Professional Paper SJ94-PP3

REVISED SPRING CONDUCTANCE COEFFICIENTS WEKIVA RIVER BASIN GROUND WATER FLOW MODEL

by

Ching-tzu Huang, Ph.D., P.E.

Professional Engineer
License No. PE 44507
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St. Johns River Water Management District
Palatka, Florida

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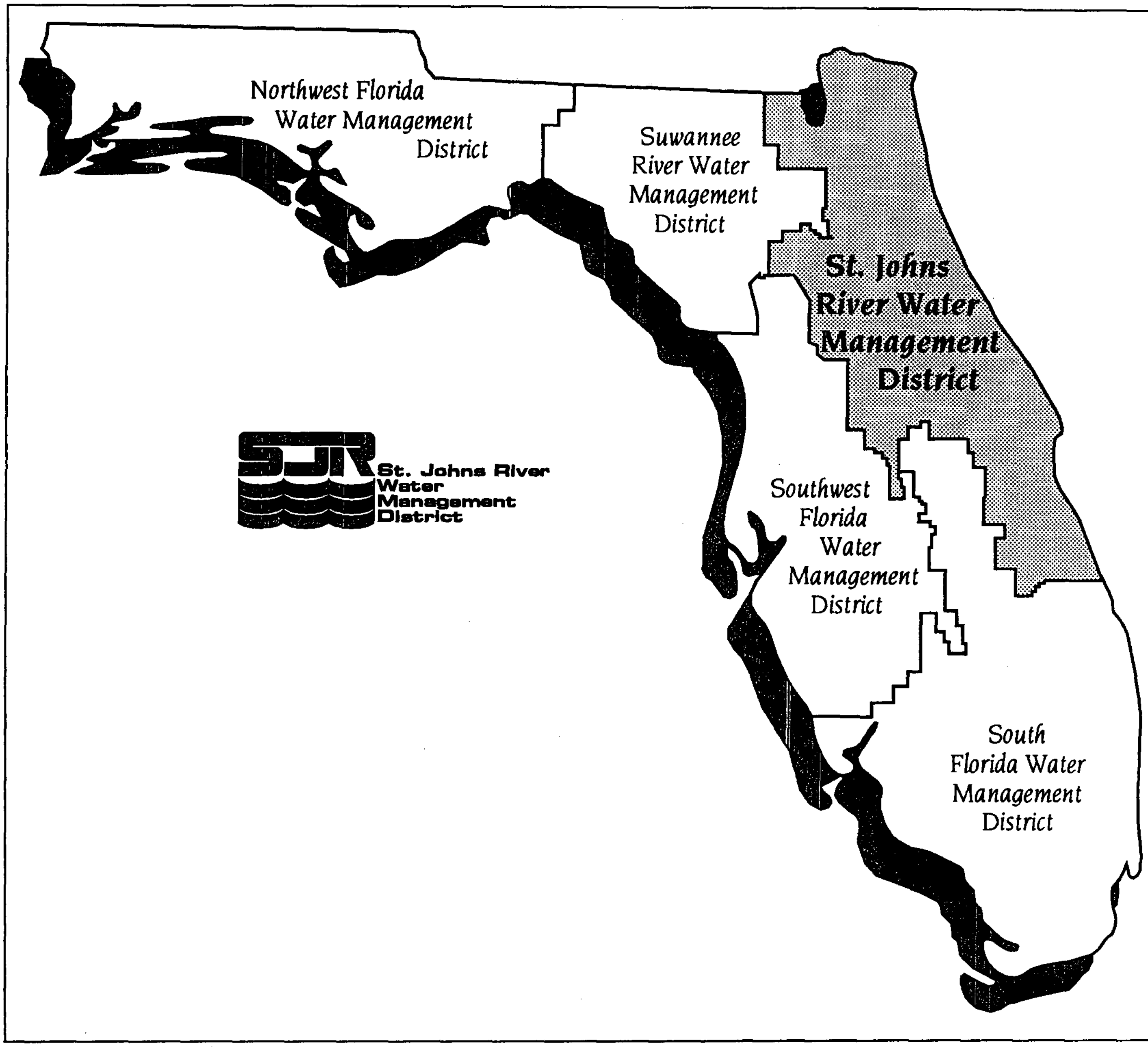

The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued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

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ABSTRACT. The St. Johns River Water Management District (SJRWMD) uses a numerical ground water flow model for the Wekiva River Basin to predict ground water levels and associated spring discharges within the basin. The model utilizes the MODFLOW three-dimensional finite difference code. Because of a change in the requirements of the project for which the model was developed, SJRWMD has revised the spring conductance coefficients in the model to increase the precision with which the model simulates spring discharges. Spring discharge rates are totally dependent on spring conductance coefficients and head differences between the elevations of the potentiometric surface of the Floridan aquifer system and the pool elevations at the spring sites. The spring conductance coefficient is the only hydraulic parameter input into the model to simulate the spring discharge rate. Nine springs contribute about one-half of the base flow into the Wekiva River. The model—using the revised discharge conductance coefficients—simulated 94.2 percent of observed 1988 postdevelopment discharges from these nine springs as compared to 87.5 percent using the unrevised discharge conductance coefficients. The revised spring conductance coefficients provided an improvement in the precision with which the model predicts spring discharges. The predictive capability of the Wekiva River Basin ground water flow model is enhanced by using the revised spring conductance coefficients.

The St. Johns River Water Management District (SJRWMD) uses a numerical ground water flow model for the Wekiva River Basin (GeoTrans 1992) to predict ground water levels and associated spring discharges within the basin (Figure 1). Springs represent the major source of base flow to the Wekiva River. Spring discharges referenced in this paper refer to ground water discharges from areas of diffuse upward leakage and from actual springs. The model was developed for SJRWMD by GeoTrans of Herndon, Virginia. The model is based on the three-dimensional finite difference MODFLOW code (McDonald and Harbaugh 1988) and represents the aquifer systems in a quasi three-dimensional form. The model grid is finest in the area of the springs. The model domain encompasses the entire Wekiva River Basin (Figure 2). The model boundaries were designed to coincide as much as possible with ground water flow boundaries.

Because of a change in the requirements of the project for which the model was developed, SJRWMD has revised the spring conductance coefficients in the model to increase the precision with which the model simulates spring discharges. The description of the methods used to achieve the revisions and the results are presented in this professional paper.

The flow model was calibrated using both predevelopment and postdevelopment hydrologic conditions (GeoTrans 1992). The predevelopment hydrologic condition (Tibbals 1981) was assumed to be the natural ground water flow system with no pumping stress acting on the system. The model first was calibrated by comparing the model-predicted elevations of the potentiometric surface of the Upper Floridan aquifer with a modified predevelopment potentiometric surface map (Tibbals 1981). The effects of pumping then were incorporated into the model, and the model was recalibrated to a postdevelopment average 1988 potentiometric surface of the Upper Florida aquifer within the model domain. GeoTrans (1992) estimated the actual potentiometric surface elevations in each grid cell for May and September 1988 using published U.S. Geological Survey potentiometric maps of the Upper Floridan aquifer

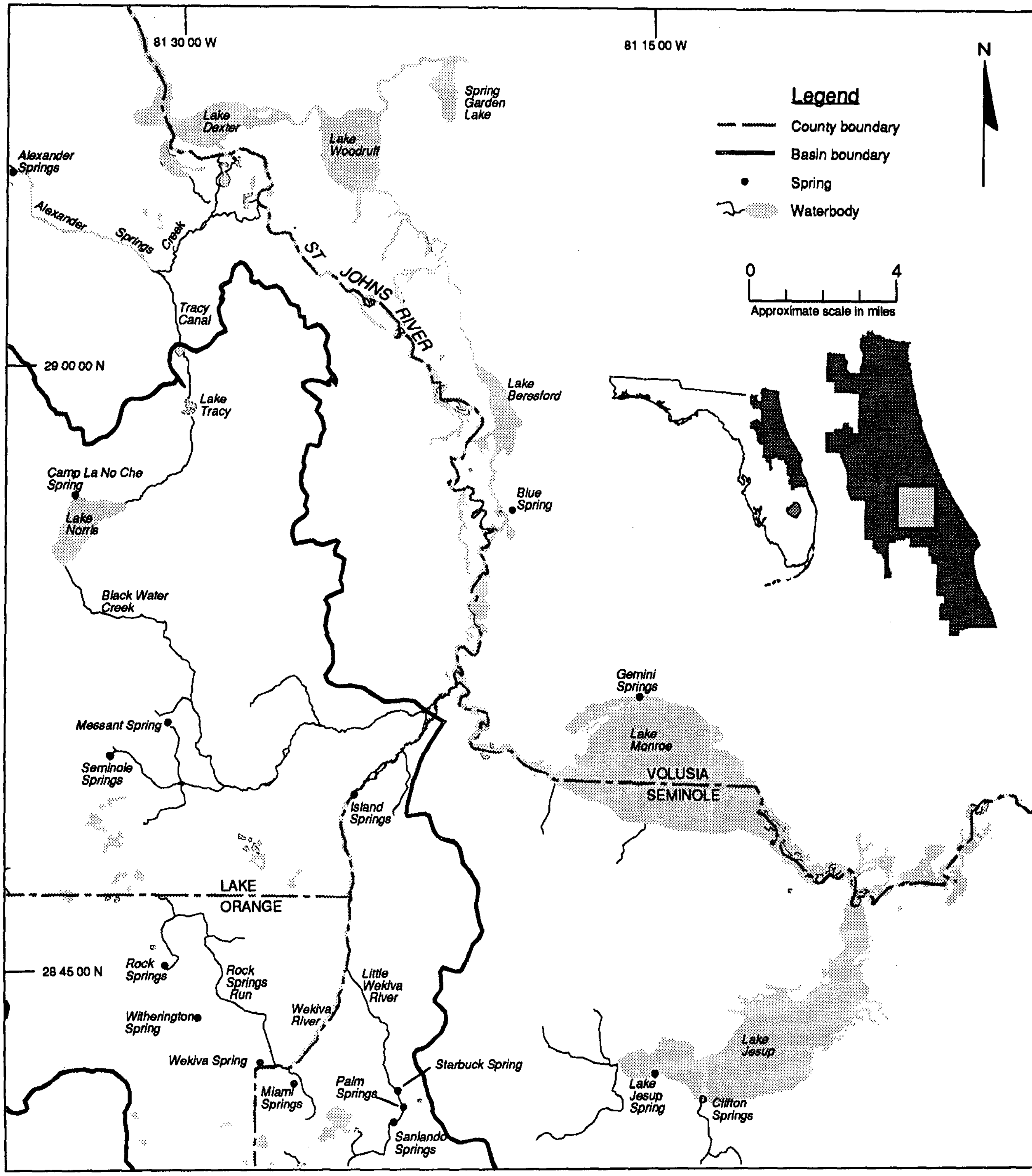


Figure 1. **Wekiva River surface water basin.** *The following waterbodies are not in the surface water basin but are in the ground water flow system: Holiday and Apopka springs west of Messant Spring, Blue Springs (Lake County) southwest of Rock Springs, and Lake Harney east of Lake Monroe on the St. Johns River.*

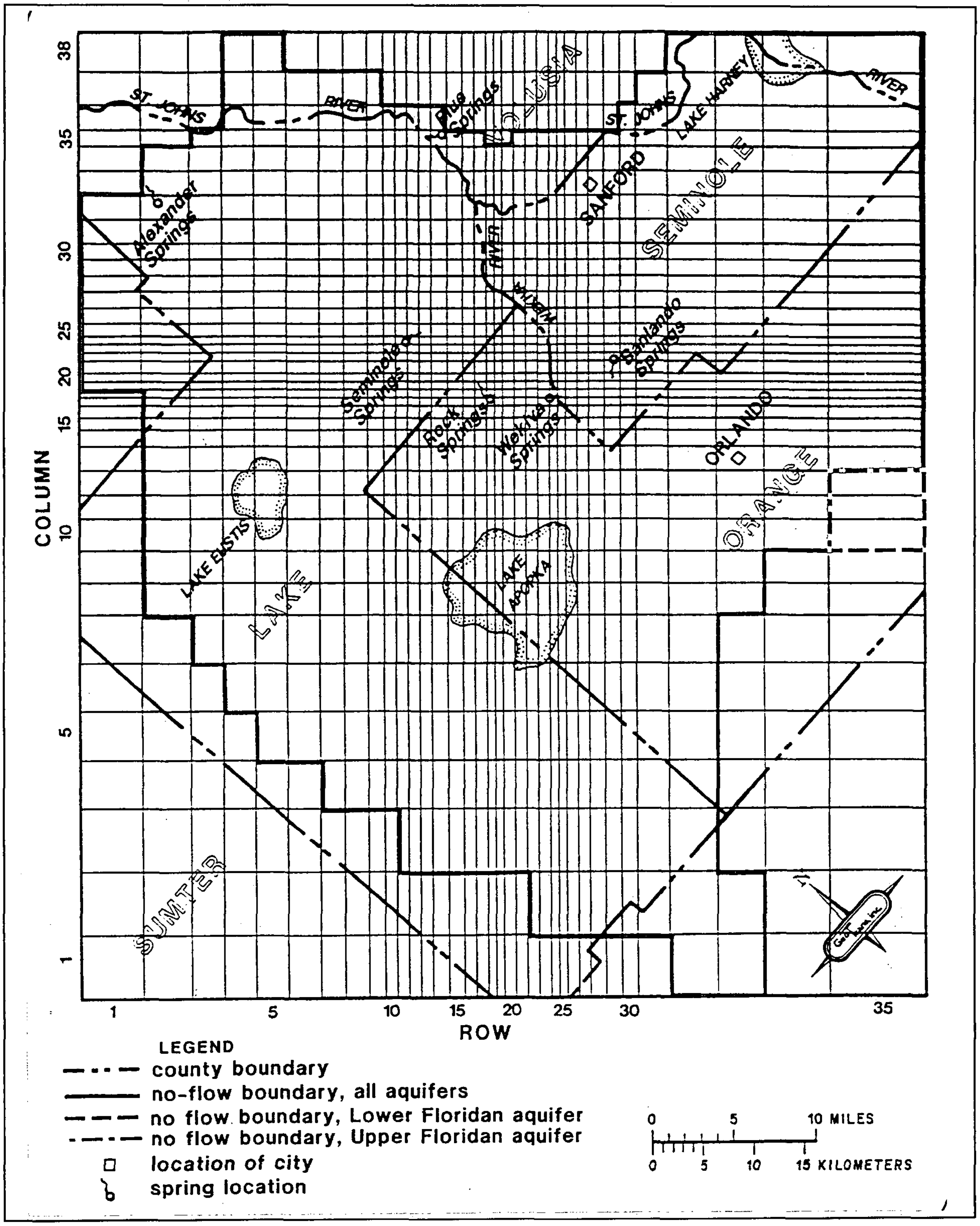


Figure 2. **The Wekiva River Basin model domain (outlined by the no-flow boundaries) used by GeoTrans (1992)**

(Schiner 1988; Rodis 1989). The average May and September potentiometric surface elevations were used to represent a steady-state ground water elevation at each grid cell. These elevations were contoured to represent the average 1988 potentiometric surface map of the Upper Floridan aquifer.

During the model development process, the simulated spring discharges for both the predevelopment and the postdevelopment conditions were compared with measured data (Tables 1 and 2). The simulated predevelopment total spring discharge matched very well (98.9 percent of total observed predevelopment spring discharge) with the total measured spring discharge in the basin (574.2 cubic feet per second [cfs] versus 580.7 cfs) (Table 1). The simulated 1988 postdevelopment total spring discharge compared to the measured spring discharge did not match as well as model results for predevelopment conditions (95.9 percent versus 98.9 percent) especially at Alexander, Apopka, Rock, Sanlando, Palm, and Starbuck springs. These six springs accounted for 52 percent of the total discharge in the basin. The 1988 simulated total spring discharge was 492.3 cfs, or about 318.2 million gallons per day (mgd). The 1988 measured total spring discharge was 513.3 cfs, or 331.7 mgd.

METHODS

Spring discharge rates are totally dependent on spring conductance coefficients and head differences between the elevations of the potentiometric surface of the Floridan aquifer system and the spring pool elevations at the spring sites. Spring pool elevations were measured and used as input in the ground water flow model (Tables 1 and 2). Elevations of the potentiometric surface are model simulated. The head difference between the elevation of the potentiometric surface of the Upper Floridan aquifer and the spring pool elevation was determined by the model. The spring conductance coefficient is the only hydraulic parameter input into the model to simulate the spring discharge rate. The spring conductance coefficient can be expressed as the product of hydraulic conductivity and cross-sectional area of flow divided by the length of the flow path (Equation 1).

$$C = K\left(\frac{A}{L}\right) \qquad (1)$$

where:

C = spring conductance coefficient (square feet per day [ft^2/d])
K = hydraulic conductivity (feet per day)
A = cross-sectional area perpendicular to the direction of flow (square feet)
L = length of the flow path (feet [ft])

Table 1. Observed and simulated spring discharges in the Wekiva River Basin based on predevelopment conditions. *Spring conductance coefficients are unrevised numbers.*

Spring	Spring Number	Pool Elevation (ft msl)	Observed Head (ft msl)	Observed Discharge (cfs)	GeoTrans, Simulated Head (ft msl)	GeoTrans, Simulated Discharge (cfs)	Spring Conductance Coefficient (sfd)
Alexander Creek*	2	5	15.00	30.0	16.71	35.1	2.59e+05
Alexander Springs	1	9	18.00	130.2	17.34	120.7	1.25e+06
Apopka Spring	13	67	77.00	70.5	71.38	65.9	1.30e+06
Blue Spring (Volusia County)	8	1	8.00	40.5	7.32	36.6	5.00e+05
Blue Springs (Lake County)	3	65	73.00	3.0	74.05	3.4	3.24e+04
Camp La No Che Spring	5	34	43.00	1.0	40.37	0.7	9.60e+03
Clifton Springs	19	3	35.00	1.7	34.28	1.7	4.59e+03
Gemini Springs	12	1	13.00	8.0	11.23	6.8	5.76e+04
Holiday Springs	4	65	73.00	3.9	74.91	4.8	4.21e+04
Island Springs**	10	7	15.00	6.0	15.85	6.4	6.93e+04
Lake Harney (North)*	22	2	5.00	10.1	5.83	12.9	2.91e+05
Lake Harney (South)*	23	3	10.00	12.3	12.62	16.9	1.52e+05
Lake Jesup*	20	1	20.00	5.6	22.64	6.4	2.55e+04
Lake Jesup Spring	18	3	35.00	1.0	37.43	1.1	2.70e+03
Messant Spring	7	26	35.00	20.0	33.74	17.2	1.92e+05
Miami Springs	15	15	35.00	5.0	36.63	5.4	2.16e+04
Rock Springs	9	30	35.00	65.0	32.34	60.7	2.24e+06
Sanlando and Palm springs	16	26	32.00	25.7	34.54	36.6	3.70e+05
Seminole Springs (Lake County)	6	32	36.00	38.9	36.00	38.9	8.40e+05
St. Johns River*	21	1	15.00	8.9	13.54	8.0	5.49e+04
Starbuck Spring	17	26	32.00	14.6	32.75	16.4	2.10e+05
Wekiva Spring	14	13	32.00	74.8	30.02	67.0	3.40e+05
Witherington Spring	11	25	40.00	4.0	42.28	4.6	2.30e+04
Total Discharge Rate				580.7		574.2	

Note: ft msl = feet above mean sea level
cfs = cubic feet per second
sfd = square feet per day

*Areas of diffuse upward leakage
***Conductance was corrected to reflect the spring pool elevation of 7 ft msl recommended* by USGS (Louis C. Murray, Jr., pers. com. 1994).

Source: GeoTrans 1992

Table 2. Observed and simulated spring discharges in the Wekiva River Basin based on 1988 postdevelopment conditions. *Spring conductance coefficients are unrevised numbers.*

Spring	Spring Number	Pool Elevation (ft msl)	1988 Observed Discharge (cfs)	GeoTrans, Simulated		Spring Conductance Coefficient (sfd)
				Head (ft msl)	Discharge (cfs)	
Alexander Creek*	2	5	30.0	16.50	34.5	2.59e+05
Alexander Springs	1	9	105.0	17.16	118.1	1.25e+06
Apopka Spring	13	67	64.3	70.01	45.3	1.30e+06
Blue Spring (Volusia County)	8	1	36.0	7.17	35.7	5.00e+05
Blue Springs (Lake County)	3	65		71.65	2.5	3.24e+04
Camp La No Che Spring	5	34	0.6	39.69	0.6	9.60e+03
Clifton Springs	19	3		28.71	1.4	4.59e+03
Gemini Springs	12	1	8.0	10.24	6.2	5.76e+04
Holiday Springs	4	65		72.43	3.6	4.21e+04
Island Springs**	10	7	6.0	13.78	5.4	6.93e+04
Lake Harney (North)*	22	2	10.1	5.42	11.5	2.91e+05
Lake Harney (South)*	23	3	12.3	11.73	15.4	1.52e+05
Lake Jesup*	20	1	5.6	19.63	5.5	2.55e+04
Lake Jesup Spring	18	3		31.06	0.9	2.70e+03
Messant Spring	7	26	14.0	32.90	15.3	1.92e+05
Miami Springs	15	15	5.2	32.43	4.4	2.16e+04
Rock Springs	9	30	57.5	31.92	49.8	2.24e+06
Sanlando and Palm springs†	16	26	40.2	31.82	24.9	3.70e+05
Seminole Springs (Lake County)	6	32	39.0	35.42	33.3	8.40e+05
St. Johns River*	21	1	8.9	12.16	7.1	5.49e+04
Starbuck Spring†	17	26		30.17	10.1	2.10e+05
Wekiva Spring	14	13	66.8	27.48	57.0	3.40e+05
Witherington Spring	11	25	3.8	39.44	3.8	2.30e+04
Total Discharge Rate			513.3		492.3	

Note: ft msl = feet above mean sea level
cfs = cubic feet per second
sfd = square feet per day

*Areas of diffuse upward leakage
**Conductance was corrected to reflect the spring pool elevation of 7 ft msl recommended by USGS (Louis C. Murray, Jr., pers. com. 1994).
†Total observed discharge for Sanlando, Palm, and Starbuck springs is 40.2 cfs.

Source: GeoTrans 1992

The spring conductance coefficient also can be expressed as:

$$C = \frac{Q}{H - H_p} \tag{2}$$

where:

C = spring conductance coefficient (ft^2/d)
Q = spring discharge rate (cubic feet per day)
H = elevation of the potentiometric surface in the Floridan aquifer system (ft)
H_p = spring pool elevation (ft)

Using Equation 2, GeoTrans (1992) calculated the spring conductance coefficients by dividing each spring's predevelopment discharge by the head difference between the spring pool elevation and the estimated head in the Upper Floridan aquifer (Table 1). GeoTrans used these calculated spring conductance coefficients in the 1988 postdevelopment simulation (Table 2).

SJRWMD used a trial-and-error iterative approach to revise the GeoTrans spring conductance coefficients. Without changing the spring pool elevation, revised spring conductance coefficients were used in the ground water flow model to simulate the 1988 postdevelopment conditions. The simulated spring discharge rates at the 23 springs in the basin were determined and then compared to the 1988 observed spring discharge rates. This iterative process was terminated when the percentage of increase of the total simulated spring discharge was less than 0.5 percent of the simulated discharge from the prior iterative step.

RESULTS

Using the revised spring conductance coefficients, the total simulated spring discharge based on 1988 postdevelopment conditions was 502.7 cfs (Table 3), compared to the GeoTrans (1992) figure of 492.3 cfs (Table 4). The difference between the total simulated spring discharges and the total measured spring discharges in the model domain was 6.8 mgd. The GeoTrans figure represents 95.9 percent of the total observed discharge in the Wekiva River Basin. Using the revised spring conductance coefficients, the total simulated discharge in the basin represents 97.9 percent of the observed value. The SJRWMD revised model improved the calculation of the total spring discharge from 318.2 mgd to 324.9 mgd. The simulated discharges were enhanced greatly at the following springs: Alexander, Apopka, Rock, Sanlando, Palm, and Starbuck.

Table 3. Observed and revised simulated spring discharges in the Wekiva River Basin based on 1988 postdevelopment conditions. *Spring conductance coefficients are revised numbers.*

Spring	Spring Number	Pool Elevation (ft msl)	1988 Observed Discharge (cfs)	SJRWMD, Simulated		Revised Spring Conductance Coefficient (sfd)
				Head (ft msl)	Discharge (cfs)	
Alexander Creek*	2	5	30.0	18.73	30.5	1.920e+05
Alexander Springs	1	9	105.0	19.48	109.2	9.000e+05
Apopka Spring	13	67	64.3	68.29	54.5	3.650e+06
Blue Spring (Volusia County)	8	1	36.0	7.12	36.0	5.080e+05
Blue Springs (Lake County)	3	65		71.5	2.4	3.240e+04
Camp La No Che Spring	5	34	0.6	40.04	0.6	9.200e+03
Clifton Springs	19	3		28.48	1.4	4.590e+03
Gemini Springs	12	1	8.0	8.24	7.7	9.200e+04
Holiday Springs	4	65		72.24	3.5	4.210e+04
Island Springs**	10	7	6.0	12.74	5.8	8.17e+04
Lake Harney (North)*	22	2	10.1	6.09	10.3	2.180e+05
Lake Harney (South)*	23	3	12.3	12.79	12.3	1.085e+05
Lake Jesup*	20	1	5.6	19.41	5.5	2.600e+04
Lake Jesup Spring	18	3		30.8	0.9	2.700e+03
Messant Spring	7	26	14.0	32.92	13.8	1.720e+05
Miami Springs	15	15	5.2	30.14	4.9	2.800e+04
Rock Springs	9	30	57.5	31.08	51.0	4.080e+06
Sanlando and Palm springs†	16	26	40.2	29.56	30.7	7.450e+05
Seminole Springs (Lake County)	6	32	39.0	34.45	36.7	1.295e+06
St. Johns River*	21	1	8.9	11.64	8.9	7.200e+04
Starbuck Spring†	17	26		29.14	7.6	2.100e+05
Wekiva Spring	14	13	66.8	24.39	64.9	4.920e+05
Witherington Spring	11	25	3.8	38.23	3.6	2.350e+04
Total Discharge Rate			513.3		502.7	

Note: SJRWMD = St. Johns River Water Management District
ft msl = feet above mean sea level
cfs = cubic feet per second
sfd = square feet per day

*Areas of diffuse upward leakage
**Conductance was corrected to reflect the spring pool elevation of 7 ft msl recommended by USGS (Louis C. Murray, Jr., pers. com. 1994).
†Total observed discharge for Sanlando, Palm, and Starbuck springs is 40.2 cfs.

Table 4. Comparison of observed, GeoTrans simulated, and St. Johns River Water Management simulated spring discharges in the Wekiva River Basin

Spring	1988 Observed Discharge (cfs)	GeoTrans Simulated Discharge (cfs)	SJRWMD Simulated	
			Discharge (cfs)	Percent of Observed Discharge
Alexander Creek*	30.0	34.5	30.5	101.7
Alexander Springs	105.0	118.1	109.2	104.0
Apopka Spring	64.3	45.3	54.5	84.8
Blue Spring (Volusia County)	36.0	35.7	36.0	100.0
Blue Springs (Lake County)		2.5	2.4	
Camp La No Che Spring	0.6	0.6	0.6	100.0
Clifton Springs		1.4	1.4	96.3
Gemini Springs	8.0	6.2	7.7	96.3
Holiday Springs		3.6	3.5	
Island Springs	6.0	5.4	5.8	96.7
Lake Harney (North)*	10.1	11.5	10.3	102.0
Lake Harney (South)*	12.3	15.4	12.3	100.0
Lake Jesup*	5.6	5.5	5.5	98.2
Lake Jesup Spring		0.9	0.9	
Messant Spring	14.0	15.3	13.8	98.6
Miami Springs	5.2	4.4	4.9	94.2
Rock Springs	57.5	49.8	51.0	88.7
Sanlando and Palm springs**	40.2	24.9	30.7	76.4
Seminole Springs (Lake County)	39.0	33.3	36.7	94.1
St. Johns River*	8.9	7.1	8.9	100.0
Starbuck Springs**		10.1	7.6	
Wekiva Spring	66.8	57.0	64.9	97.2
Witherington Spring	3.8	3.8	3.6	94.7
Total Discharge Rate	513.3	492.3	502.7	97.9

Note: SJRWMD = St. Johns River Water Management District
cfs = cubic feet per second

*Areas of diffuse upward leakage
**Total observed discharge for Sanlando, Palm, and Starbuck springs is 40.2 cfs.

DISCUSSION

Nine springs contribute about one-half of the base flow into the Wekiva River (Messant, Seminole, Rock, Wekiva, Miami, Sanlando, Palm, Starbuck, and Island). The base flow supplied by these springs protects instream habitats during low-flow events. Therefore, an analysis was performed to determine the effect of the revised spring conductance coefficients on the simulated discharge rates for these springs located in the Little Wekiva River, Wekiva River, Rock Springs Run, and a tributary to Black Water Creek (Figure 1). The total simulated spring discharge from these nine springs, based on 1988 postdevelopment conditions and unrevised spring conductance coefficients, was 200.2 cfs (Table 2), compared to the total observed spring discharge of 228.7 cfs. The total simulated spring discharge, based on 1988 postdevelopment conditions and revised spring conductance coefficients, was 215.4 cfs (Table 3), compared to the total observed spring discharge of 228.7 cfs (Table 2). The GeoTrans (1992) figure represents about 87.5 percent of the total observed discharge for these springs. Using the revised spring conductance coefficients, the total simulated discharge for these springs represents about 94.2 percent of the observed value.

An analysis was performed to determine the effect of the revised spring conductance coefficients on the potentiometric head distribution of the Upper Floridan aquifer in the model domain. The potentiometric head for 1988 postdevelopment conditions was contoured using unrevised spring conductance coefficients (Figure 3) and using revised spring conductance coefficients (Figure 4). A comparison of the contour plots (Figure 5) indicates that there is little potentiometric head difference in the model domain except in the areas near Wekiva, Miami, Sanlando, Starbuck, and Lake Jesup springs (spring numbers 14–18). The maximum head difference in the vicinity of two springs, Miami and Sanlando (spring numbers 15 and 16), is approximately 3 ft.

CONCLUSIONS

The revised spring conductance coefficients provided an improvement in the precision with which the model predicts spring discharges. The predictive capability of the Wekiva River Basin ground water flow model is enhanced by using the revised spring conductance coefficients. Using the revised values, the model simulates between 94.2 and 97.9 percent of observed 1988 (postdevelopment) spring discharges, compared to 87.5 and 95.9 percent using the unrevised spring conductance coefficients. The potentiometric head difference for 1988 postdevelopment conditions using the unrevised and revised spring conductance coefficients indicated that the revised spring conductance coefficients did not alter the potentiometric head contour distribution in the model area except in the close vicinity of several springs.

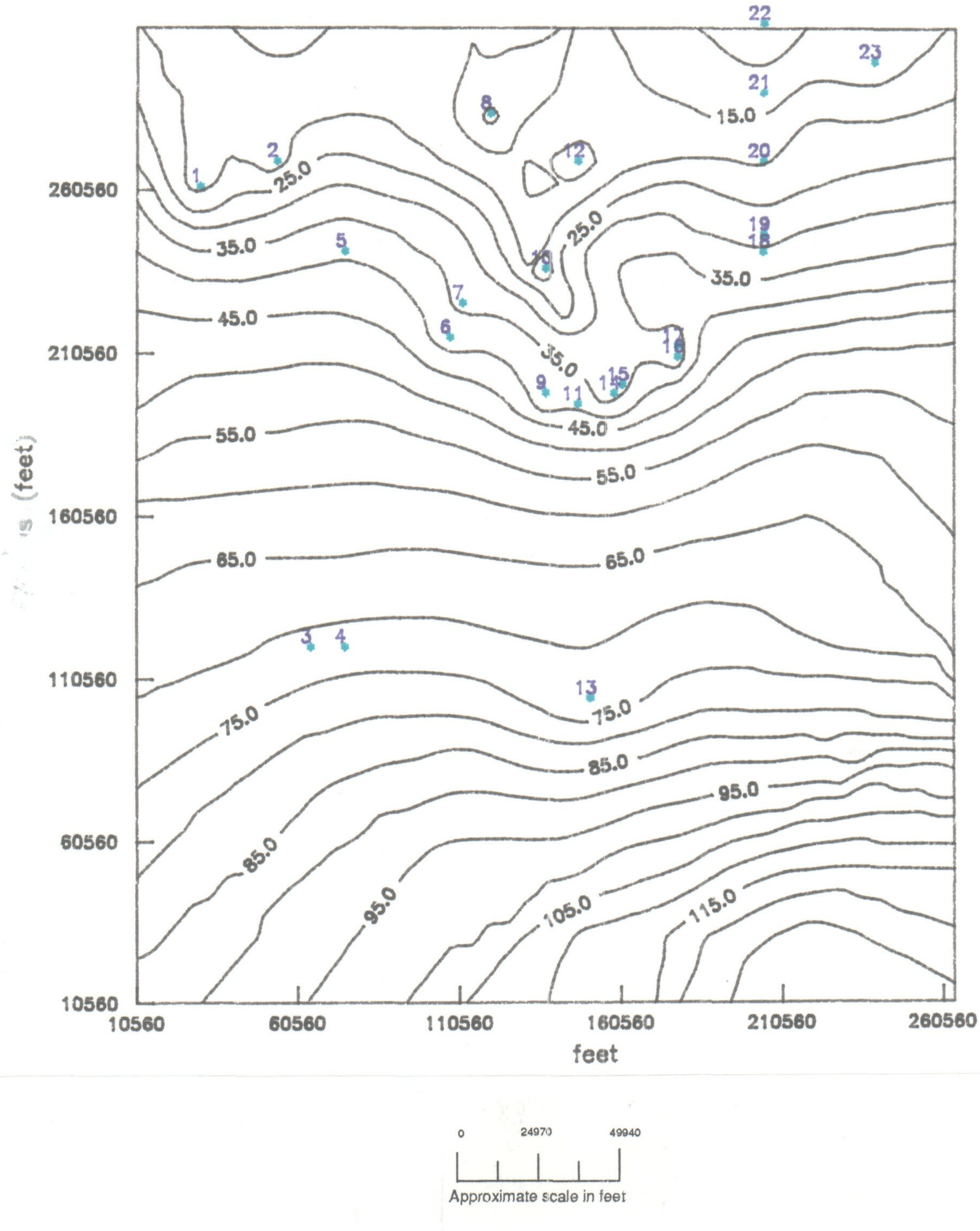


Figure 3. Upper Floridan aquifer contours for the Wekiva River Basin based on 1988 postdevelopment conditions and unrevised spring conductance coefficients

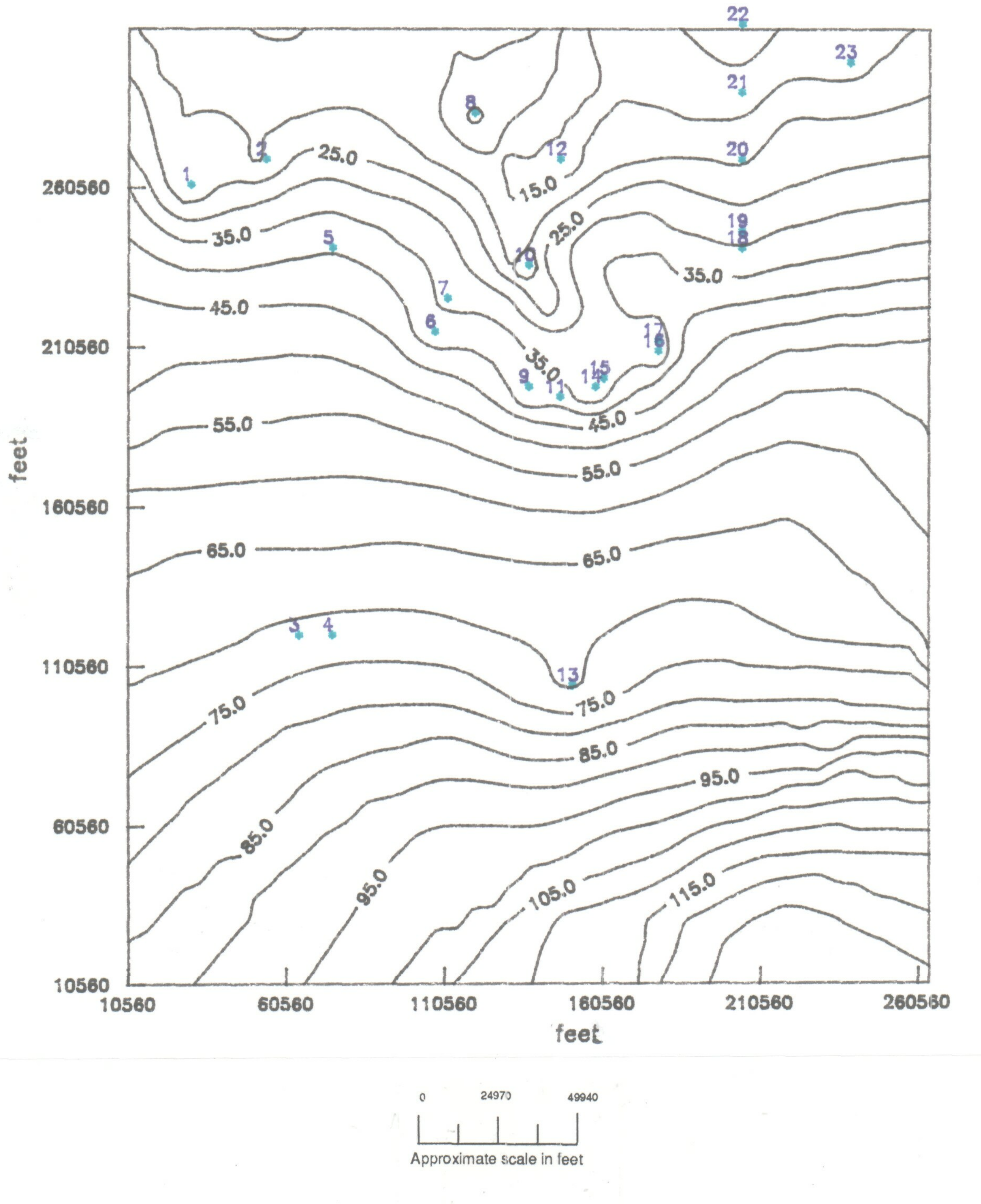
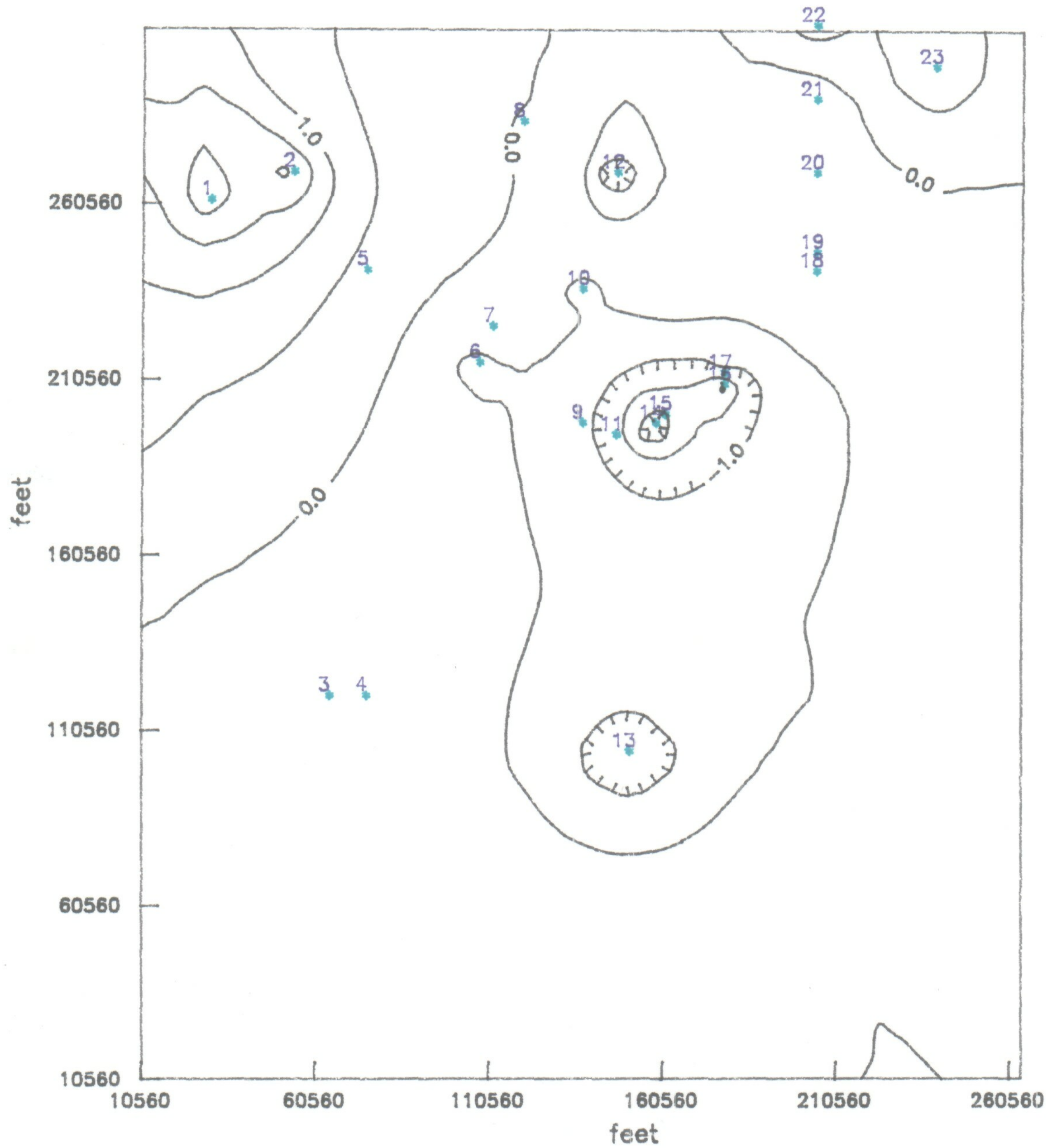


Figure 4. **Upper Floridan aquifer contours for the Wekiva River Basin based on 1988 postdevelopment conditions and revised spring conductance coefficients**



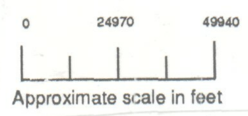


Figure 5. **Potentiometric head difference between unrevised and revised spring conductance coefficients in the Wekiva River Basin**

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CONVERSION TABLE

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