumpage (mgd)			
			1995	2010	2015	2020
Surficial Aquifer						
1	295700.2	812303.3	0.15	0.18	0.18	0.19
2	295714.6	812307.6	0.10	0.14	0.14	0.15
3	295729.0	812311.9	0.08	0.07	0.07	0.07
4	295742.6	812318.9	0.04	0.07	0.07	0.07
6	295809.5	812333.0	0.07	0.07	0.07	0.07
7	295818.4	812337.4	0.06	0.10	0.11	0.11
10	295858.3	812404.0	0.44	0.53	0.54	0.55
11	295911.9	812411.2	0.19	0.49	0.50	0.52
12	295924.9	812419.1	0.49	0.56	0.58	0.59
Upper Floridan Aquifer						
D8	295831.9	812344.7	0.18	0.50	0.52	0.53
D9	295846.2	812355.1	0.22	0.50	0.51	0.53
D10	295858.8	812404.2	0.22	0.50	0.52	0.53
Total			2.24	3.71	3.81	3.91

Note: mgd = million gallons per day

Latitude and longitude determined by global positioning system.

HYDROGEOLOGY

The hydrogeology at the city of St. Augustine wellfield consists of the following units in descending order: the unconfined surficial aquifer or water table; the confining unit for the surficial aquifer system; the confined surficial aquifer; the upper confining unit or Hawthorn Group; and the Upper Floridan aquifer. A more thorough description of the hydrogeology can be found in CH2M HILL (1982), Spechler and Hampson (1984), and Toth (1994).

Aquifer characteristics for the unconfined surficial aquifer were obtained from three step-drawdown tests. Aquifer characteristics for the confined surficial aquifer and the Upper Floridan aquifer were obtained from aquifer performance tests (CH2M HILL 1982). The values used in the model are in Toth (1994).

Unconfined Surficial Aquifer

The transmissivity values of the unconfined portion of the surficial aquifer system determined by step-drawdown tests at SJ0291, SJ0292, and SJ0293 (Figure 1) are 373, 4,329, and 1,208 gallons per day per foot (gpd/ft), respectively. The step-drawdown tests were conducted in 1997 by Huss Drilling during construction of the unconfined surficial aquifer monitor wells. Results of the tests were based upon an average saturated thickness of 22 feet (ft). The average transmissivity and hydraulic conductivity of the unconfined portion of the surficial aquifer system is 1,970 gpd/ft and 12 ft/day respectively. A transmissivity value of 1,970 gpd/ft was used in the model.

Unconfined aquifer characteristics (transmissivity values) from the step-drawdown tests are almost a factor of three greater than the transmissivity value used in Toth (1994), which was derived from a saturated thickness of 15 ft for the unconfined portion of the surficial aquifer and a hydraulic conductivity of 6.7 ft/day. Use of the larger transmissivity value will have a negligible simulated effect on the drawdown in the unconfined portion of the surficial aquifer system. The model is insensitive to the transmissivity of the water table because drawdowns in this aquifer are primarily governed by vertical leakage through the confining unit.

Confined Surficial Aquifer

Aquifer characteristics for the confined surficial aquifer were derived from three aquifer performance tests which were conducted at wells 1, 7, and 12 (CH2M HILL 1982). The transmissivity at well 12 is an order of magnitude greater than that at wells 1 and 7. Because of this large difference in transmissivity between wells 1, 7, and 12, for the purposes of this analysis, the wellfield was divided in two. Wells 1–7 were included in one half and wells D8–D10 and 10–12 were included in the other half. The transmissivity value of 17,000 gpd/ft was used for wells 1–7. The transmissivity value of 128,000 gpd/ft was used for wells 10–12 (Toth 1994). Even though it appears that different values of transmissivity exist in the confined surficial aquifer, an average value of leakance was used in the model for the entire wellfield. The low (6.4×10^{-4} $gpd/ft^2/ft$) and high (2.5×10^{-1} $gpd/ft^2/ft$) values of leakance which occur at wells 1 and 7, respectively, are assumed to be isolated occurrences and not representative of the entire wellfield. An average value was assumed to best represent the wellfield. The value used was 0.0075 $gpd/ft^2/ft$ (Toth 1994).

Floridan Aquifer

Other aquifer characteristics used in the models include the transmissivity of the Upper Floridan aquifer (165,000 gpd/ft) and the leakance of the upper confining unit (0.000000748 $gpd/ft^2/ft$) (Toth 1994). The aquifer characteristics for the Upper Floridan aquifer are derived from an aquifer performance test (CH2M HILL 1982).

Evapotranspiration Reduction Coefficient

The evapotranspiration reduction coefficient describes the rate at which evapotranspiration is reduced per unit of water table drawdown. It too was used in the model. The initial value used for E (0.00046 ft/day/ft) was obtained from a graph in Tibbals (1990, p. E10). This value was varied within a reasonable range to produce a best-fit measurement between observed and predicted water table drawdowns at six monitor wells during the stress test (see Calibration). Emphasis was placed on minimizing the differences between observed and predicted drawdowns in monitor wells adjacent to wetlands. The best-fit measurements of drawdown were obtained for an E of 0.0023 ft/day/ft.

WELLFIELD MODEL

Impacts to the groundwater flow system resulting from withdrawals at the city of St. Augustine wellfield were evaluated using the MLTLAY (SJRWMD 1993) and SURFDOWN (Huang and Williams 1996) 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 and Floridan aquifer systems. The model simulated steady-state conditions and considers the flow of water through multiple aquifers separated by semipervious leaky layers. The model also 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.

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 superimposing the drawdowns from the two runs.

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. Unlike numerical models where drawdowns are constrained by the boundary, the model boundary does not affect the drawdown calculation in an analytical model because the domain is considered to be infinite. The dimensions of the model domain were 22,150 ft wide and 30,050 ft long. A coordinate spacing of 50 ft was used between grid nodes. The origin for the model domain was at 363,992 ft for x and 2,034,527 ft for y (Figure 1).

Calibration

In an effort to provide for a qualitative level of calibration of the wellfield model, drawdowns simulated for the confined surficial aquifer were compared with measured drawdowns in monitor wells during the stress test (Table 2). Three monitor wells in the confined surficial aquifer were available for this purpose. The monitor wells used were OW1 near well 1, OW11 near well 7, and 8-1. There were no monitor wells in the confined surficial aquifer in the north part of the wellfield. The existing production wells were pumped at rates of 33.5 to 432.1 gpm during the stress test (Table 3). Visual comparisons between the measured and calculated drawdowns were generally good.

Table 2. Drawdowns in confined surficial aquifer monitor wells during stress test, city of St. Augustine wellfield

Well	Drawdown (feet)	
	Calculated	Measured
South Zone Test		
OW1	5.05	5.24
OW11	3.22	0.96
North Zone Test		
OW1	0.04	0.08
OW11	0.46	0.24
8-1	0.79	0.38

During the south zone test, comparisons could be made at only two locations: OW1 and OW11. At OW1, the difference between simulated and measured drawdowns was 0.21 ft. However, at OW11, the difference was greater than 2 ft. This is because the aquifer performance test analysis utilizing well 7 calculated a higher leakance ($2.5x10^{-1}$ gpd/ft^2/ft) value than was used in the model. If this higher leakance value were used in the model, less drawdown in the confined surficial aquifer would be simulated.

Table 3. Pumpage during stress test, city of St. Augustine wellfield

Well	Pumpage	
	Gallons per Minute	Gallons per Day
1	131.0	188,640
2	57.8	83,232
3	70.3	101,232
4	33.5	48,240
6	82.0	118,080
7	71.5	102,960
10	378.8	545,472
11	432.1	622,224
12	338.0	486,720

During the north zone test, comparisons could be made at only three locations: OW1, OW11, and 8-1. The difference between simulated and measured drawdowns is less than 0.5 ft. With the limited number of observation wells, the agreement between simulated and measured drawdowns was reasonable. Comparisons between simulated and measured drawdowns could be improved with additional observation wells in the confined surficial aquifer in both the south and north parts of the wellfield. The good agreement between simulated and measured drawdowns suggests that the model is a reasonable representation of the physical system and supports the superposition of calculated drawdowns. Simulated drawdowns for the confined surficial aquifer during the south (Figure 3) and north (Figure 4) zone tests overlap less than 1 ft at the location of well 8-1 (compare Figures 3, 4, and 1). Drawdowns at well 8-1 observed in the field during the stress test were also less than 1 ft. Thus, these observations lend confidence to the model and its usefulness for predicting future drawdowns.

In the application of the analytical model, drawdown in the unconfined surficial aquifer is dependent on the value used for E (the evapotranspiration reduction coefficient). In order to better predict drawdown in the unconfined surficial aquifer, data collected during the north zone stress test were used to calibrate the water table drawdowns calculated by the model. Calculated drawdowns for the unconfined surficial aquifer (water table) were compared with measured drawdowns at wells SJ0292, SJ0293, SJ0311, SJ0312, SJ0313, and SJ0314 for a range of E values. For this comparison, model simulations were performed with pumpage occurring only at wells 10–12. Wells 10–12 were pumped at 338–432.1 gpm in the field and simulated in the model at those rates. The drawdowns were compared by performing a sensitivity analysis on E. The value for E used in the model was adjusted within a reasonable range in order that the model-calculated drawdown would best fit the observed water levels collected in the field at monitor wells adjacent to wetlands during the north zone stress test (SJ0311, SJ0313, SJ0314).

The initial value used for E (0.00046 ft/day/ft) was obtained from a graph in Tibbals (1990, p. E10), which relates estimated average evapotranspiration to water table depth. The average measured depth to water in the wellfield is 7 ft, which corresponds to this initial value of E. The value for E was then decreased and increased by 50%. A better agreement between calculated and measured water levels was obtained by increasing E. The best fit between measured and predicted drawdowns in the water table at the six monitor wells occurred for an E value of 0.0023 ft/day/ft (Table 4). The difference between observed and calculated water table drawdowns is less than or equal to ±0.20 ft at SJ0292, SJ0311, SJ0313, and SJ0314. At water table monitor wells SJ0293

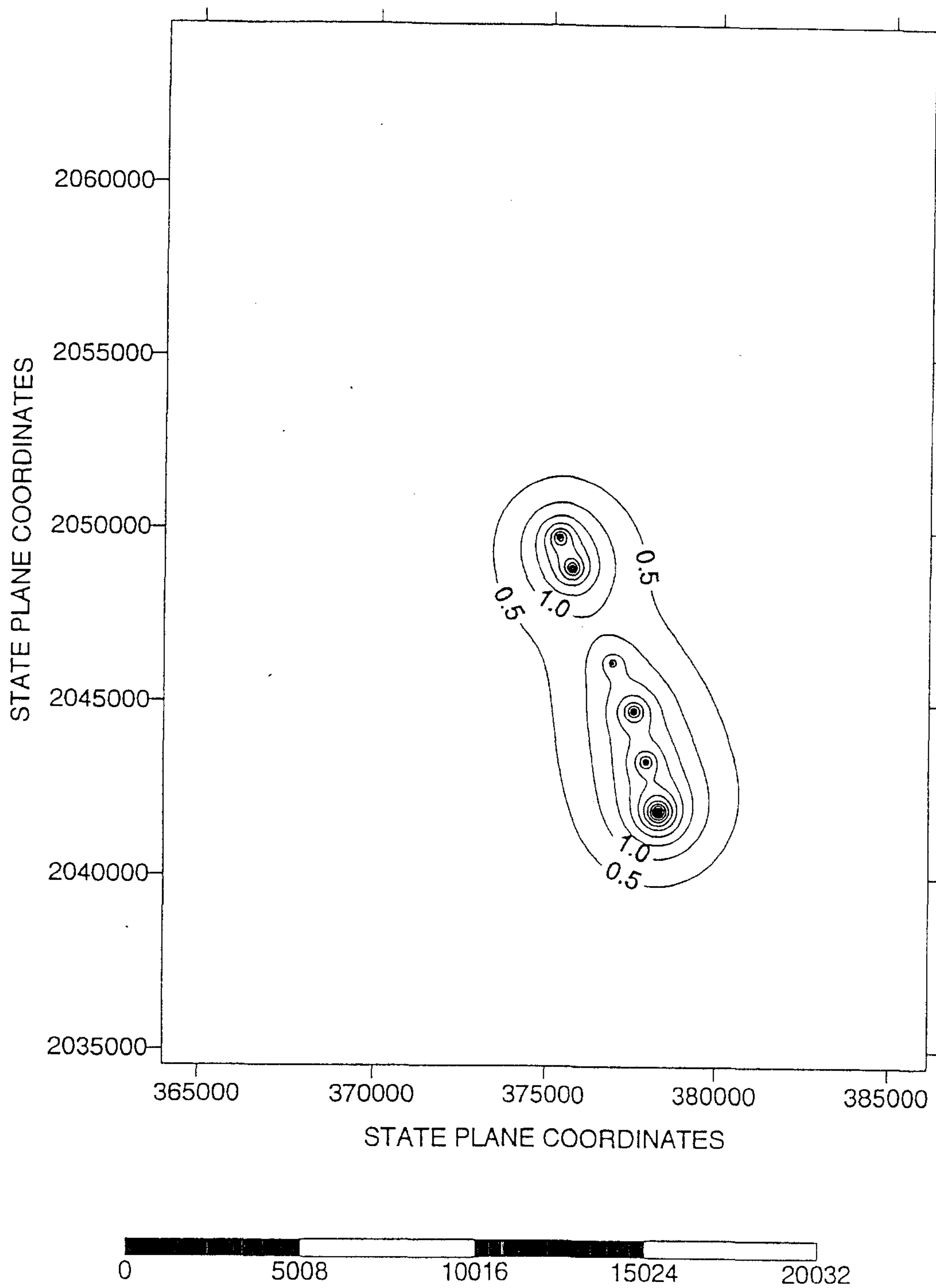

Figure 3. Calculated drawdowns for the confined portion of the surficial aquifer system during the south zone stress test, city of St. Augustine wellfield (measured in feet)

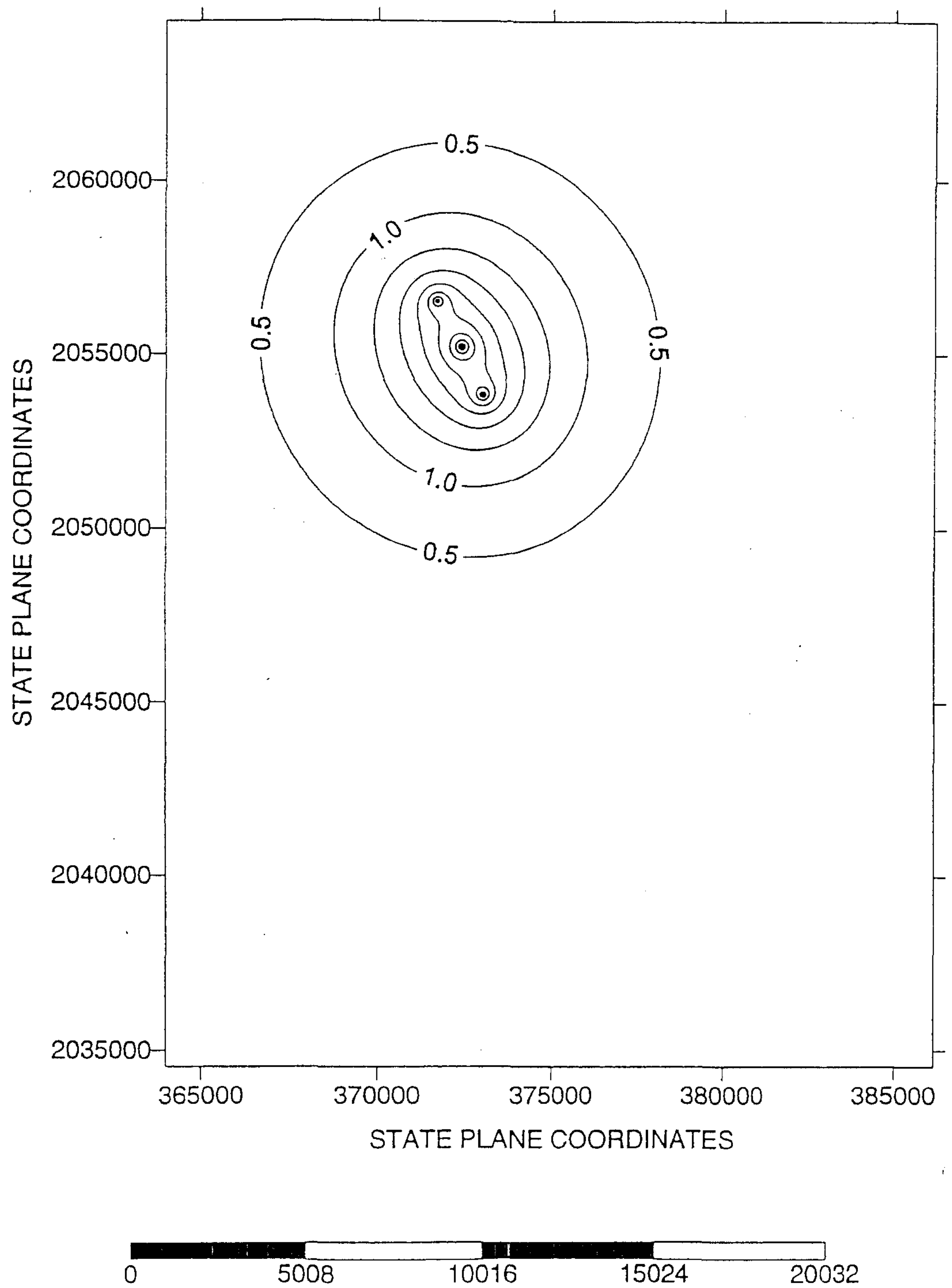

Figure 4. Calculated drawdowns for the confined portion of the surficial aquifer system during the north zone stress test, city of St. Augustine wellfield (measured in feet)

Table 4. Water table drawdowns, north zone stress test, city of St. Augustine wellfield

Evapotranspiration Reduction Coefficient	Water Table Drawdown (feet)					
	SJ0292	SJ0293	SJ0311	SJ0312	SJ0313	SJ0314
Observed						
——	0.33	4.80	1.07	0.30	0.85	0.30
Calculated						
4.60e-04	0.54	3.28	1.97	2.06	2.38	1.01
2.30e-04	0.64	3.89	2.34	2.44	2.82	1.20
6.90e-04	0.46	2.84	1.71	1.78	2.06	0.87
9.75e-04	0.40	2.43	1.46	1.53	1.77	0.75
1.20e-03	0.36	2.18	1.31	1.37	1.58	0.67
2.30e-03	0.24	1.45	0.87	0.91	1.05	0.45
4.60e-03	0.14	0.86	0.51	0.54	0.62	0.26

and SJ0312, which are near pumping wells, the difference between observed and calculated drawdowns is 3.35 and –0.61 ft, respectively. Water table monitor wells SJ0293 and SJ0312 are located on a ridge and are not near wetlands.

The same value of E (0.0023 ft/day/ft) was used for the south zone. Only one water table monitor well (SJ0291) is in the south zone; it occurs at production well No. 1. The observed and calculated water table drawdowns at SJ0291 are 3.97 and 2.48 ft, respectively.

Projected Groundwater Withdrawal Simulation

Projected water use for 2010, 2015, and 2020 for the city of St. Augustine is 3.71, 3.81, and 3.91 mgd (Preuss 1998; Regan 1999). The 2010, 2015, and 2020 individual well pumpages were estimated to range between 49 to 410 gpm from the surficial aquifer and from 347 to 368 gpm from the Upper Floridan aquifer. The simulated drawdowns in the potentiometric surface of the confined portion of the surficial aquifer system at the wells ranged from 3.39 to 10.96 ft in 1995 and from 5.95 to 13.61 ft in 2020 (Table 5). Projected 2020 drawdowns in the confined portion of the surficial aquifer system at the wells are as much as 4.1 ft greater than calculated 1995 drawdowns.

Table 5. Simulated drawdowns in the potentiometric surface, city of St. Augustine wellfield

Well	Simulated Drawdown (feet)			
	1995	2010	2015	2020
Surficial Aquifer System				
1	10.96	12.87	13.24	13.61
2	7.90	10.86	11.17	11.48
3	6.50	6.02	6.19	6.36
4	3.39	5.62	5.78	5.95
6	5.50	6.04	6.21	6.37
7	4.66	8.29	8.52	8.76
10	5.35	6.72	6.90	7.08
11	3.44	6.77	6.95	7.13
12	5.77	7.03	7.22	7.40
Upper Floridan Aquifer				
D8	4.55	11.61	11.93	12.24
D9	4.99	11.99	12.31	12.62
D10	4.89	11.68	11.99	12.30

Simulated drawdowns in the potentiometric surface of the Upper Floridan aquifer at the Floridan aquifer production wells ranged from 4.55 to 4.99 ft in 1995 to 12.24 to 12.62 ft in 2020 (Table 5). Projected 2020 drawdowns in the potentiometric surface of the Upper

Floridan aquifer at the wells are as much as 7.7 ft greater than calculated 1995 drawdowns.

SURFDOWN does not calculate drawdowns at the wells for the unconfined portion of the surficial aquifer system; however, it does calculate drawdowns at the grid nodes. In response to the 1995 withdrawals from the confined surficial and Floridan aquifers, the unconfined surficial aquifer would have responded by declining slightly more than 0.9 ft. As a result of the 2010, 2015, and 2020 withdrawals, the unconfined surficial aquifer is anticipated to decline more than 1.1 ft over a very small part of the wellfield.

Previously, Toth (1994) simulated 2010 drawdown in the unconfined surficial aquifer greater than 2.5 ft. As a result of calibrating drawdowns for the unconfined surficial aquifer from observations during the north zone stress test, this drawdown is now expected to be only slightly greater than 1.1 ft. The areas that were projected in Toth 1994 to experience more than 0.5 ft of drawdown in the unconfined surficial aquifer in 2010 are also now expected to experience less drawdown.

Simulated drawdowns in the city of St. Augustine wellfield were contoured for 1995, 2010, 2015, and 2020 for the unconfined and confined portions of the surficial aquifer system and the Upper Floridan aquifer (Figures 5–16). Differences between the simulated drawdowns in 1995 and in 2020 were also contoured (Figures 17–19). Figures 5–16 show the localized effect that pumping of these wells has on the aquifer. In reality, the effect of the pumping extends beyond the model domain.

Potential Wetland Impact

As part of SJRWMD's water supply planning process, a varying range of water table drawdowns was established as a planning-level constraint for characterizing potential wetland impacts (CH2M HILL 1998). The city of St. Augustine wellfield area is characterized by the presence of wetlands including bay swamps, wet prairies, cypress swamps, and freshwater marshes (Epting 1999). The planning-level water table drawdown constraints for these wetland types are 0.35, 0.35, 0.55, and 0.55 ft, respectively. However, for purposes of this analysis of potential wetland impacts in the area of the city wellfield, a generalized water table drawdown value of 0.5 ft in wetland areas was used to assess the sustainability of groundwater withdrawals.

Simulated water level drawdowns in the unconfined surficial aquifer range from 0.1 ft to more than 0.9 ft for 1995 and from 0.1 ft to more than 1.1 ft for 2020 withdrawal scenarios (Figures 5 and 14). Maximum water level drawdowns occur near production wells which are not located in wetlands. In addition, the simulated drawdowns in several isolated wetlands exceed 0.5 ft in 1995 and 2020 (Figures 5 and 14). Based on this information, many isolated wetlands in the city's wellfield may be impacted as a result of the 1995 withdrawals, and this potential impact may continue as a result of the proposed projected 2020 withdrawal.

CONCLUSIONS

Maximum drawdowns in the wellfield due to 2020 withdrawals are projected to be 12.6 ft for the Upper Floridan aquifer, 13.6 ft for the confined surficial aquifer, and greater than 1.1 ft for the unconfined surficial aquifer from pre-pumping conditions. Based on the generalized planning-level water table drawdown constraint of 0.5 ft in the unconfined surficial aquifer, the city of St. Augustine can meet its projected 2020 demand by

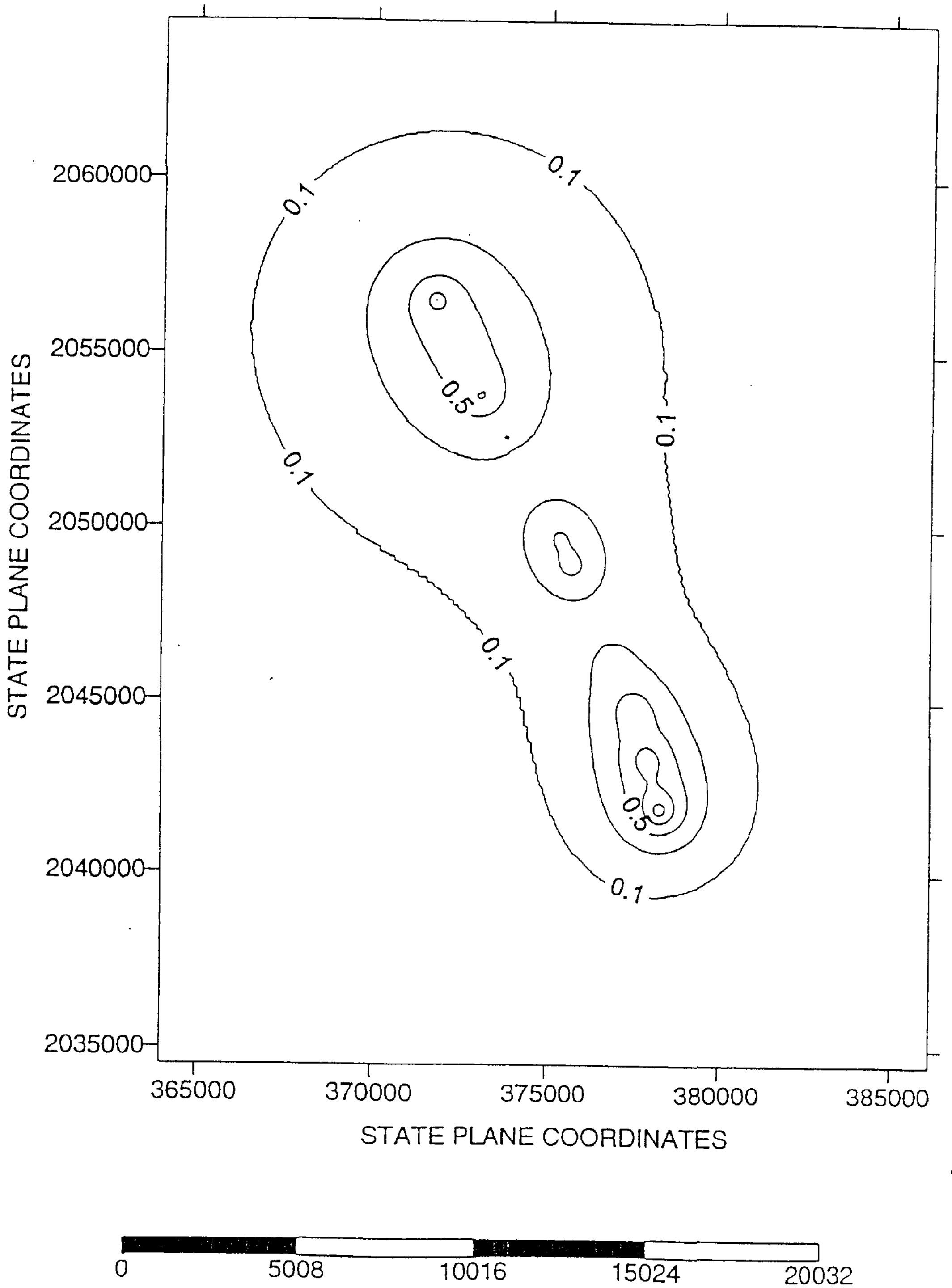

Figure 5. Simulated drawdowns in the unconfined portion of the surficial aquifer system for 1995 pumpage, city of St. Augustine wellfield (measured in feet)

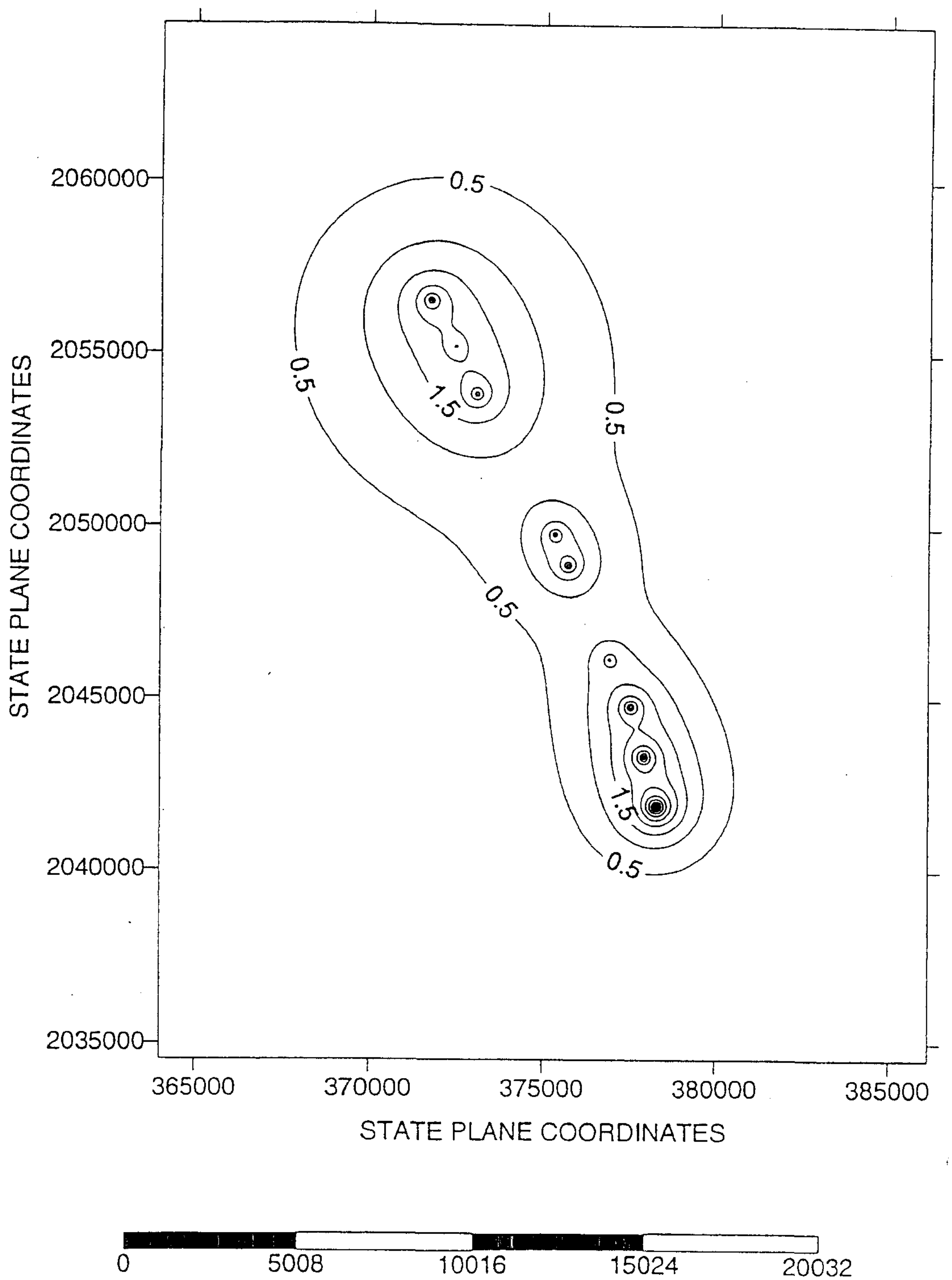

Figure 6. Simulated drawdowns in the confined portion of the surficial aquifer system for 1995 pumpage, city of St. Augustine wellfield (measured in feet)

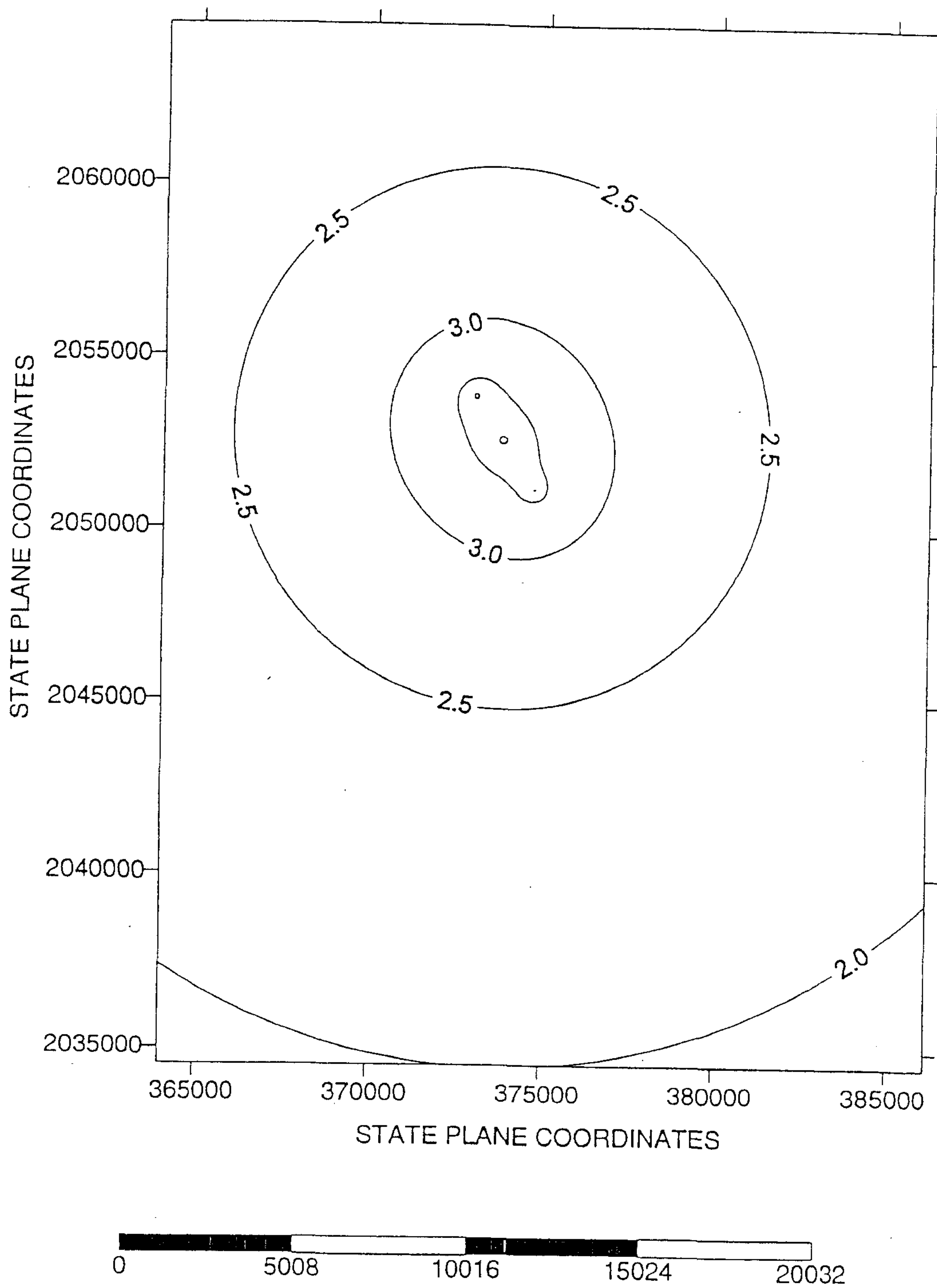

Figure 7. Simulated drawdowns in the Upper Floridan aquifer for 1995 pumpage, city of St. Augustine wellfield (measured in feet)

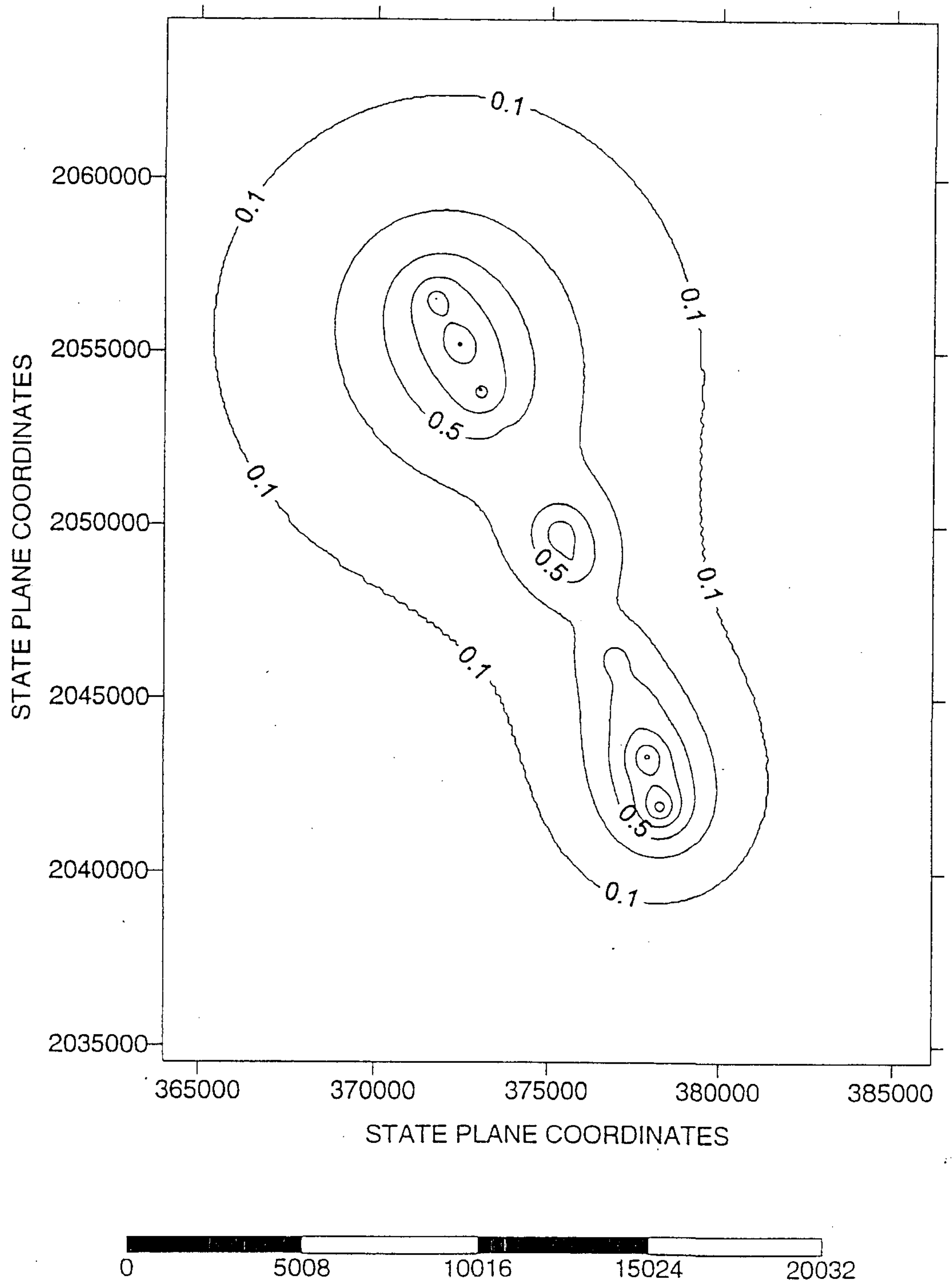

Figure 8. Simulated drawdowns in the unconfined portion of the surficial aquifer system for 2010 pumpage, city of St. Augustine wellfield (measured in feet)

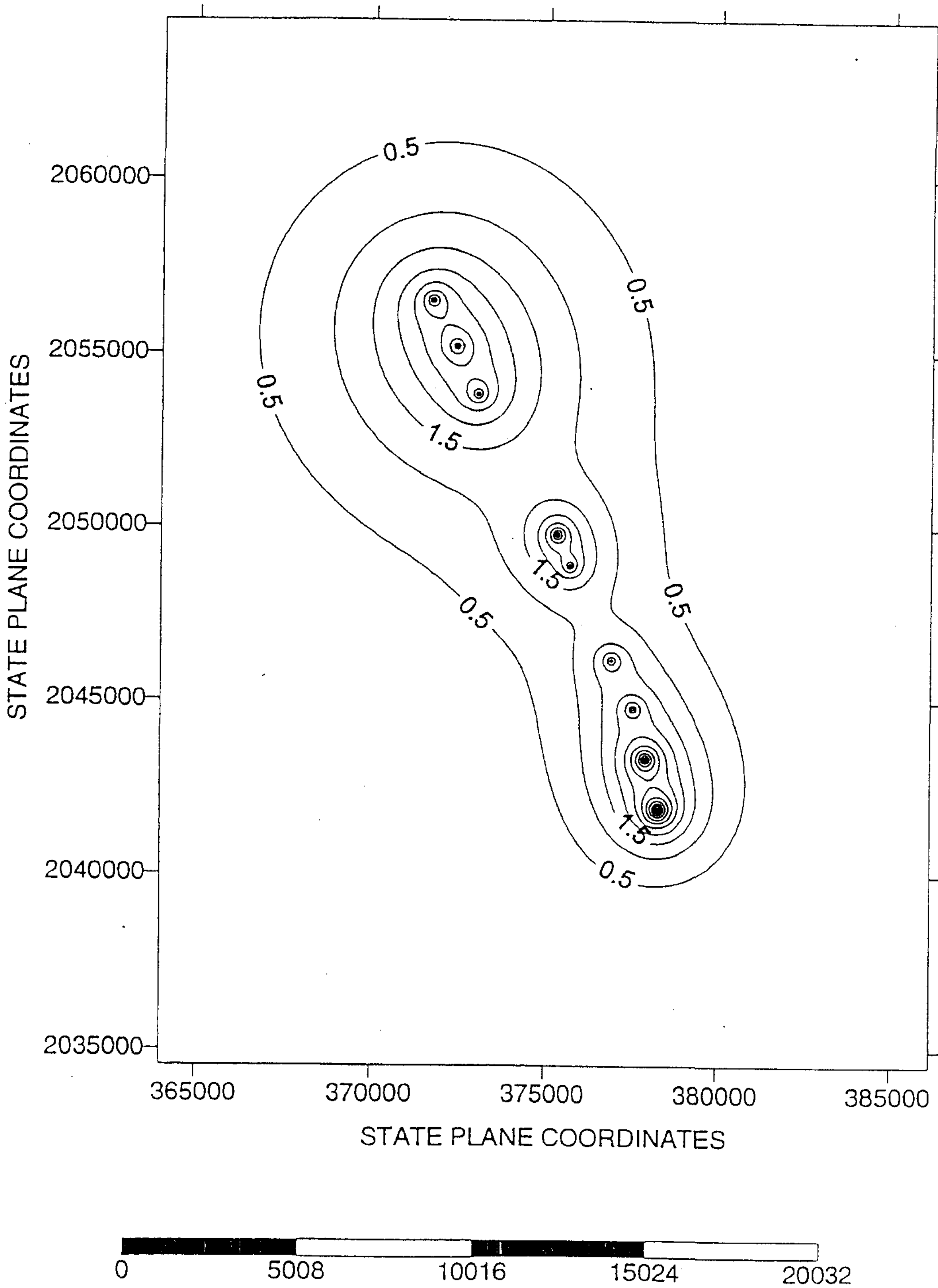

Figure 9. Simulated drawdowns in the confined portion of the surficial aquifer system for 2010 pumpage, city of St. Augustine wellfield (measured in feet)

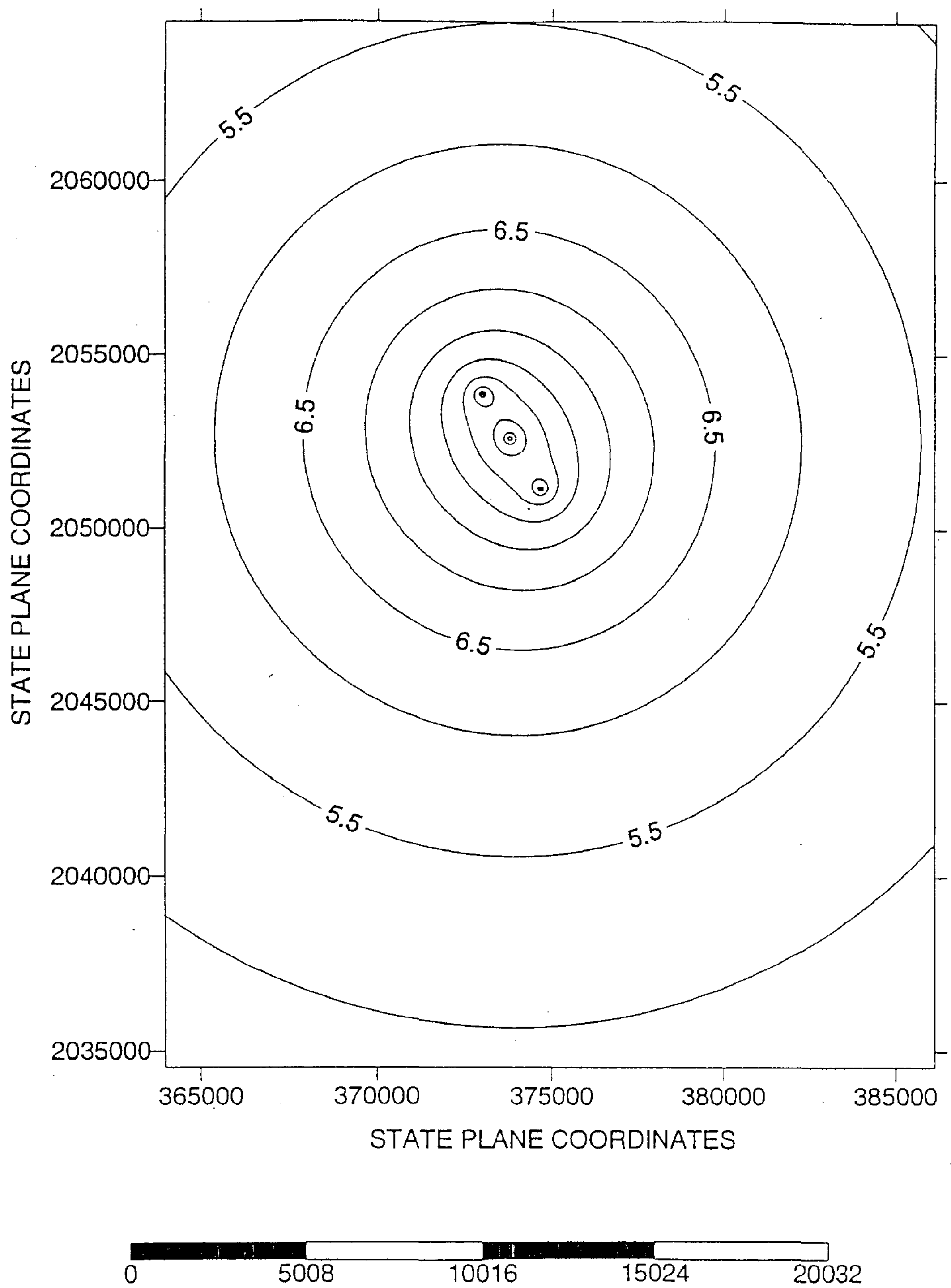

Figure 10. Simulated drawdowns in the Upper Floridan aquifer for 2010 pumpage, city of St. Augustine wellfield (measured in feet)

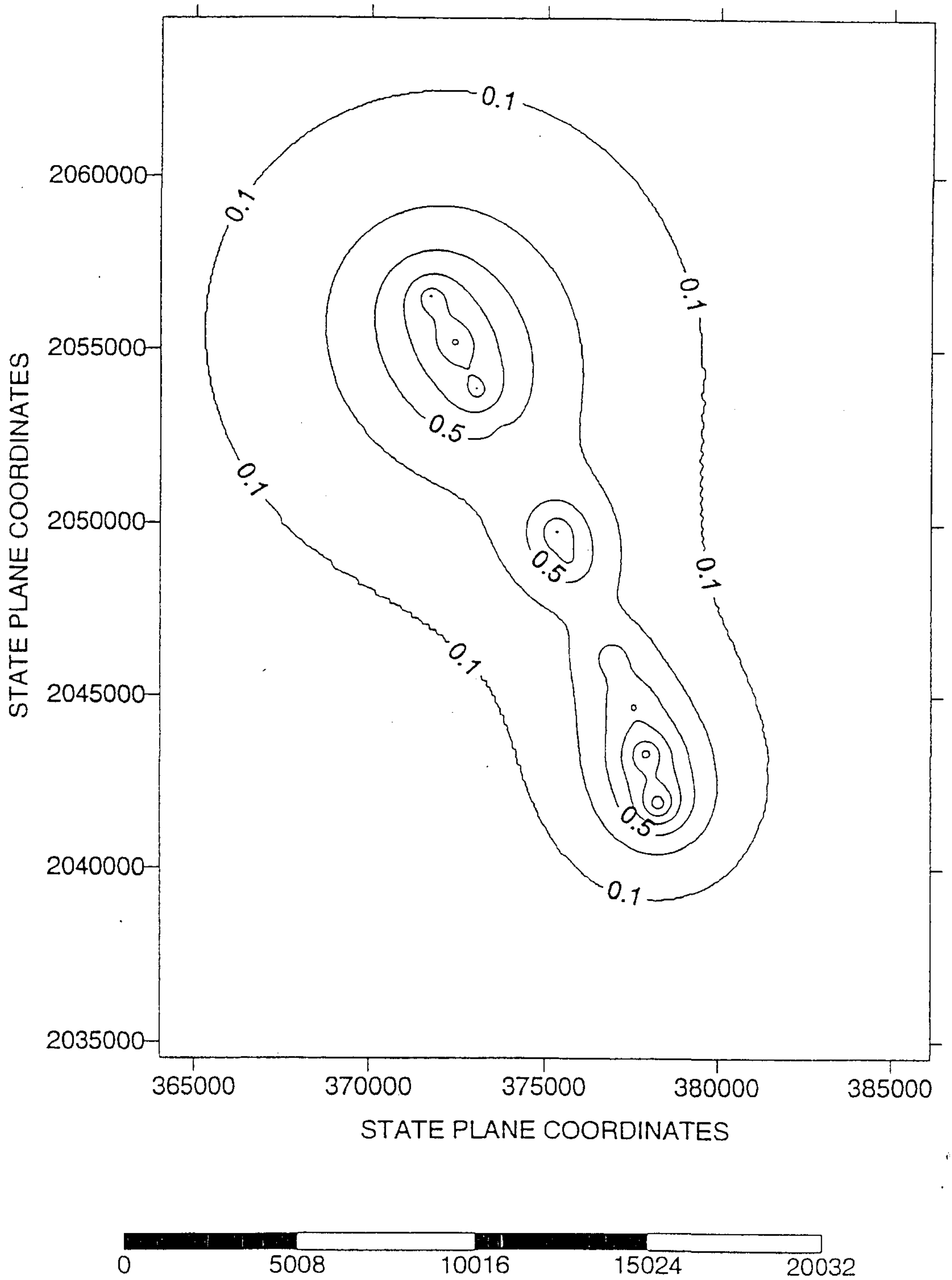

Figure 11. Simulated drawdowns in the unconfined portion of the surficial aquifer system for 2015 pumpage, city of St. Augustine wellfield (measured in feet)

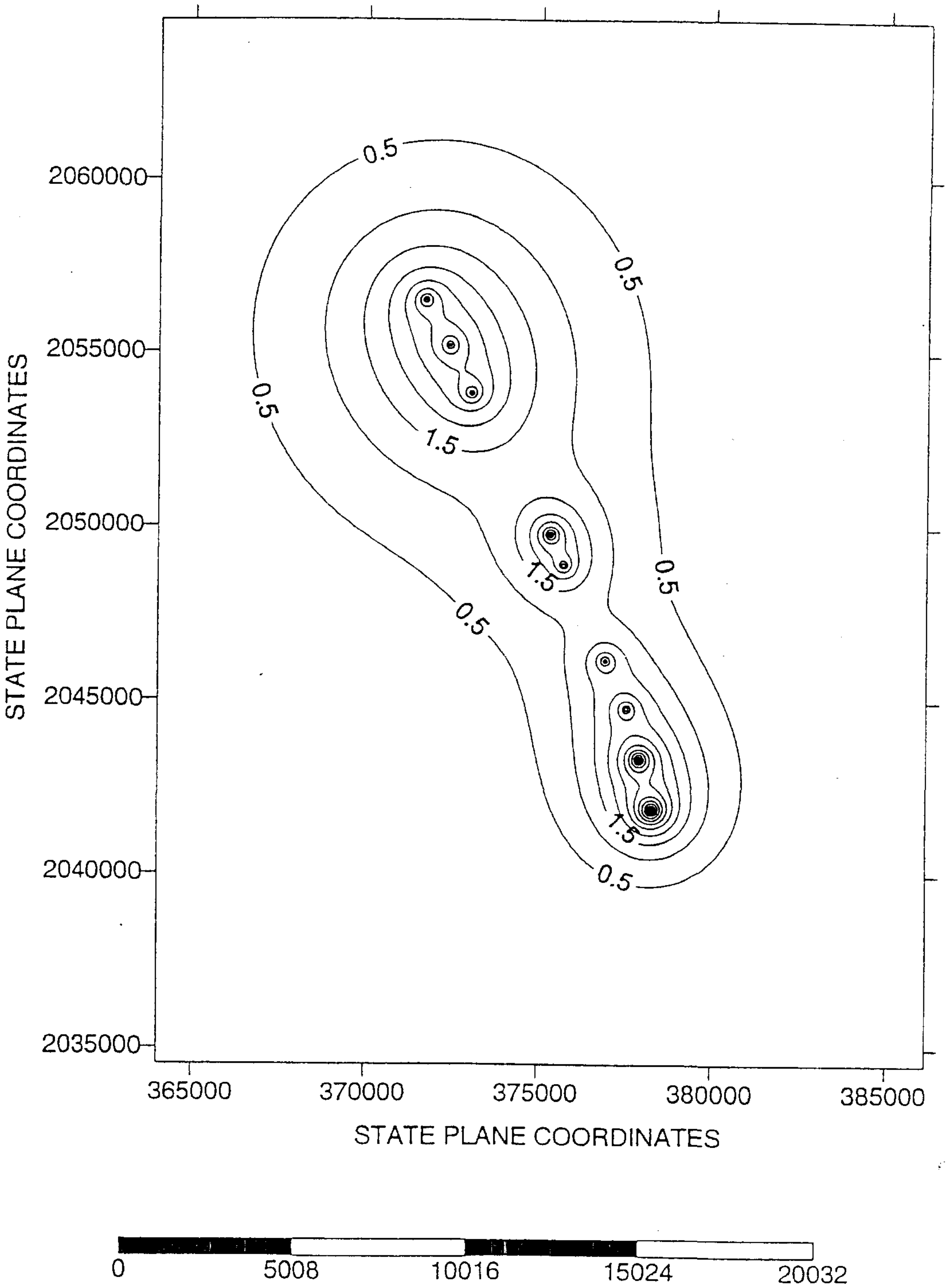

Figure 12. Simulated drawdowns in the confined portion of the surficial aquifer system for 2015 pumpage, city of St. Augustine wellfield (measured in feet)

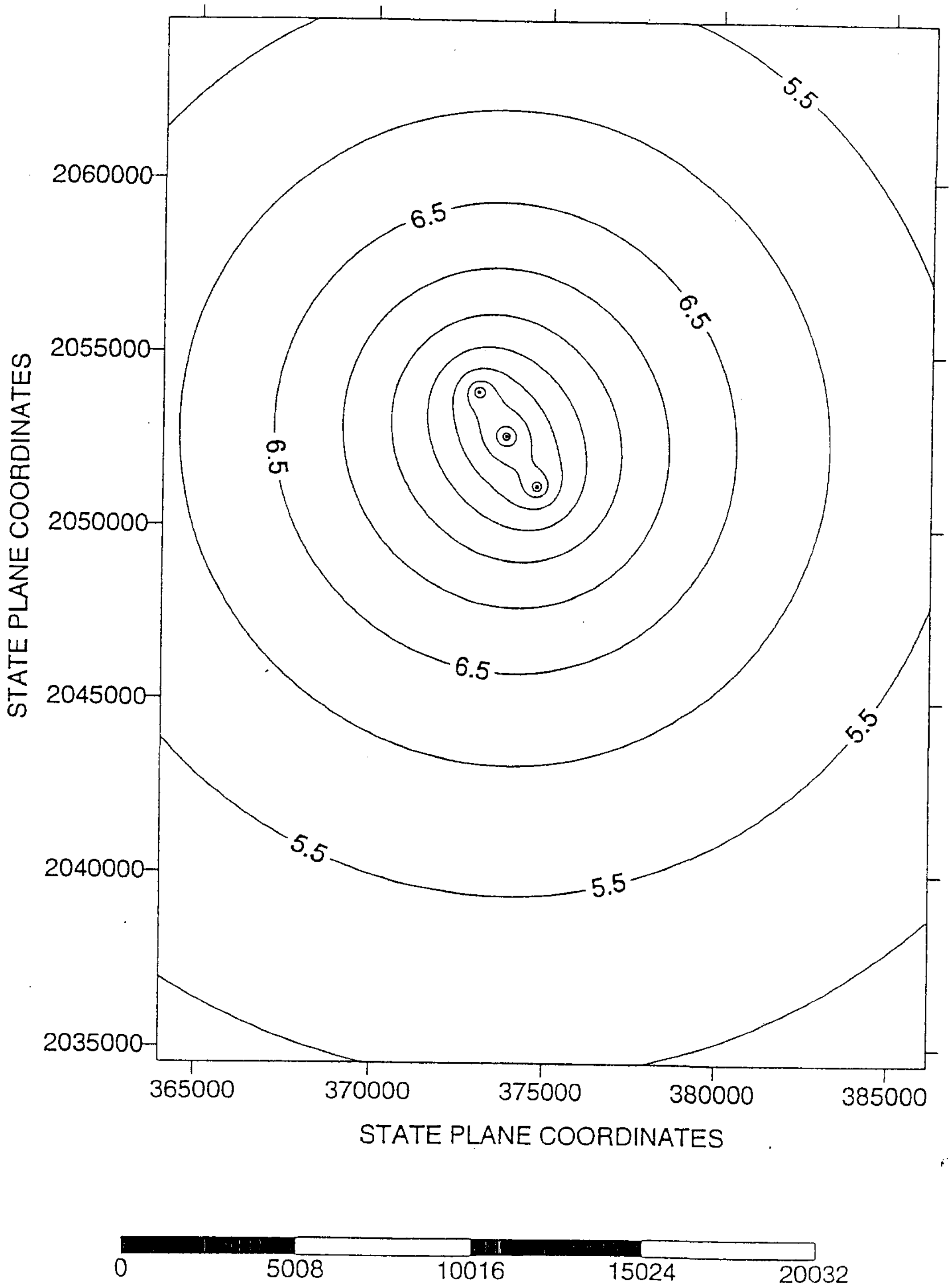

Figure 13. Simulated drawdowns in the Upper Floridan aquifer for 2015 pumpage, city of St. Augustine wellfield (measured in feet)

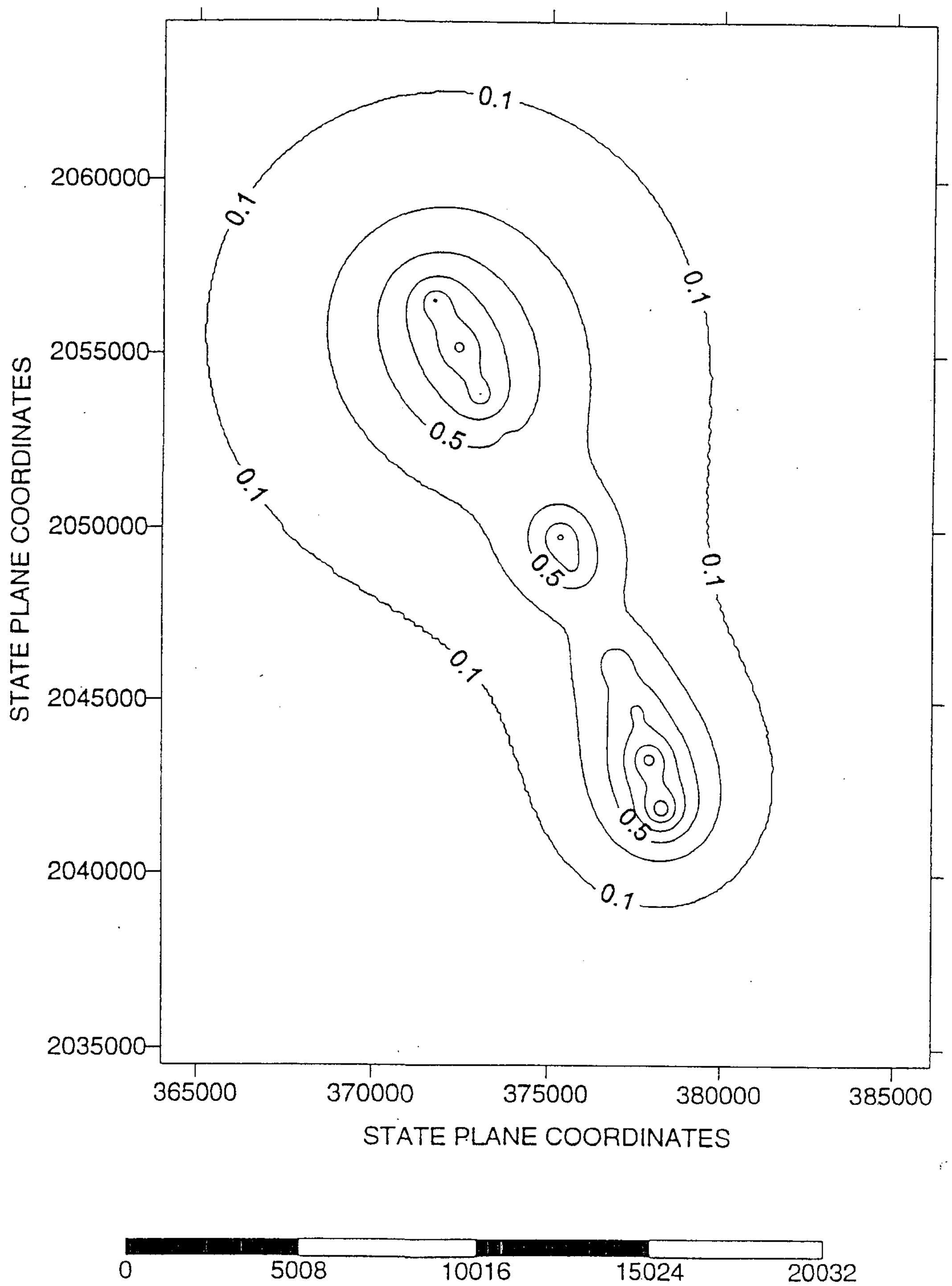

Figure 14. Simulated drawdowns in the unconfined portion of the surficial aquifer system for 2020 pumpage, city of St. Augustine wellfield (measured in feet)

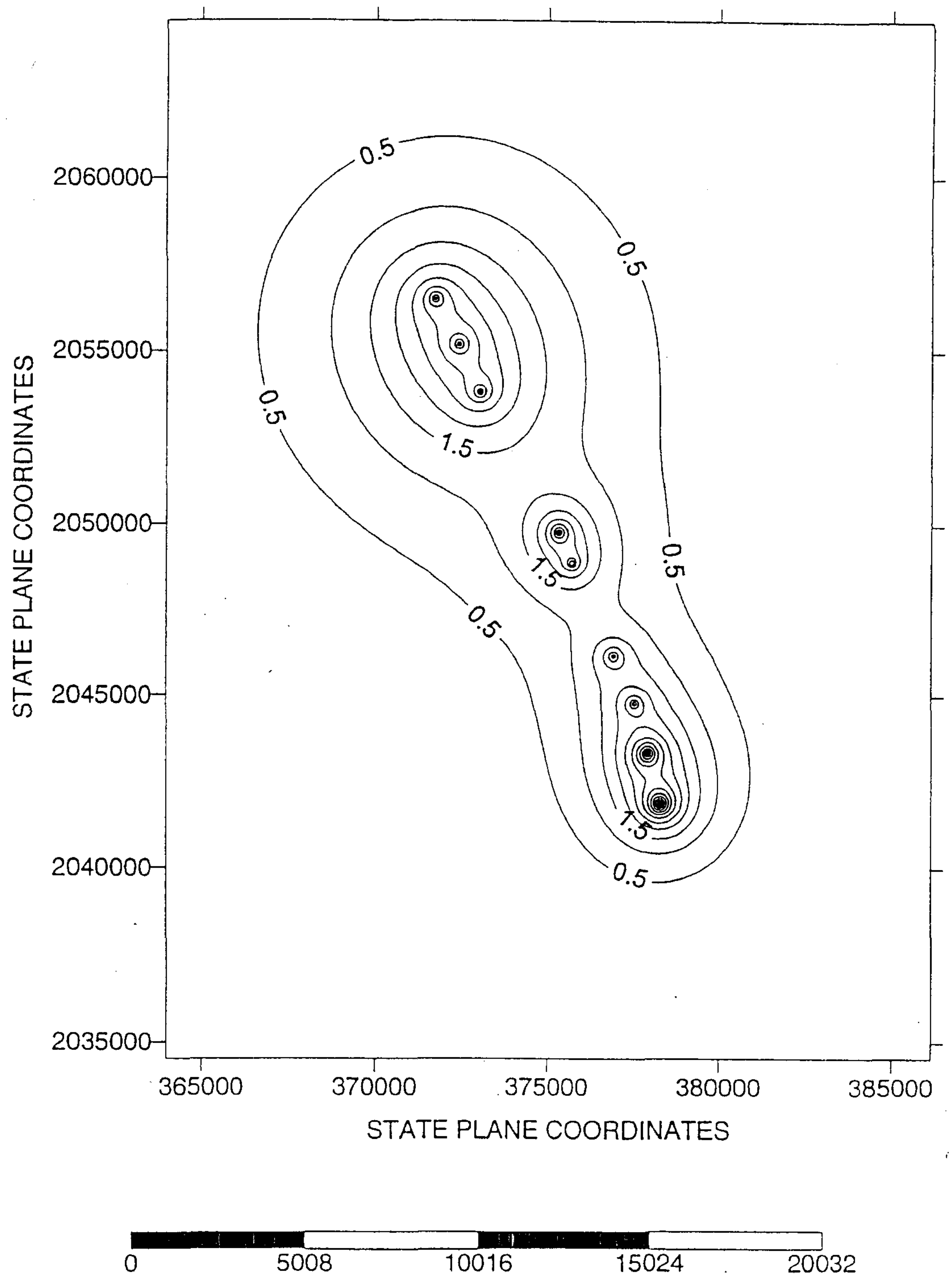

Figure 15. Simulated drawdowns in the confined portion of the surficial aquifer system for 2020 pumpage, city of St. Augustine wellfield (measured in feet)

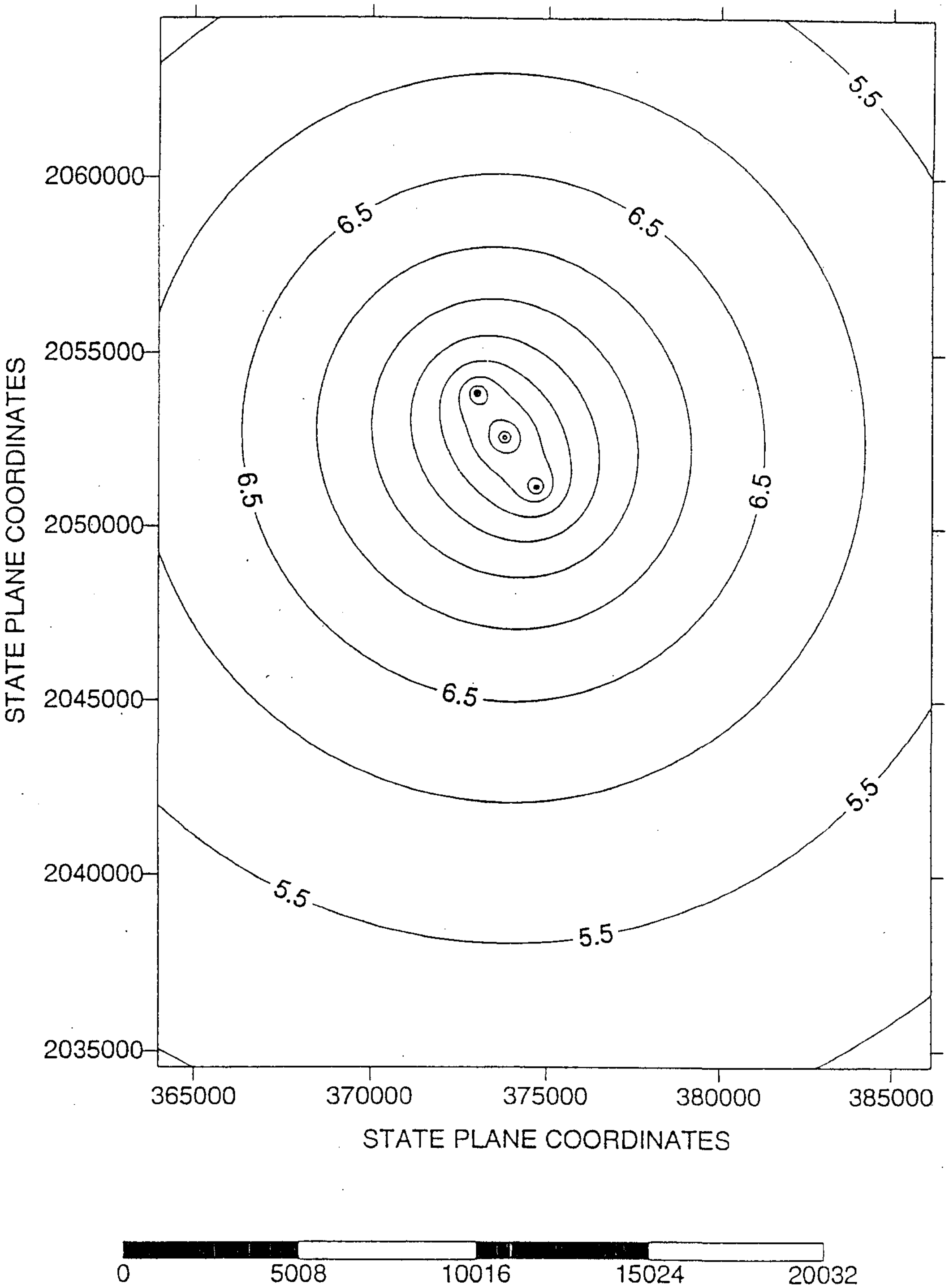

Figure 16. Simulated drawdowns in the Upper Floridan aquifer for 2020 pumpage, city of St. Augustine wellfield (measured in feet)

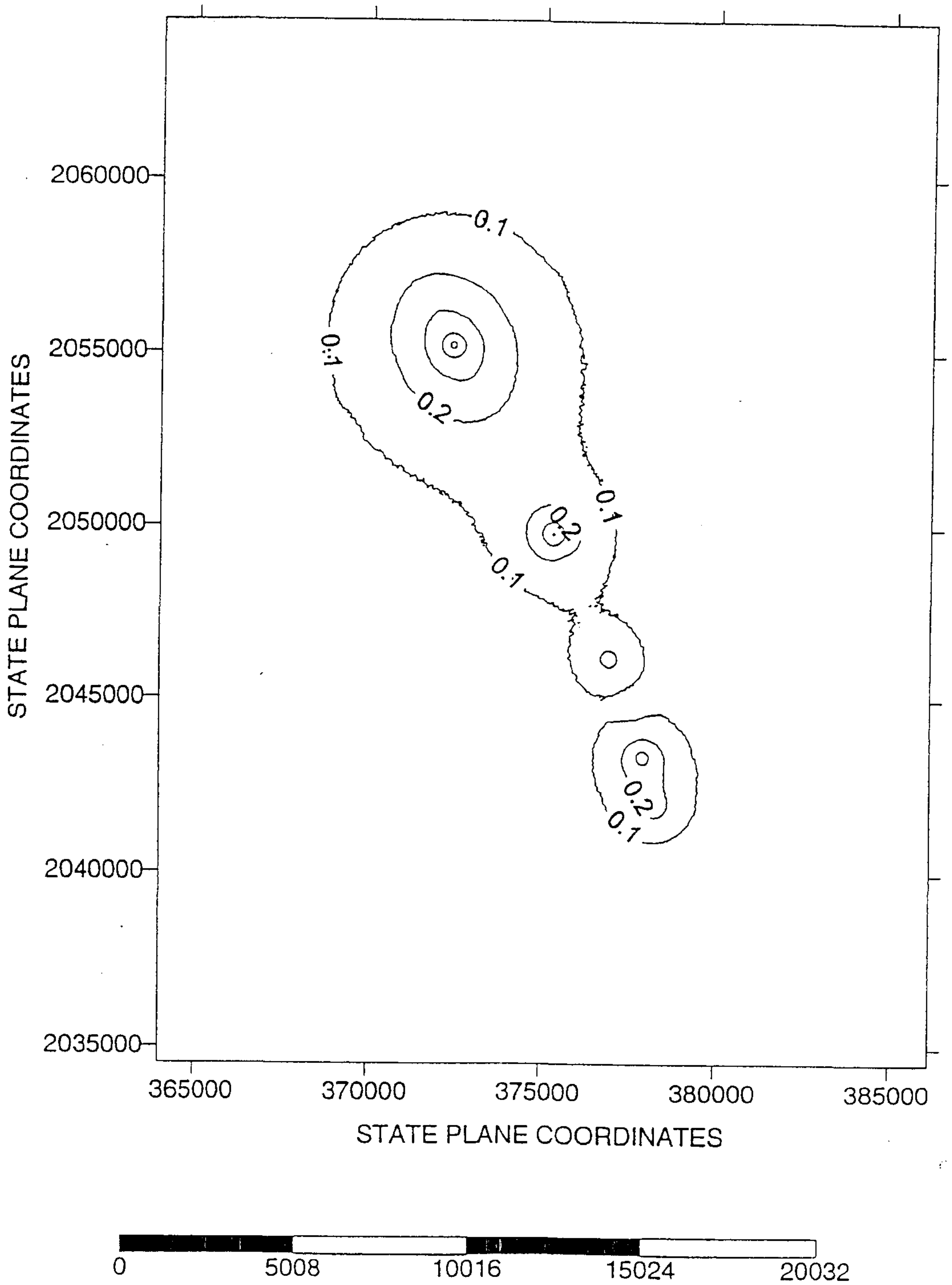

Figure 17. Difference in the simulated drawdowns for the unconfined portion of the surficial aquifer system between 2020 and 1995 pumpages, city of St. Augustine wellfield (measured in feet)

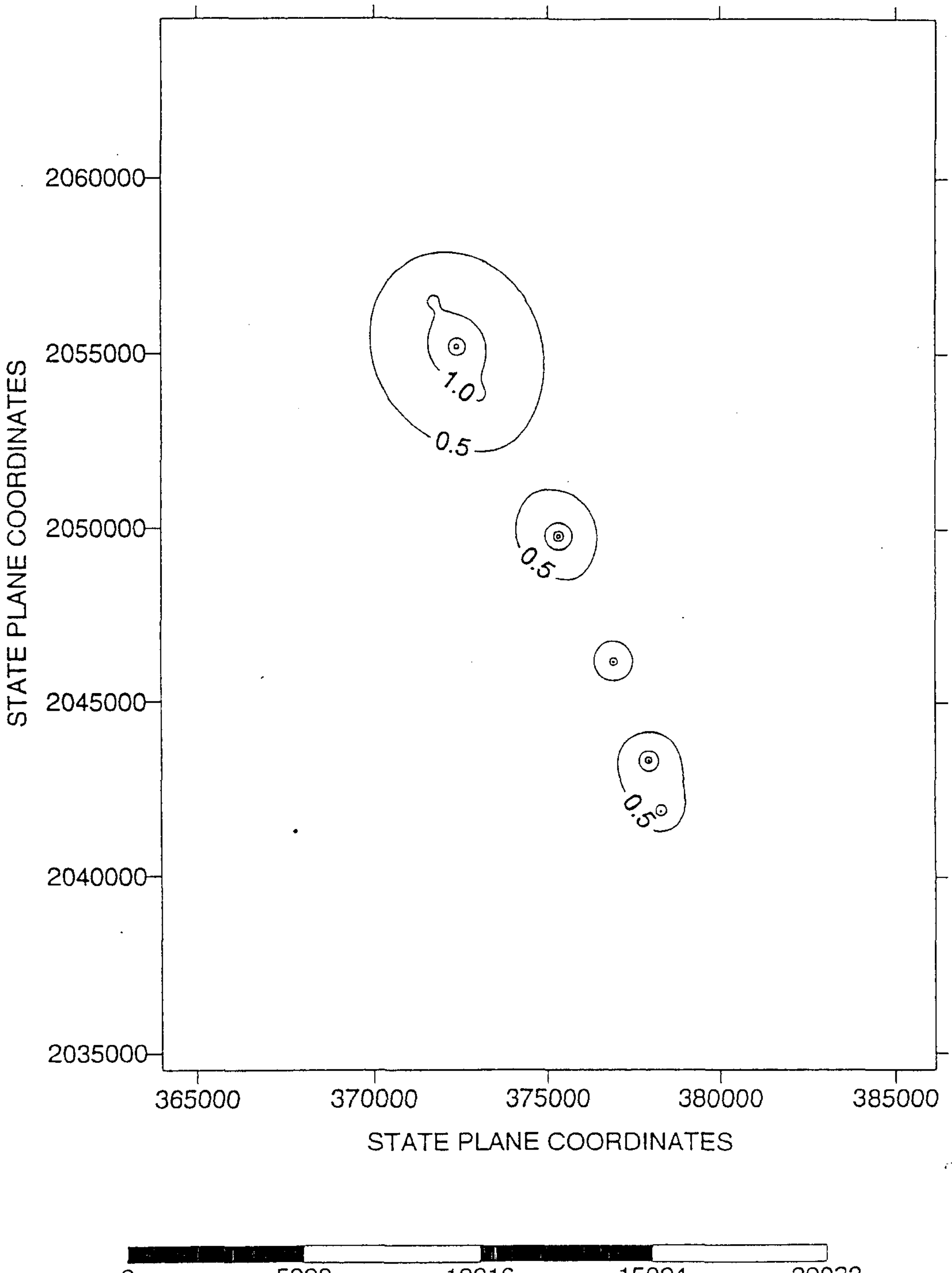

Figure 18. Difference in the simulated drawdowns for the confined portion of the surficial aquifer system between 2020 and 1995 pumpages, city of St. Augustine wellfield (measured in feet)

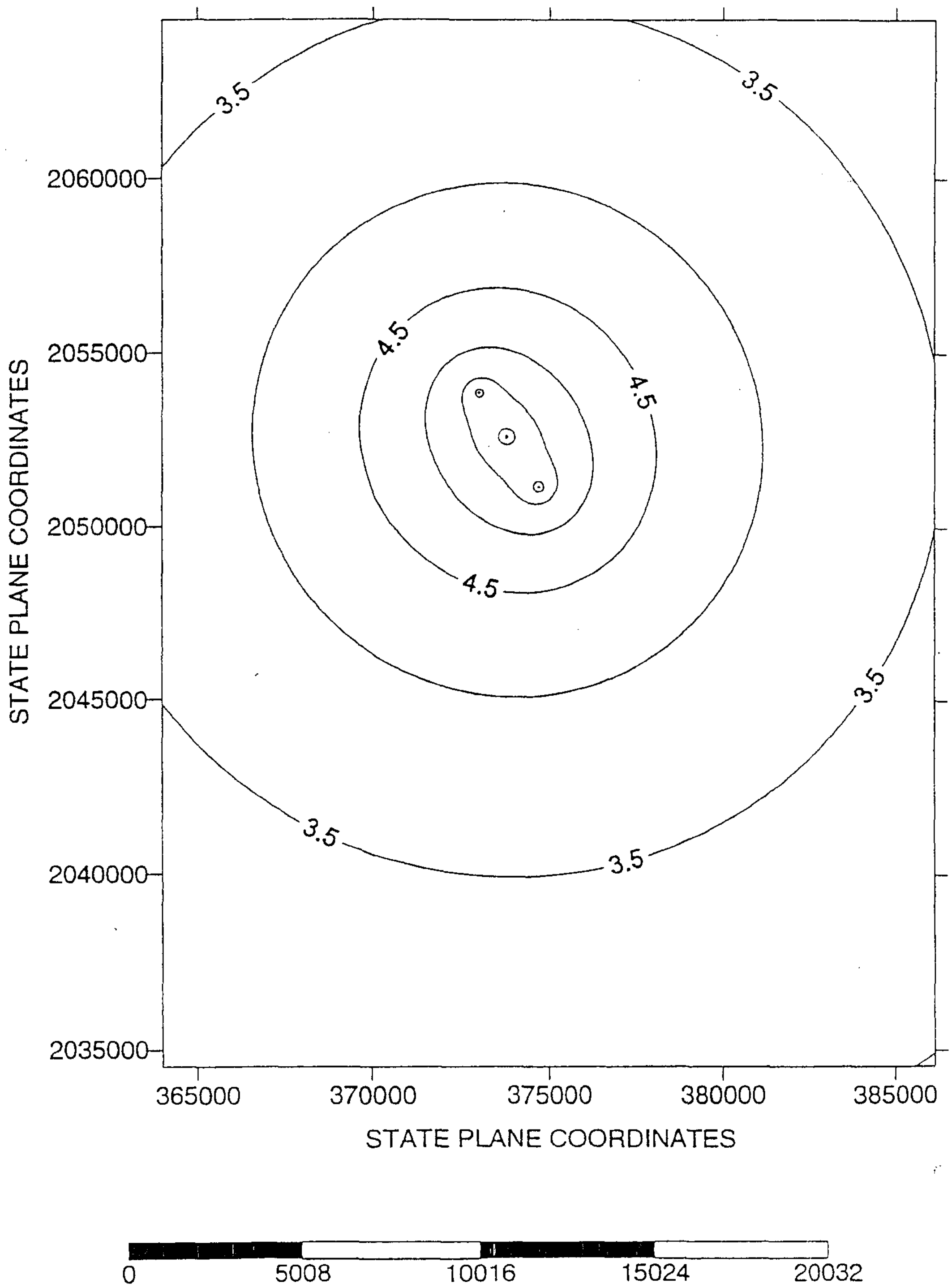

Figure 19. Difference in the simulated drawdowns for the Upper Floridan aquifer between 2020 and 1995 pumpages, city of St. Augustine wellfield (measured in feet)

reducing projected withdrawals from existing surficial aquifer production wells and constructing additional surficial aquifer production wells north of the wellfield or by increasing withdrawals from the Floridan aquifer, or both.

Estimates of the extent of potential wetland impacts at the city of St. Augustine wellfield may be improved by improving calibrations of the groundwater models. Additional water level drawdown information is necessary to accomplish such improved calibrations. Constructing and monitoring water levels in water table monitor wells in the vicinity of the south zone of the wellfield will be necessary to provide this additional water level information.

In addition, another stress test of the city wellfield conducted after placement of additional water table monitor wells in the vicinity of the south zone of the wellfield would provide data important to the improvement of model calibration.

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APPENDIX A

Well construction reports for monitor wells SJ0291, SJ0292, and SJ0293; results from step-drawdown tests, with lithologic descriptions

DOWN
Construction
Preliminary Data
St. Augustine Wellfield

Aquifer System Monitor Wells:
Surficial SJ0291
Surficial SJ0292
Surficial SJ0293

SJRWMD Program No. 31-58200

Division of Ground Water Programs,
Department of Resource Management
St. Johns River Water Management District
Palatka, Florida

September 22, 1999

All data, figures, tables and information are provisional and generated for the Division of Ground Water Program's use.

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Site Layout

Asbuilt

Ground Water Quality

APT   Step Drawdown

Lithologic Logs

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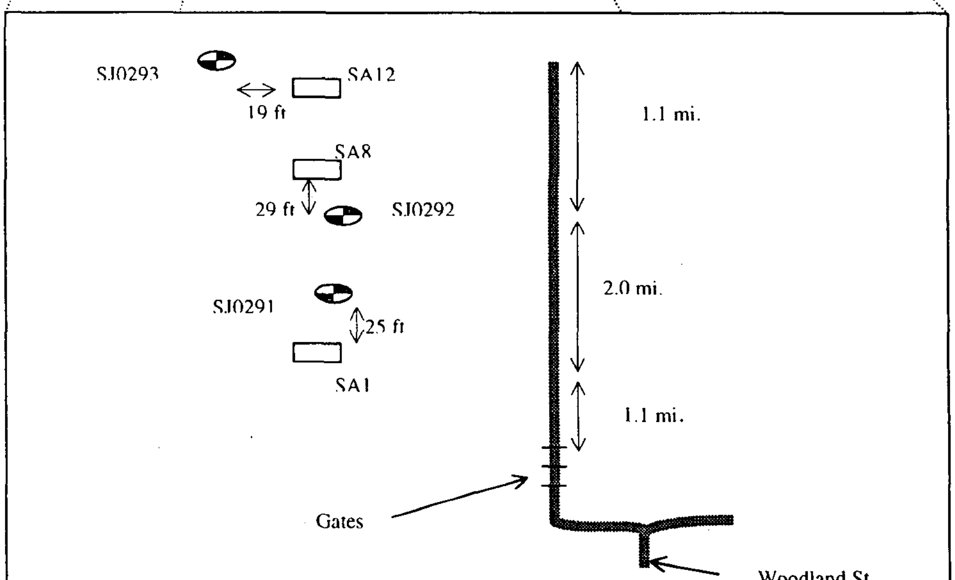
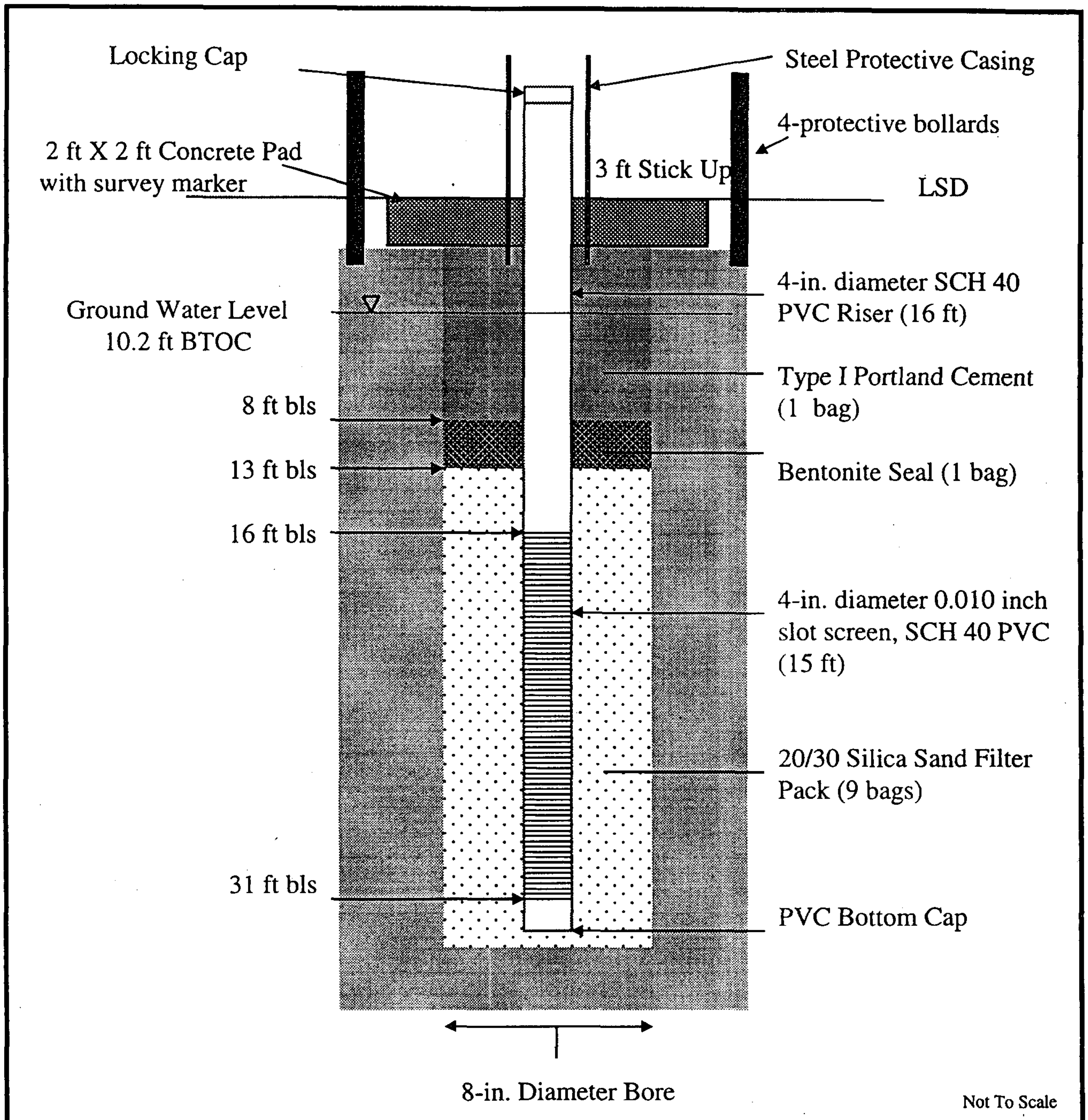
I:data/gwpcom/prelim/ counties/ St. Johns/SJ0291p

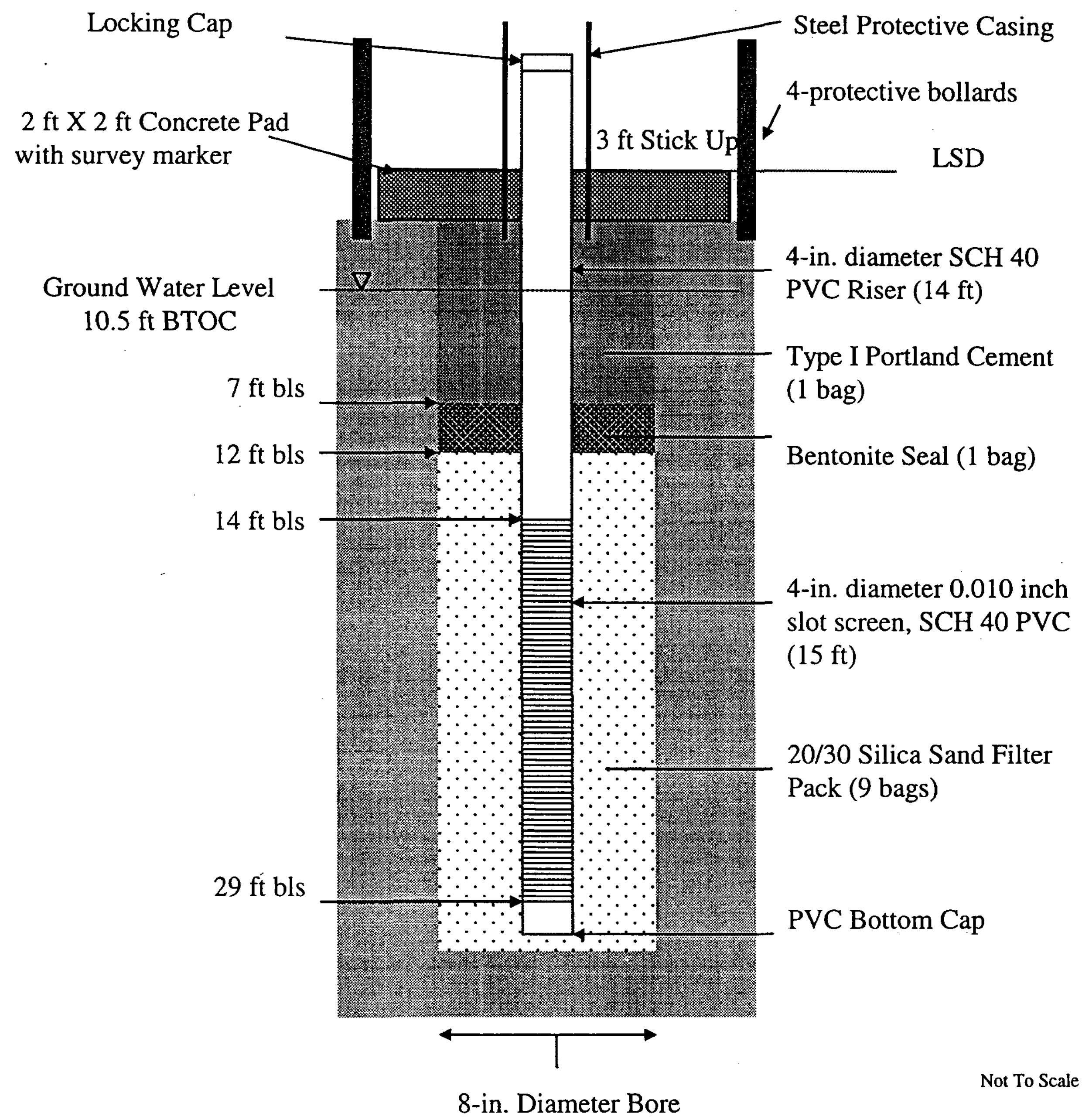


Not To Scale

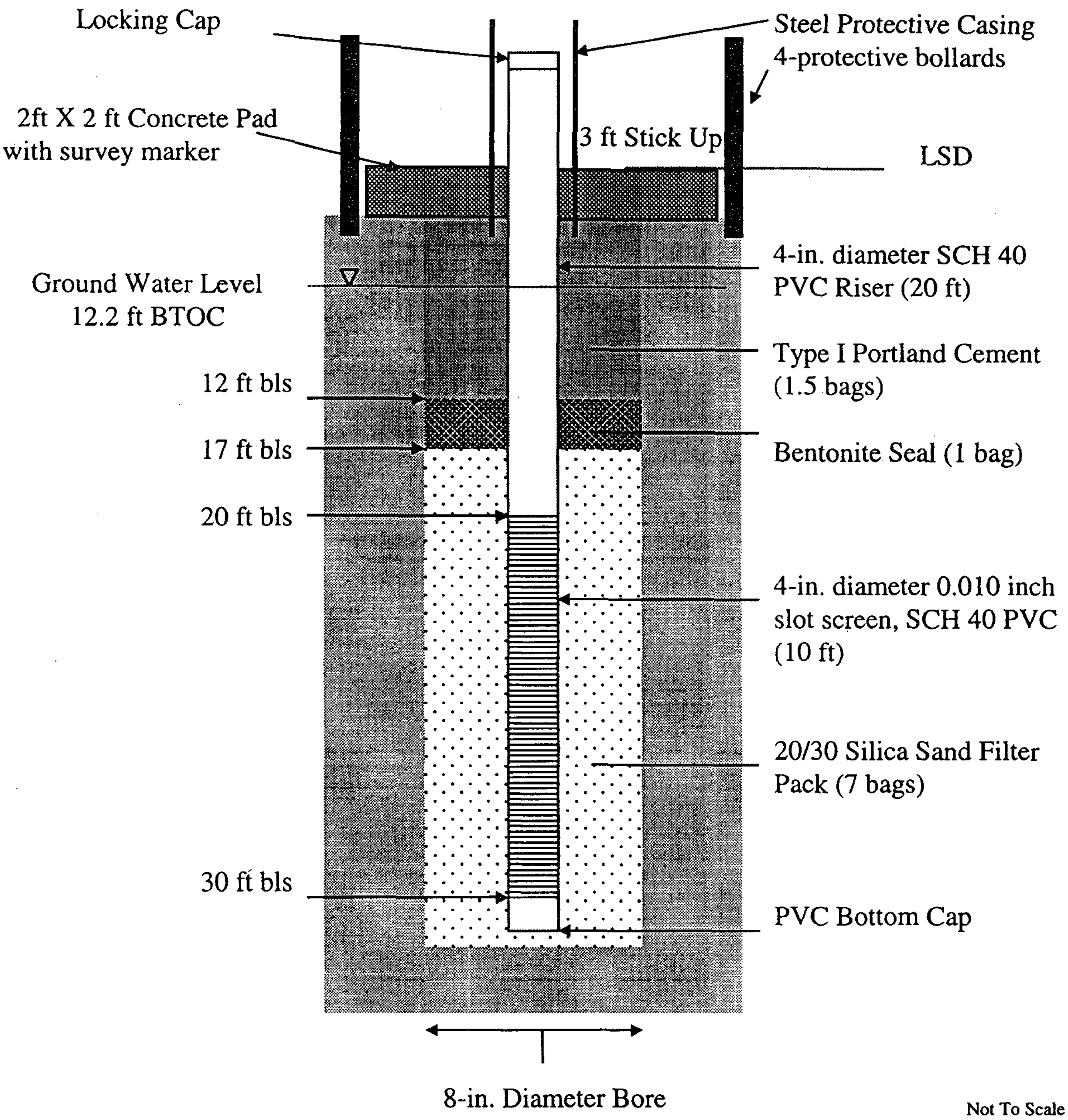
Site: St. Augustine Wellfield	**SJ0291**	**SJ0292**	**SJ0293**	**SJRWMD**
Lat/Long:	295701/812302	295832/812302	295925/812302	
TRS:	062928	062974	062908	
Topo:	Bakersville	Bakersville	Bakersville	
Elevation:	~36 ft NGVD	~35 ft NGVD	~36 ft NGVD	
Project No: 31- 52800				**Figure 1. Site Map**



Site:	St. Augustine Wellfield	**SJRWMD**
Driller:	Huss Drilling Inc.	**Figure 2**. Surficial Monitor Well SJ0291
Well Completed:	October 7, 1997	



Site:	St. Augustine Wellfield	**SJRWMD**
Driller:	Huss Drilling Inc.	**Figure 3**. Surficial Monitor Well SJ0292
Well Completed:	October 7,1997	



Site:	St. Augustine Wellfield
Driller:	Huss Drilling Inc.
Well Completed:	October 7, 1997

SJRWMD

Figure 4. Surficial Monitor Well SJ0293

Table 1. **Groundwater Quality**

Site: St. Augustine Wellfield

Hydrologist: D. Toth

LAB ✓	Date/Time (yy:mm:dd/hh:mm)	Well Number	Sample Depth (ft, bls)	Screen Interval (ft)	Temp (Deg C)	pH	Conductivity (us/cm)
✓	991007/1156	SJ0291	31	16-31	23.4	6.4	321
✓	991007/1055	SJ0292	29	14-29	22.3	6.4	701
✓	991007/0912	SJ0293	30	20-30	22.5	4.4	118

Table 2. Step Drawdown

Pump Specs.	Type: Drill rig mud pump		Size: NA				Depth Set: NA					
Date	October 7, 1997				October 7, 1997				October 7, 1997			
Start Time	11:28				10:08				08:38			
Step	1	2	3									
Well No.	SJ0291	SJ0291	SJ0291	SJ0291	SJ0292	SJ0292	SJ0292	SJ0292	SJ0293	SJ0293	SJ0293	SJ0293
Pump Rate (gpm)	6.7	8.8	9.4	0 Recovery	10	16.7	20	0 Recovery	13.0	13.6	13.0	0 Recovery
Time (min) After pumping starts	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)	GWL (ft, TOC)
0	10.21	20.85	23.47	23.95	10.55	12.46	13.69	14.52	12.23	18.75	18.97	18.95
1	-	22.92	23.85	15.20	12.59	13.73	14.42	10.61	18.93	18.90	18.95	12.59
2	15.00	22.93	23.95	12.20	12.55	13.72	14.41	10.61	18.89	19.91	18.95	12.37
3	17.55	23.04	23.96	11.20	12.48	13.70	14.40	10.60	18.85	18.91	18.95	12.32
4	19.35	23.28	24.07	10.87	12.47	13.69	14.40	10.60	18.82	18.97	18.95	12.30
5	19.95	23.45	24.07	10.70	12.47	13.69	14.40	10.59	18.78	18.97	18.95	12.29
6	20.14	23.46	23.95	10.62	12.47	13.69	14.40	10.59	18.77			12.28
7	20.37	23.45		10.58	12.47	13.69	14.41	10.58	18.76			
8	20.55	23.30		10.55	12.47	13.69	14.41	10.58	18.76			
9	20.65	23.43		10.53	12.47	13.69	14.41	10.57	18.76			
10	20.75	23.47		10.51	12.46	13.69	14.41	10.57	18.76			
11	20.82			10.49			14.52		-			
12	20.85			10.48			14.52		-			
13							14.52		-			
14							14.52		-			
15							14.52		18.75			
16							14.52					

Lithologic Description

Site: St. Augustine Wellfield **Well ID:** SJ0291

Samples Described By: R Brooks

From (ft)	To (ft)	Lithology
0	5	Sand, gray, fine
5	11	Sand, light tan, fine
11	31	Sand, light tan, fine, shell (~15%) medium
31	-	Clay, gray sandy

Lithologic Description

Site: St. Augustine Wellfield **Well ID:** SJ0292

Samples Described By: R Brooks

From (ft)	To (ft)	Lithology
0	5	Sand, light tan, fine to medium
5	8	Sand, orange, fine to medium
8	11	Sand, light tan, fine
11	20	Sand, light tan, fine, shell (~20 %), medium
20	29	Sand, light tan, fine, shell (~40 %), medium

Lithologic Description

Site: St. Augustine Wellfield **Well ID:** SJ0293

Samples Described By: R Brooks

From (ft)	To (ft)	Lithology
0	5	Sand, gray, very fine
5	12	Sand, brown, very fine
12	17	Sand, dark brown, fine, highly organic (roots)
17	30	Sand, brown, fine

APPENDIX B

Well construction reports for monitor wells SJ0311, SJ0312, SJ0313, and SJ0314, groundwater quality and groundwater levels

DOWN
Construction
Preliminary Data
City of St. Augustine Wellfield, St. Johns County

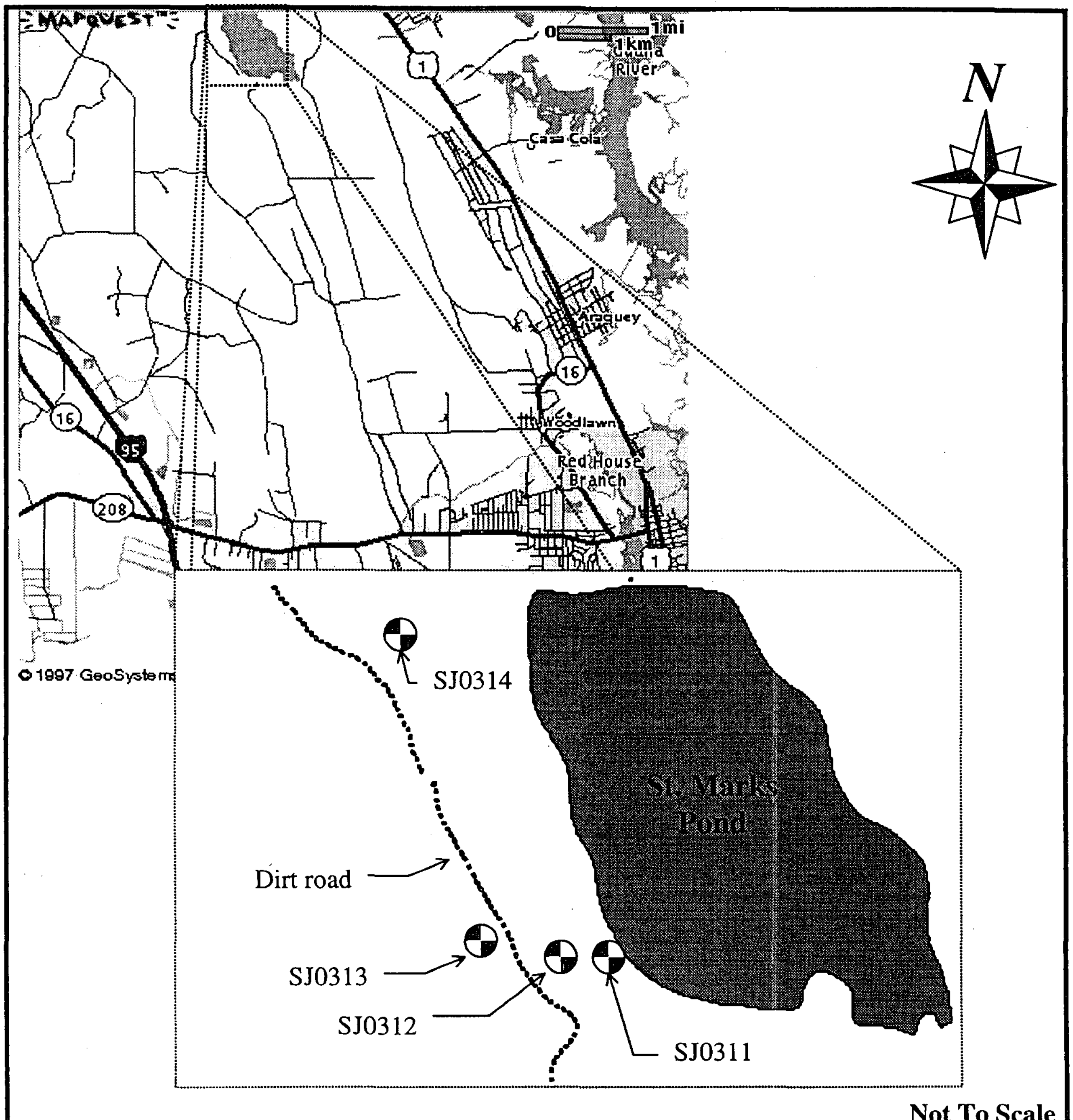
Aquifer System Monitor Wells:
Surficial SJ0311
Surficial SJ0312
Surficial SJ0313
Surficial SJ0314

SJRWMD Program No. 31-58200

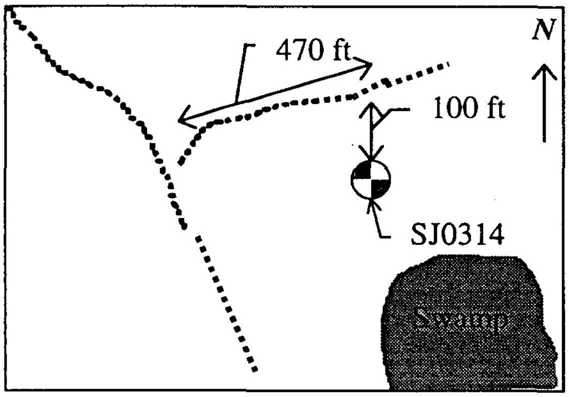
Division of Ground Water Programs,
Department of Resource Management
St. Johns River Water Management District
Palatka, Florida

October 7, 1999

All data, figures, tables and information are provisional and generated for the Division of Ground Water Program's use.

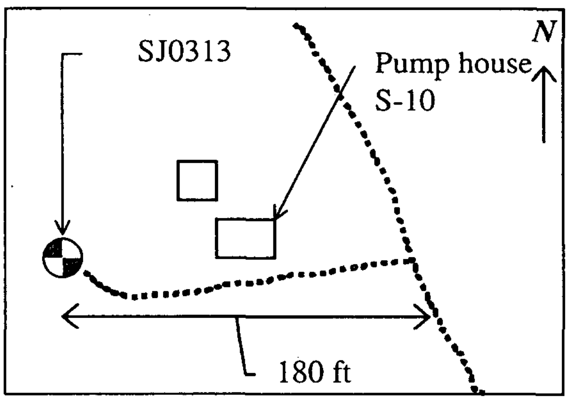


Site:	City of St. Augustine Wellfield	**SJRWMD**	
Project No:	31-58200	**Figure 1. Site Vicinity Map**	



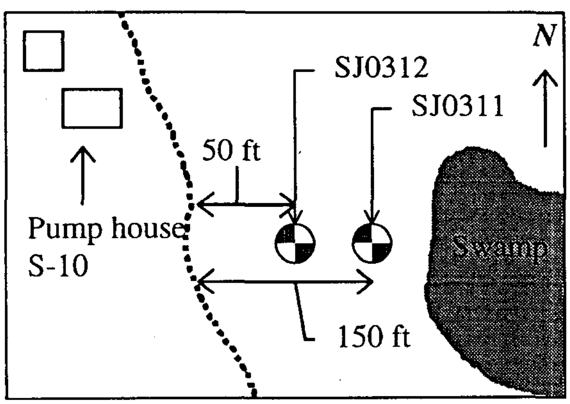
SJ0314

Travel 4 miles from entry gate in the vicinity of private residence to pump house S-10. Proceed 0.9 miles north of S-10 pump house to fork in road. Proceed east (right) @ 0.2 mile. Well SJ-0314 is @ 100 feet south of dirt road.



SJ0313

Travel 4 miles from entry gate in the vicinity of private residence to pump house S-10. Well SJ-0313 is @ 180 feet west of dirt road.



SJ0311 & SJ0312

Travel 4 miles from entry gate in the vicinity of private residence to pump house S-10. Wells SJ-0311 and SJ-0312 are @ 100 feet south of of the pumphouse and 150 feet and 50 feet west of the dirt road.

Not To Scale

Site:	City of St. Augustine Wellfield	**SJRWMD**
Project No:	31-58200	**Figure 2. Site Maps**

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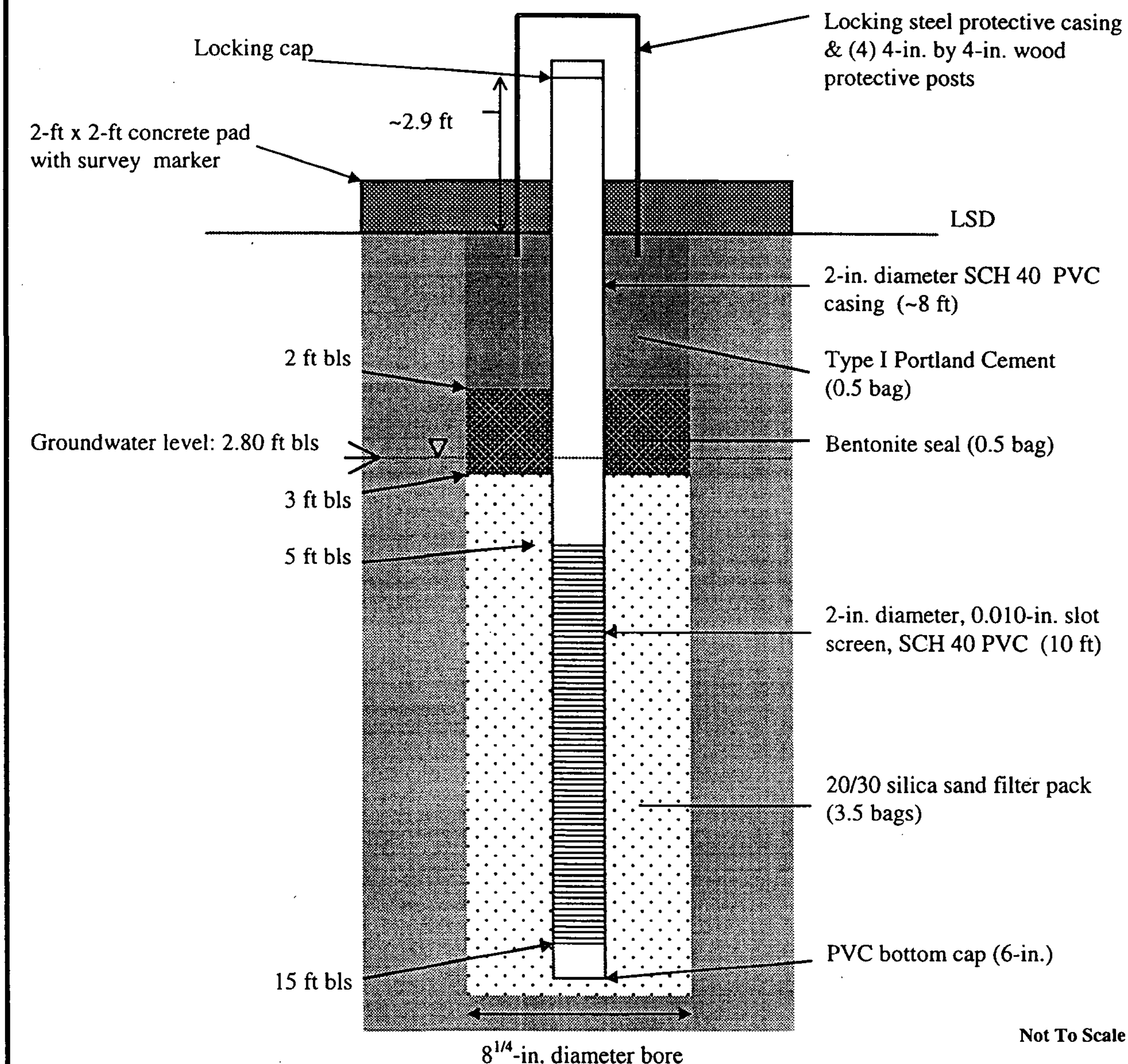

Site:	City of St. Augustine Wellfield	**SJRWMD**
Well Completed:	October 13, 1998	**Figure 3. Monitor Well: SJ0311**

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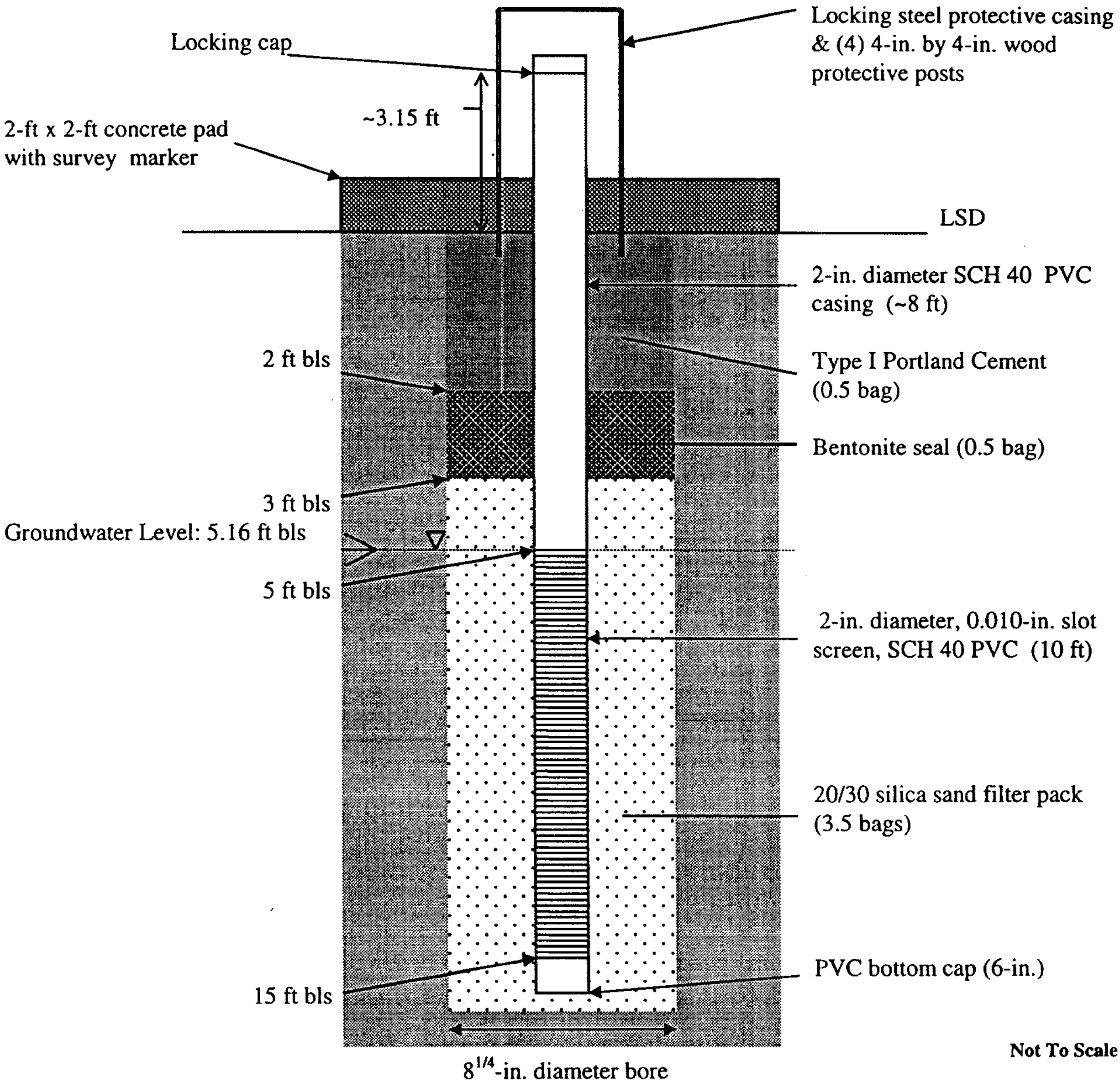
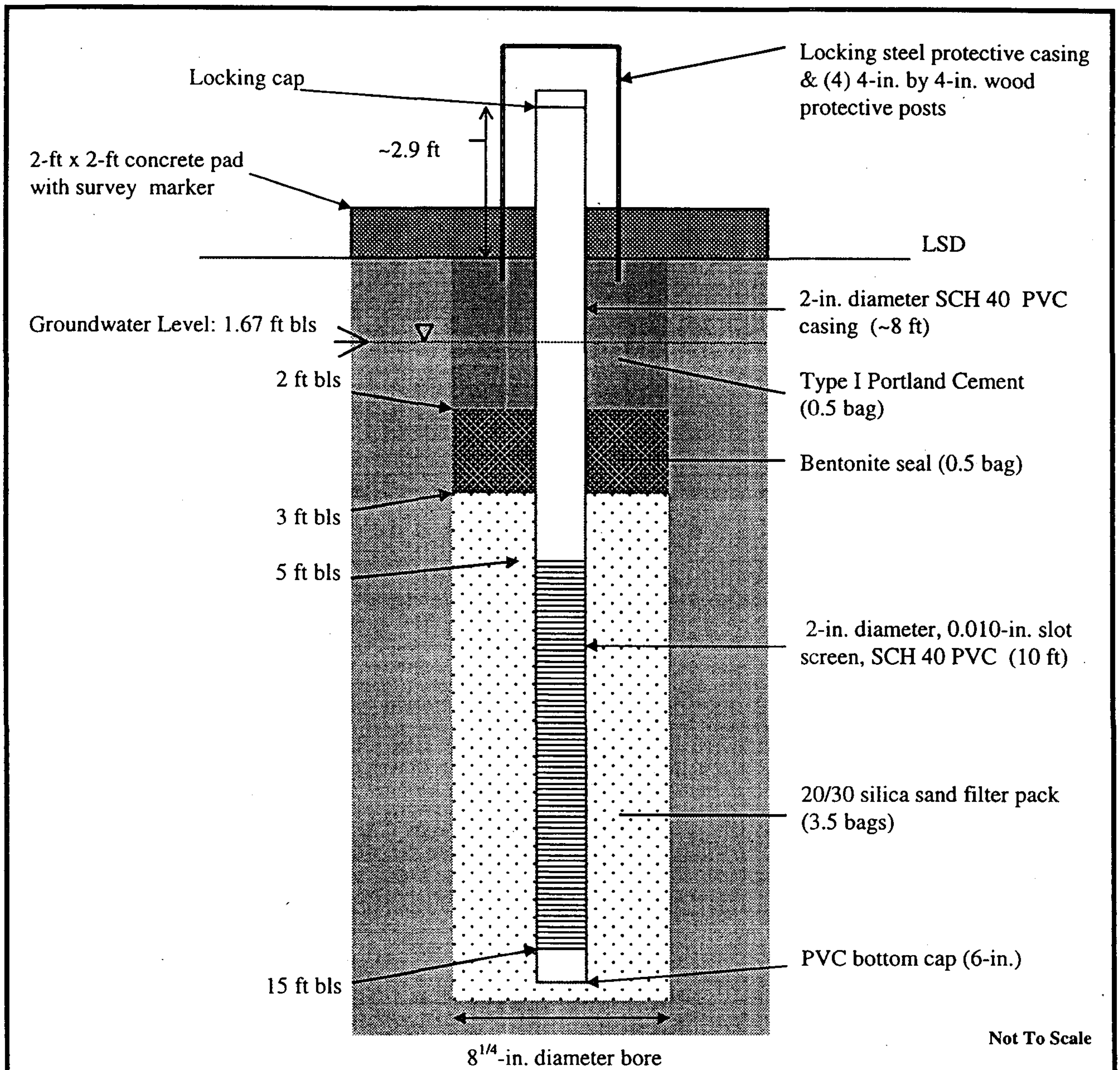
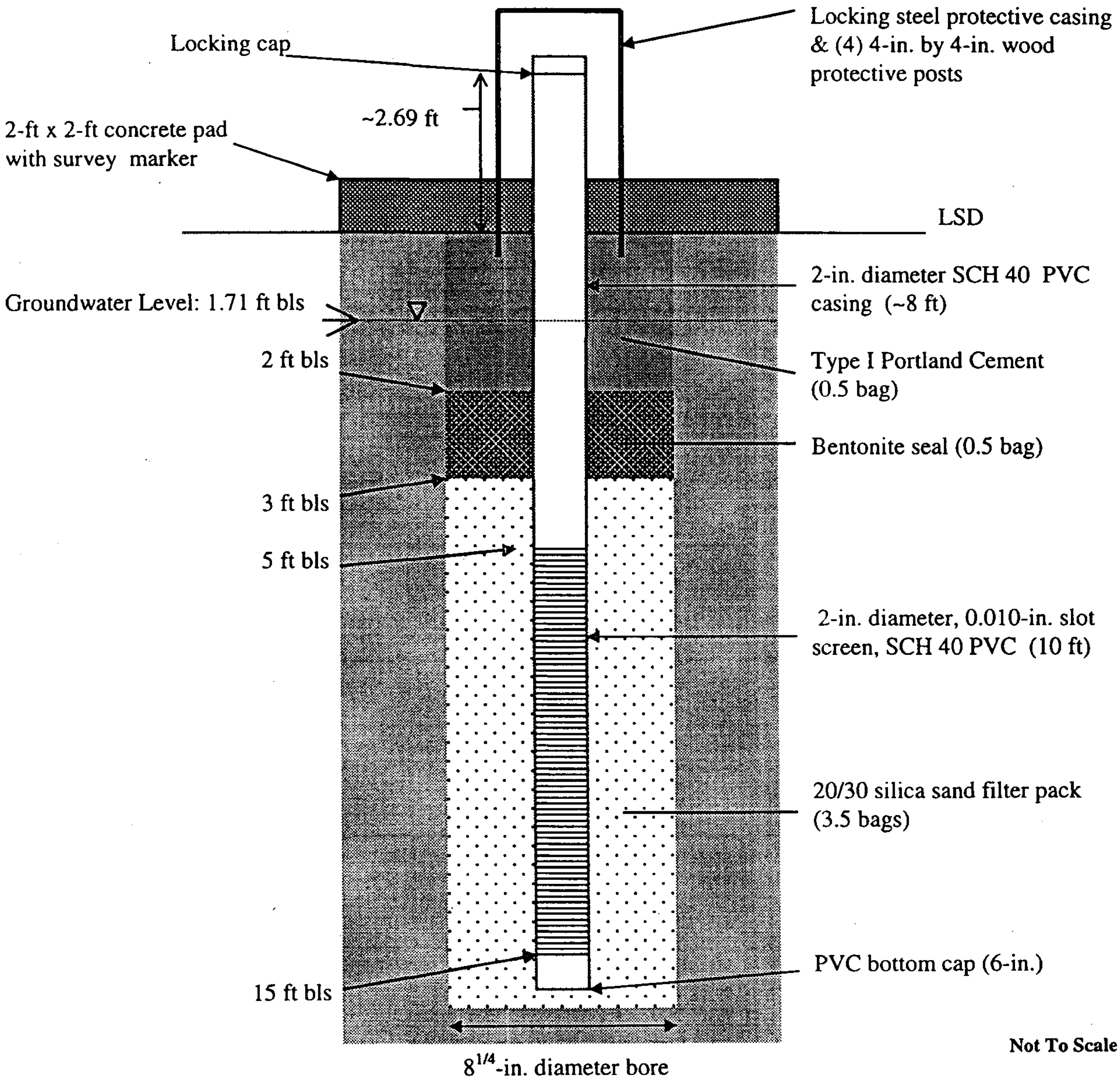


Site:	City of St. Augustine Wellfield	**SJRWMD**
Well Completed:	October 13, 1998	**Figure 4. Monitor Well: SJ0312**



Site: City of St. Augustine Wellfield	**SJRWMD**
Well Completed: October 13, 1998	**Figure 5. Monitor Well: SJ0313**



Site:	City of St. Augustine Wellfield	**SJRWMD**
Well Completed:	October 13, 1998	**Figure 6. Monitor Well: SJ0314**

DRAFT

Table 1. Groundwater Quality

Site: City of St. Augustine Wellfield **Well Number**: SJ0311

Hydrologist: J. Sego **Casing Depth**: Screened 5 ft to 15 ft bls

LAB ✓	Date/Time (yy:mm:dd/hh:mm)	Sample Depth (ft, bls)	Screened Interval (ft, bls)	Temp (Deg F)	pH	Conductivity (us/cm)
	981013-1215	NA	5-15	78.8	6.71	63.3
	981013-1220	NA	5-15	77.5	4.84	60.6
	981013-1225	NA	5-15	77.3	4.93	59.7
	981013-1230	NA	5-15	NR	4.80	60.5
	981013-1235	NA	5-15	78.3	4.85	59.1

Comments: Water turbid (dark brown, tannin) throughout well development @ 5 gpm.

Table 2. Groundwater Quality

Site: City of St. Augustine Wellfield **Well Number**: SJ0312

Hydrologist: J. Sego **Casing Depth**: Screened 5 ft to 15 ft bls

LAB ✓	Date/Time (yy:mm:dd/hh:mm)	Sample Depth (ft, bls)	Screened Interval (ft, bls)	Temp (Deg C)	pH	Conductivity (us/cm)
	981013-1312	NA	5-15	26.5	NR	73.1
	981013-1315	NA	5-15	26.5	4.79	73.9
	981013-1325	NA	5-15	25.4	4.78	65.1
	981013-1330	NA	5-15	25.2	NR	65.1
	981013-1335	NA	5-15	25.6	4.78	64.5

Comments: Water turbid (dark brown, tannin) throughout well development @ 5 gpm.

Table 3. Groundwater Quality

Site: City of St. Augustine Wellfield **Well Number:** SJ0313

Hydrologist: J. Sego **Casing Depth:** Screened 5 ft to 15 ft bls

LAB ✓	Date/Time (yy:mm:dd/hh:mm)	Sample Depth (ft, bls)	Screened Interval (ft, bls)	Temp (Deg C)	pH	Conductivity (us/cm)
	981013-1440	NA	5-15	27.7	4.38	61.6
	981013-1445	NA	5-15	23.0	4.35	61.0
	981013-1450	NA	5-15	23.0	4.28	61.3
	981013-1455	NA	5-15	23.5	4.30	60.6
	981013-1500	NA	5-15	23.4	4.28	60.2
	981013-1505	NA	5-15	22.8	4.26	61.1

Comments: Water opaque throughout well development @ 5 gpm.

Table 4. Groundwater Quality

Site: City of St. Augustine Wellfield **Well Number:** SJ0314

Hydrologist: J. Sego **Casing Depth:** Screened 5 ft to 15 ft bls

LAB ✓	Date/Time (yy:mm:dd/hh:mm)	Sample Depth (ft, bls)	Screened Interval (ft, bls)	Temp (Deg F)	pH	Conductivity (us/cm)
	981013-1045	NA	5-15	75.0	5.05	64.2
	981013-1050	NA	5-15	75.2	4.92	61.4
	981013-1053	NA	5-15	75.0	4.94	59.4
	981013-1055	NA	5-15	75.0	4.82	53.5
	981013-1100	NA	5-15	75.0	4.85	53.2
	981013-1105	NA	5-15	74.7	4.80	52.3

Comments: Water turbid (dark brown, tannin) throughout well development @ 15 gpm.

Table 5. Groundwater Levels (10/13/98)

	SJ0311	SJ0312	SJ0313	SJ0314
Depth to water (ft, BTOC)	5.7	8.31	4.57	4.4
Top of Casing (ft, als)	2.9	3.15	2.9	2.69
Groundwater Level (ft, bls)	2.8	5.16	1.67	1.71

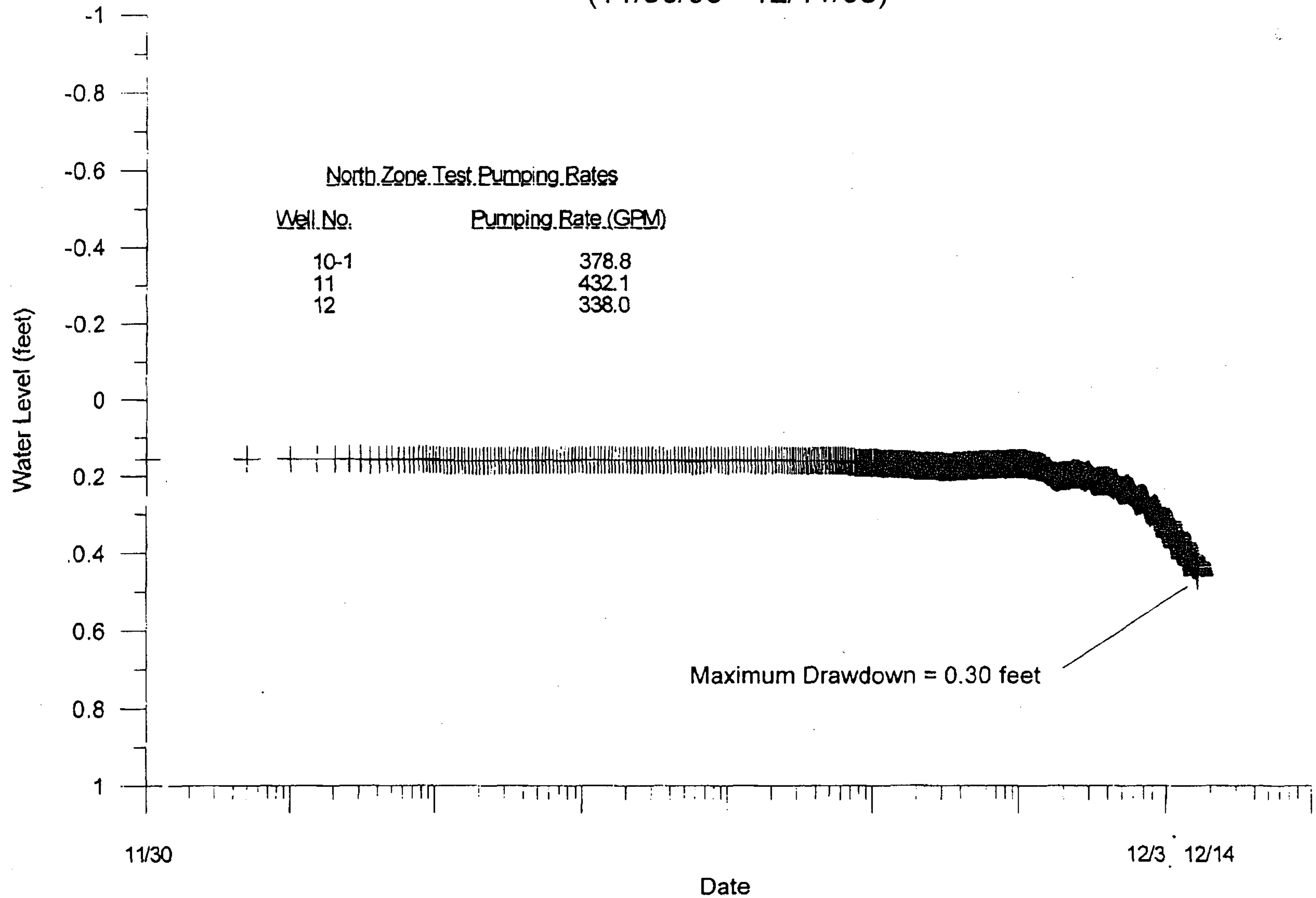
Table 6. Groundwater Levels (10/20/98)

	SJ0311	SJ0312	SJ0313	SJ0314
Depth to water (ft, BTOC)	5.62	8.29	5.08	4.57
Top of Casing (ft, als)	2.9	3.15	2.9	2.69
Groundwater Level (ft, bls)	2.72	5.14	2.18	1.88

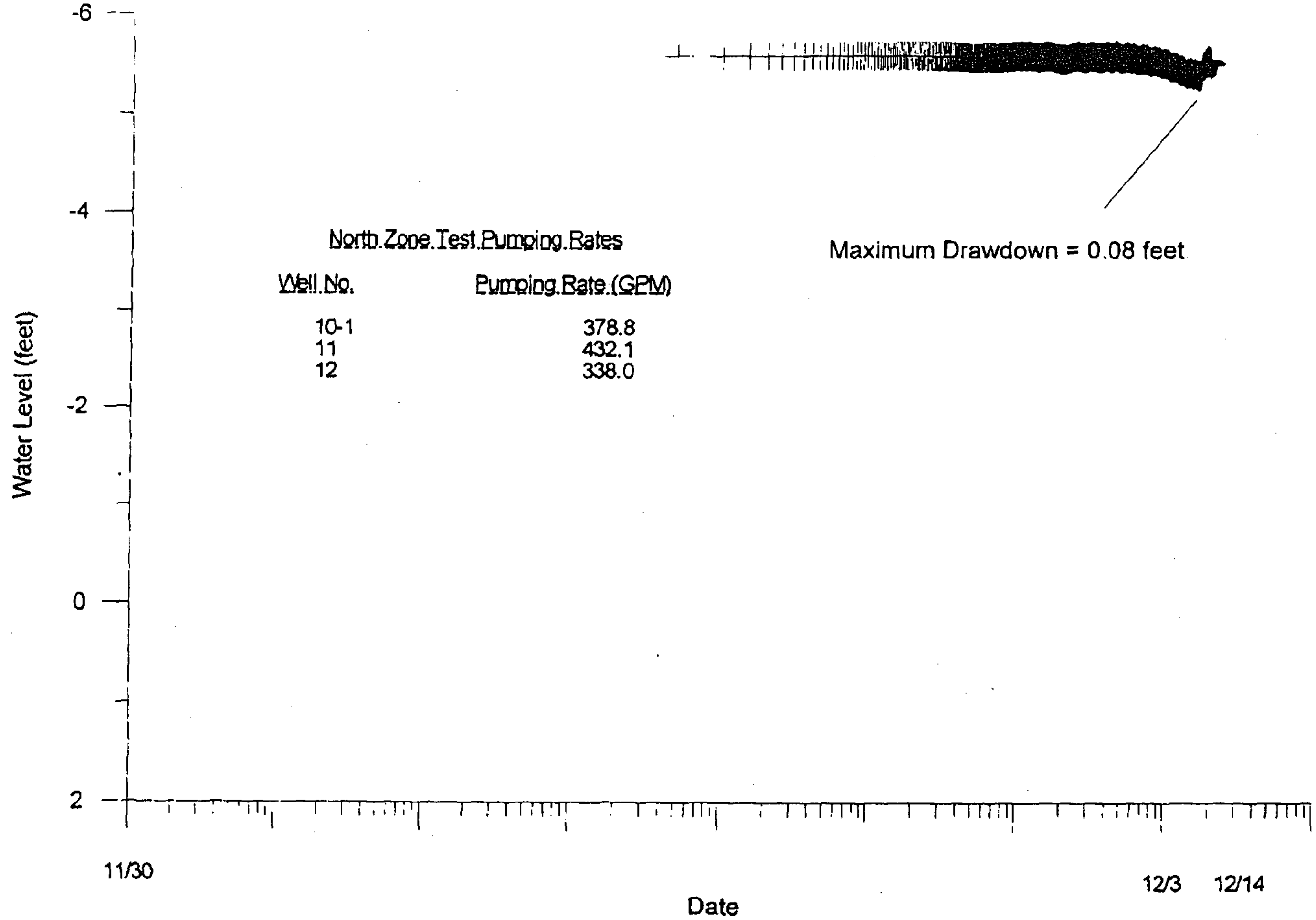
APPENDIX C

Drawdowns measured during stress test at the city of St. Augustine wellfield

Observation Well SJO 314
Adjacent to St. Marks Pond
North Zone Test - Drawdown
(11/30/98 - 12/11/98)

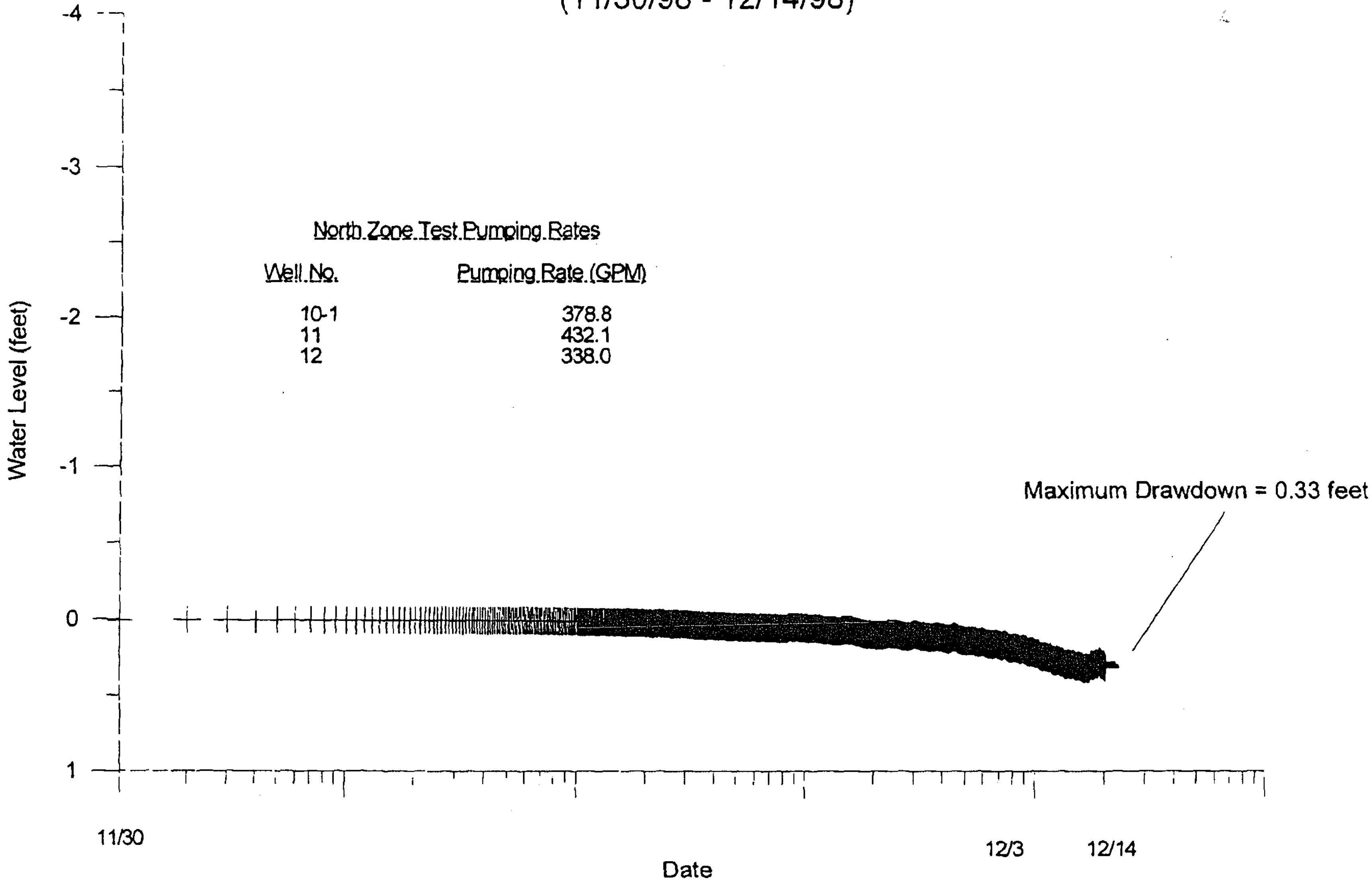


Observation Well OW-1
Adjacent to Production Well #1
North Zone Test - Pumping
(11/30/98 - 12/14/98)

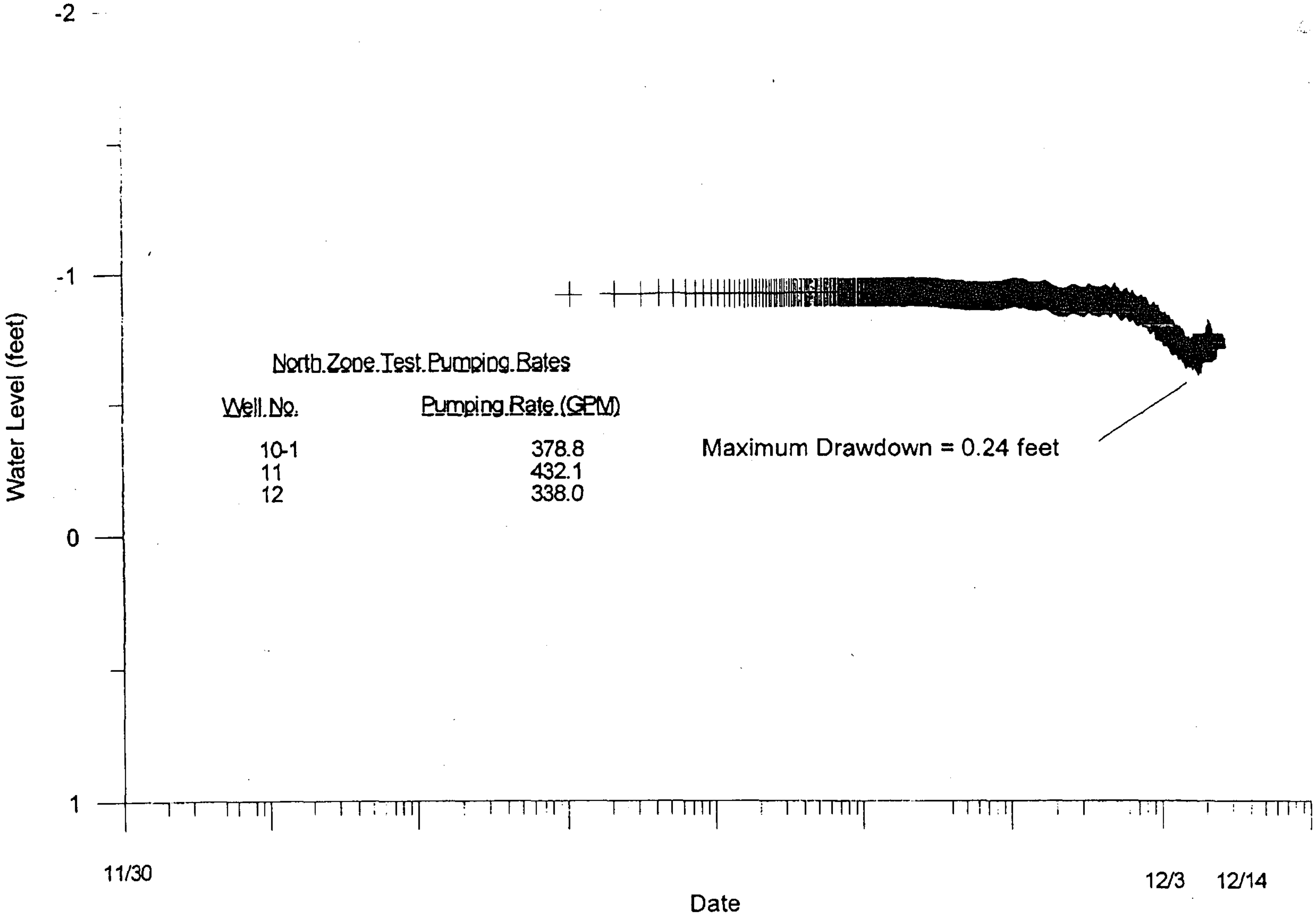


Gary E.Eichler 561-368-1423
Tuesday, March 09, 1999 1:23 PM

Observation Well SJO 292
Adjacent to Production Well #8
North Zone Test - Drawdown
(11/30/98 - 12/14/98)



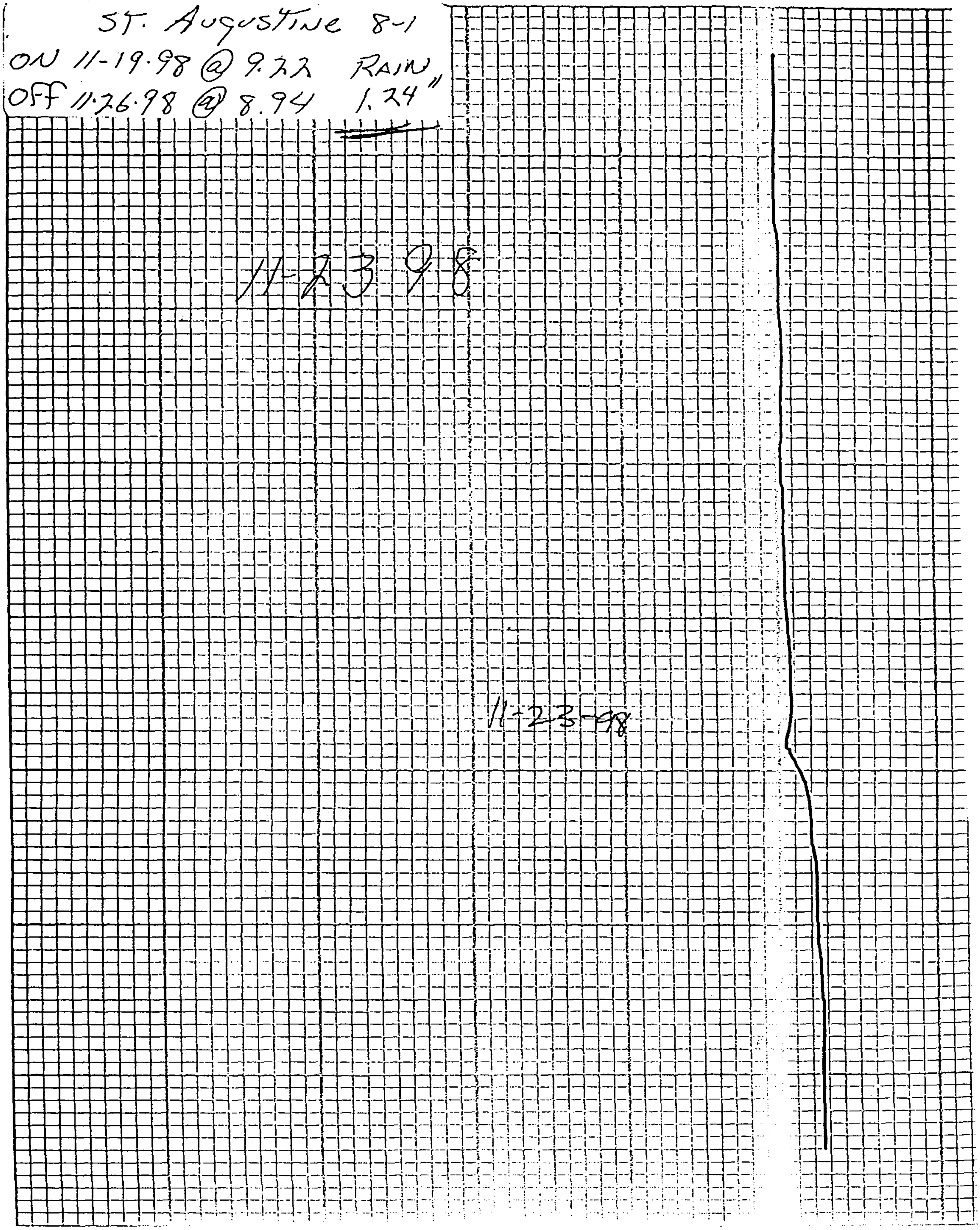
Observation Well OW-11
Adjacent to Production Well #7
North Zone Test - Drawdown
(11/30/98 - 12/14/98)



RAIN 1.24

Leupold & Stevens, Inc., Beaverton, Ore.

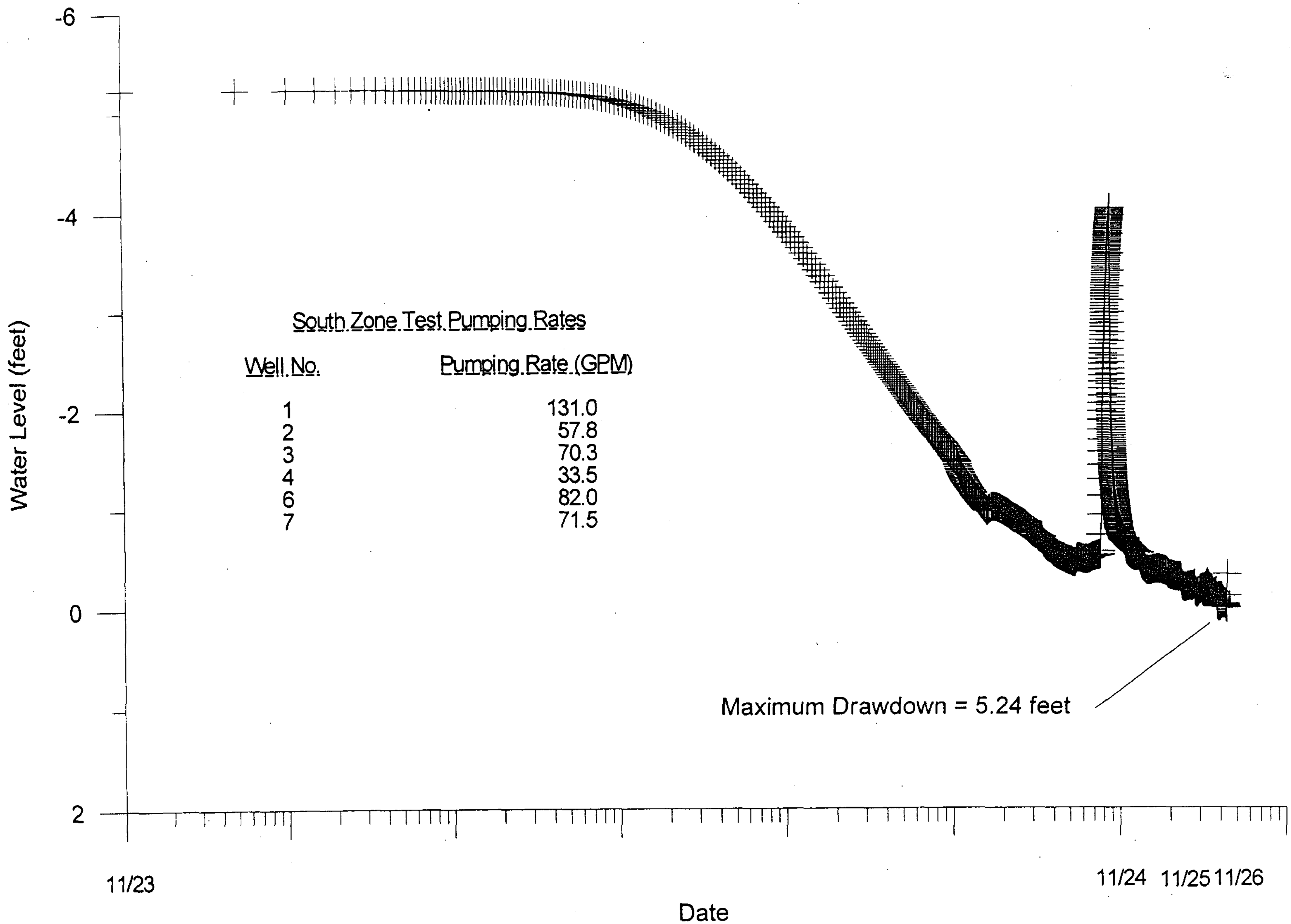
ST. AUGUSTINE 8-1
ON 11-19-98 @ 9.22 RAIN
OFF 11-26-98 @ 8.94 1.24"



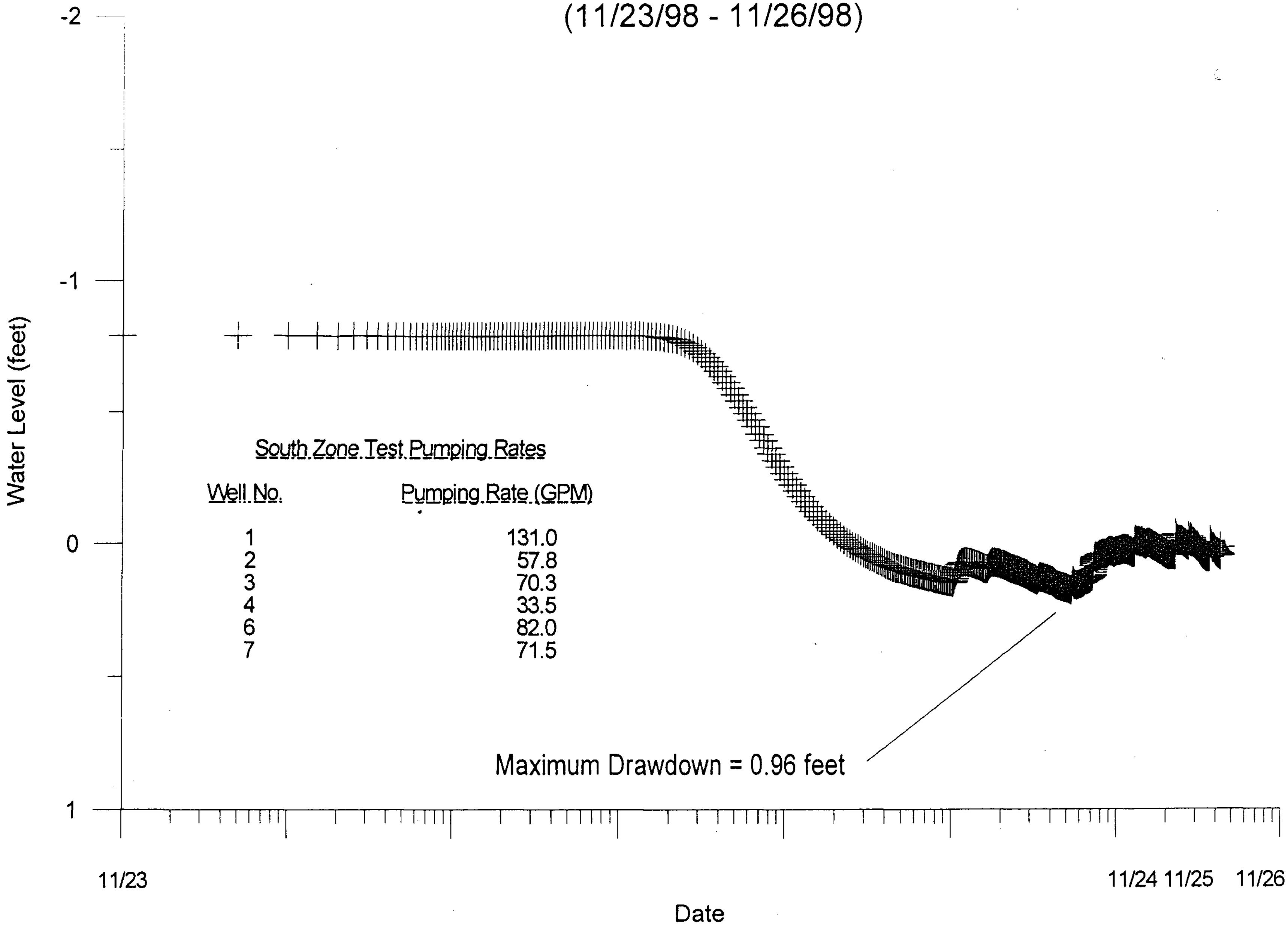
Well testing Time Line

Date	Time	Action
11/20	8 AM	South Wells Off
11/22	9 AM	North Wells Off
11/23	11AM	South Wells On
11/23	12AM	North Wells (11,12) On
11/26	11AM	South Wells Off
11/29	9 AM	North Wells Off
11/30	11AM	North Wells On
12/14	11AM	North Wells Off
12/15	11AM	South Wells On
12/15	11AM	North Wells (10-1,12) On
12/17	9 AM	South Wells Off
12/17	9 AM	North Wells Off
12/17 18?	9 AM	South Wells On
12/18	9 AM	North Wells On
12/18	9 PM	South Wells Off
12/18	9 PM	North Wells Off
12/19	9 AM	South Wells On
12/19	9 AM	North Wells On

Observation Well OW-1
Adjacent to Production Well #1
South Zone Test - Drawdown
(11/23/98 - 11/26/98)

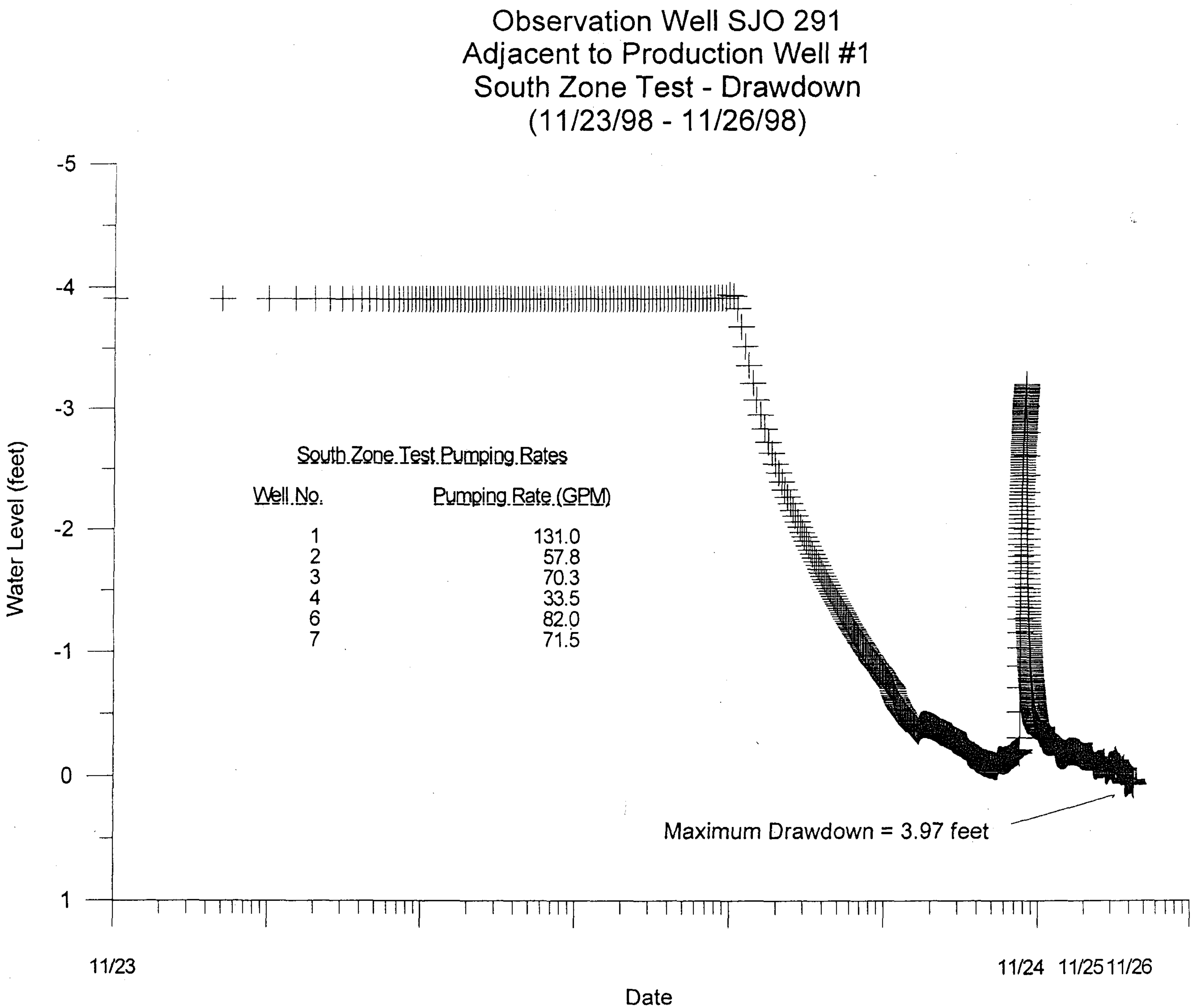


Observation Well OW-11
Adjacent to Production Well #7
South Zone Test - Drawdown
(11/23/98 - 11/26/98)



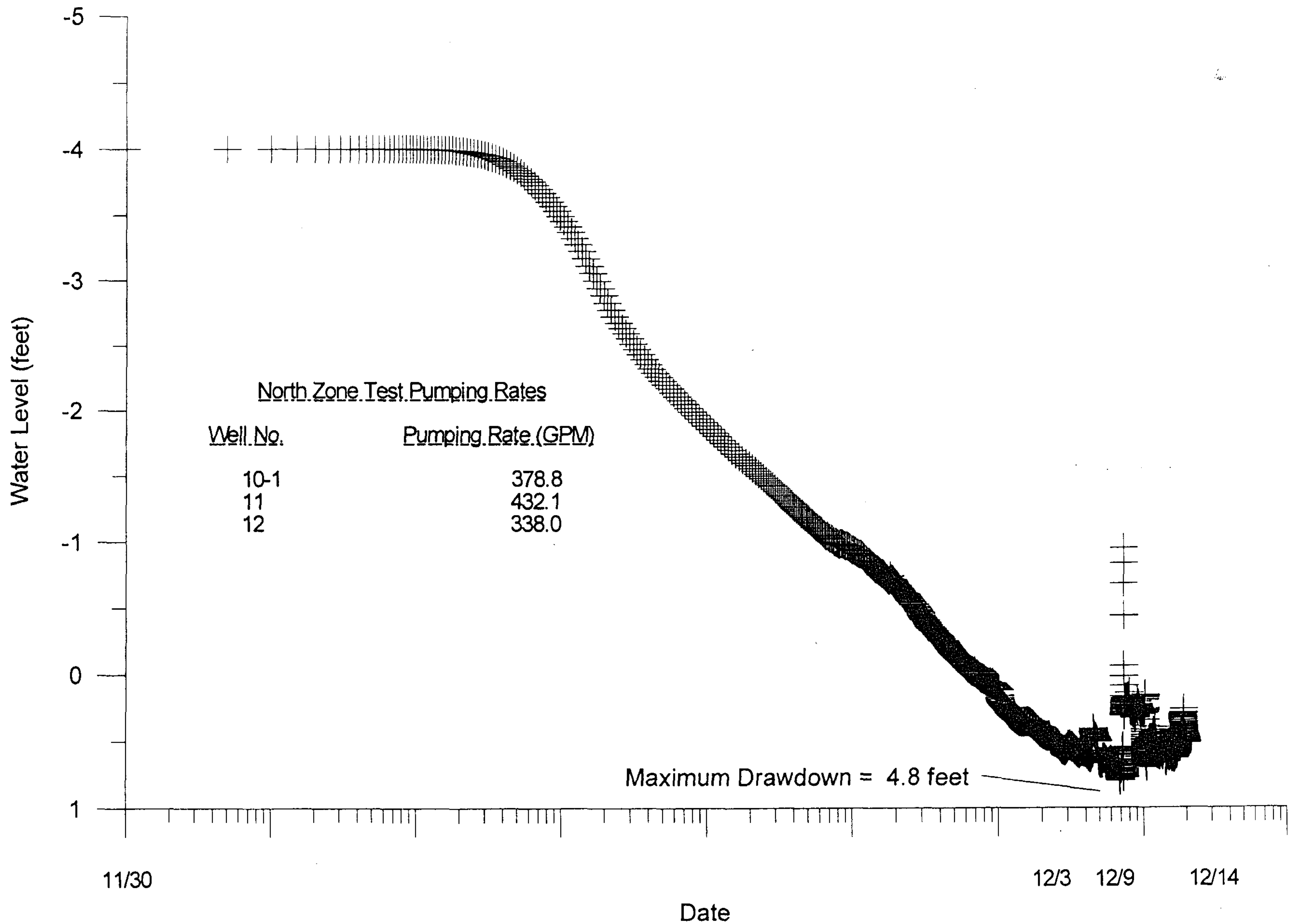
South Zone Test Pumping Rates

Well No.	Pumping Rate (GPM)
1	131.0
2	57.8
3	70.3
4	33.5
6	82.0
7	71.5

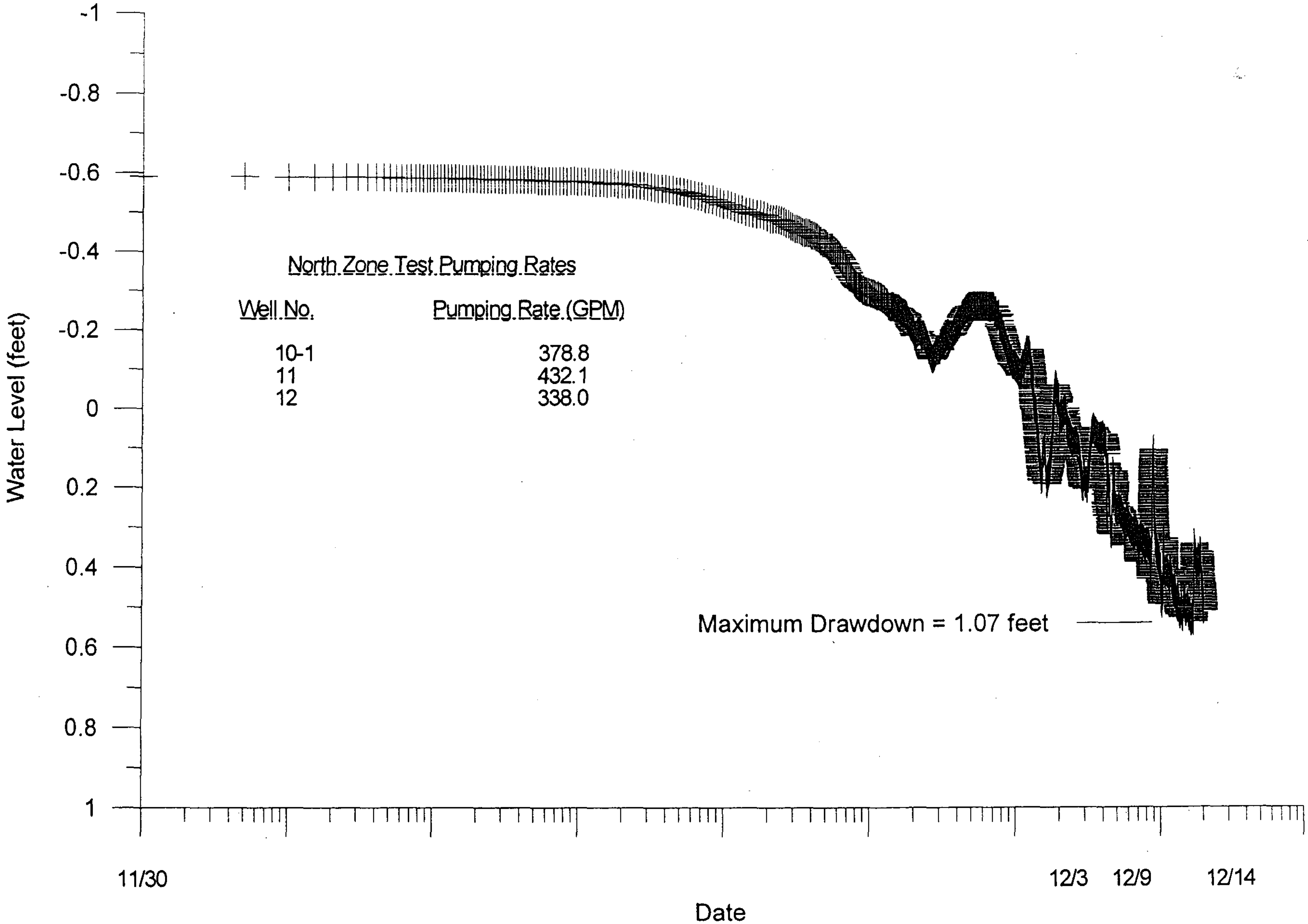


Observation Well SJO 291
Adjacent to Production Well #1
South Zone Test - Drawdown
(11/23/98 - 11/26/98)
Water Level (feet)
-5
-4
-3
-2
-1
0
1
South Zone Test Pumping Rates
Well No.
Pumping Rate (GPM)
1 131.0
2 57.8
3 70.3
4 33.5
6 82.0
7 71.5
Maximum Drawdown = 3.97 feet
11/23
11/24
11/25
11/26
Date

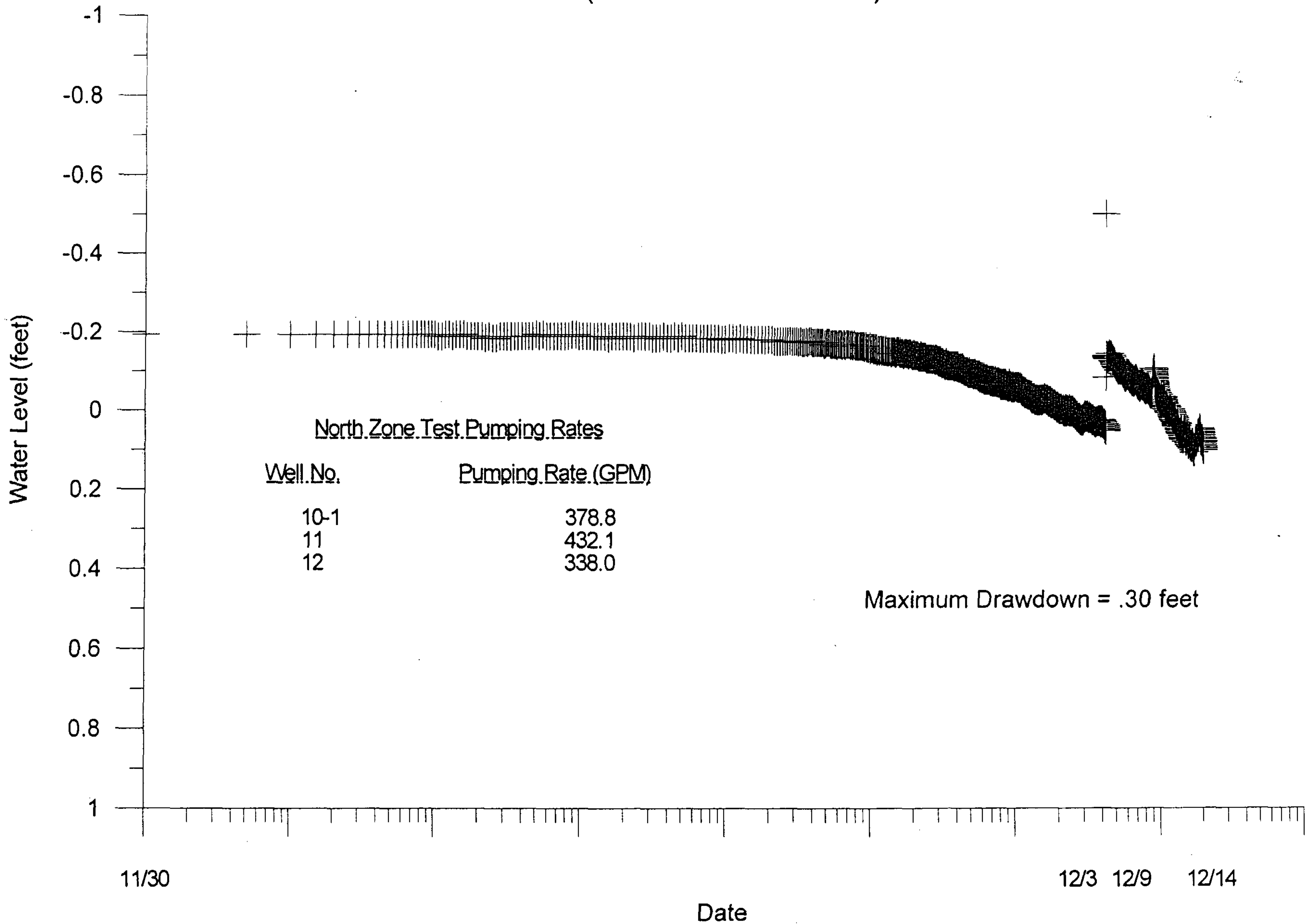
Observation Well SJO 293
Adjacent to Production Well #12
North Zone Test - Drawdown
(11/30/98 - 12/14/98)



Observation Well SJO 311
Adjacent to Production Well #10
North Zone Test - Drawdown
(11/30/98 - 12/14/98)



Observation Well SJO 312
Adjacent to Production Well #10
North Zone Test - Drawdown
(11/30/98 - 12/14/98)



Observation Well SJO 313
Adjacent to Production Well #10
North Zone Test - Drawdown
(11/30/98 - 12/14/98)