GROUND-WATER RESOURCES OF DARLINGTON, DILLON, FLORENCE, MARION, AND MARLBORO COUNTIES, SOUTH CAROLINA

WITH AN ANALYSIS OF MANAGEMENT ALTERNATIVES FOR THE CITY OF FLORENCE

STATE OF SOUTH CAROLINA
DEPARTMENT OF NATURAL RESOURCES

WATER RESOURCES DIVISION
REPORT 1

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By

J. Alberto Rodriguez, Roy Newcome, Jr., and Andrew Wachob

Including
Lithologic Descriptions of Cored Boreholes at Lake Darpo and Lake City and Tabulation of Selected Chemical Analyses of Ground Water
by

W. Fred Falls
U.S. Geological Survey

Second Printing, October 1997

STATE OF SOUTH CAROLINA
DEPARTMENT OF NATURAL RESOURCES

WATER RESOURCES DIVISION
REPORT 1

1994

State of South Carolina

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ACKNOWLEDGMENTS

The authors extend their appreciation to all the individuals who contributed to the completion of this project. In particular, gratitude is due Bobby Holland, Public Works Director, City of Florence; Marty Lawing, Administrator, City of Bennettsville; Pete Rogers, Executive Director, Marion County Development Board; Pat Kelly and Don Clark, former and present executive directors of the Darlington County Development Board; and Will Arnette, Manager, Trico Water Company. Special thanks are extended to Forest M. Whittington, City Engineer, City of Florence, and Larry Green, Manager, Water and Wastewater Division, City of Florence, for their valuable suggestions and the information they provided.

The authors are also grateful to Bruce G. Campbell, Glen G. Patterson, and Marge Davenport, U.S. Geological Survey, for their assistance in the application of the three-dimensional ground-water flow model.

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ABSTRACT

Long-term pumping has caused a 200-foot lowering of ground-water levels at the city of Florence and lesser amounts throughout much of the five-county surrounding area. About 40 million gallons of water per day were withdrawn from wells in the region in 1992, about 20 percent of this at Florence.

Major wells tapping confined aquifers in the five counties yield between 100 and 2,400 gallons per minute. Wells range in depth from less than 100 to nearly 1,000 feet, and some of them tap aquifers in both the Middendorf and Black Creek Formations. The freshwater-bearing Upper Cretaceous section extends to about sea level at the north end of Marlboro County, to 500 feet below sea level at Florence and Dillon, and to 1,000 feet below sea level at the south end of the region.

The large water-level decline at Florence has taken place since 1900, as a result of pumping from the Middendorf Formation. Effects of pumping from the Black Creek Formation have been minor in comparison.

Pumping tests indicate a median transmissivity of 19,000 gallons per day per foot for the Middendorf aquifers and 13,000 for the Black Creek. These values are close to the medians determined for the two formations in the Coastal Plain as a whole.

If pumping from wells is to continue as the source of water supplies, a plan should be formulated to distribute withdrawals areally and among the aquifers. An effective plan will moderate drawdown of the potentiometric surface of the Middendorf Formation and direct additional development of the Black Creek Formation.

A finite-difference computer model has been utilized to ascertain the effects of selected pumpage increases on water levels in Darlington, Dillon, Florence, Marion, and Marlboro Counties. The model simulated aquifer response to hypothetical pumping from wells in Darlington, Dillon, Florence, Marion, and Marlboro Counties from 1989 through 2003. The simulations indicate that the Black Creek and Middendorf aquifers are capable of sustaining long-term pumping at 1992 rates with little change in potentiometric levels. The only significant influence on the Black Creek aquifers is the city of Marion pumping, which is predicted to cause more than 20 feet of localized water level declines from 1993 through 2003. In that period--if the city of Florence maintains its reported 1992 pumping rate--annual pumping increases in the five-county region will cause a 10-foot lowering of the Middendorf's potentiometric surface in much of this study area, with localized declines of 15 to 25 feet near Hartsville, Dillon, Timmonsville, Lake City, and Marion. In Marlboro County, the Middendorf aquifers will not be significantly affected. If, however, the city of Florence increases its pumpage by 3 percent annually during that period, the Middendorf's potentiometric surface will undergo 60 feet of decline at Florence and 20 feet or more throughout much of Darlington, Florence, Dillon, and Marion Counties.

A ground-water management modeling program based on simulation and optimization techniques was developed to investigate mangement alternatives for the city of Florence well system. The model simulates a management framework in which pumping is restricted by a specified total available drawdown. Three management alternatives were evaluated: (1) redistributing pumpage, (2) increasing total available drawdown, and (3) adding new wells to the system. Although some improvments were achieved, none of these alternatives provided sufficient ground water to satisfy the demand for the next 10 years while maintaining potentiometric levels at acceptable elevations.

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

The ground-water resources of five counties that constitute the major part of the Pee Dee Region in South Carolina were studied in a cooperative project by the South Carolina Water Resources Commission and the U.S. Geological Survey. These counties, Darlington, Dillon, Florence, Marion, and Marlboro, (Fig. 1) are in one of the principal agricultural areas of the State. Part of the financing of the project was provided by the cities of Florence, Bennettsville, Marion, Dillon, and Mullins; the counties of Darlington and Dillon; and Marco and Trico Rural Water Companies.

A preliminary report (Curley, 1990) provided a description of the geologic framework, historical ground-water levels, chemical quality of the ground water, and hydraulic properties of the aquifers. Included also was a geologic description of the materials penetrated in a 716-foot test hole at Florence. It is a comprehensive report and serves as the principal reference for this final report of the project.

The report that follows has a two-fold purpose: (1) the analysis of the effects of continuing pumping in the five counties of the study area and (2) the description of computer simulations of ground-water management alternatives for the city of Florence,

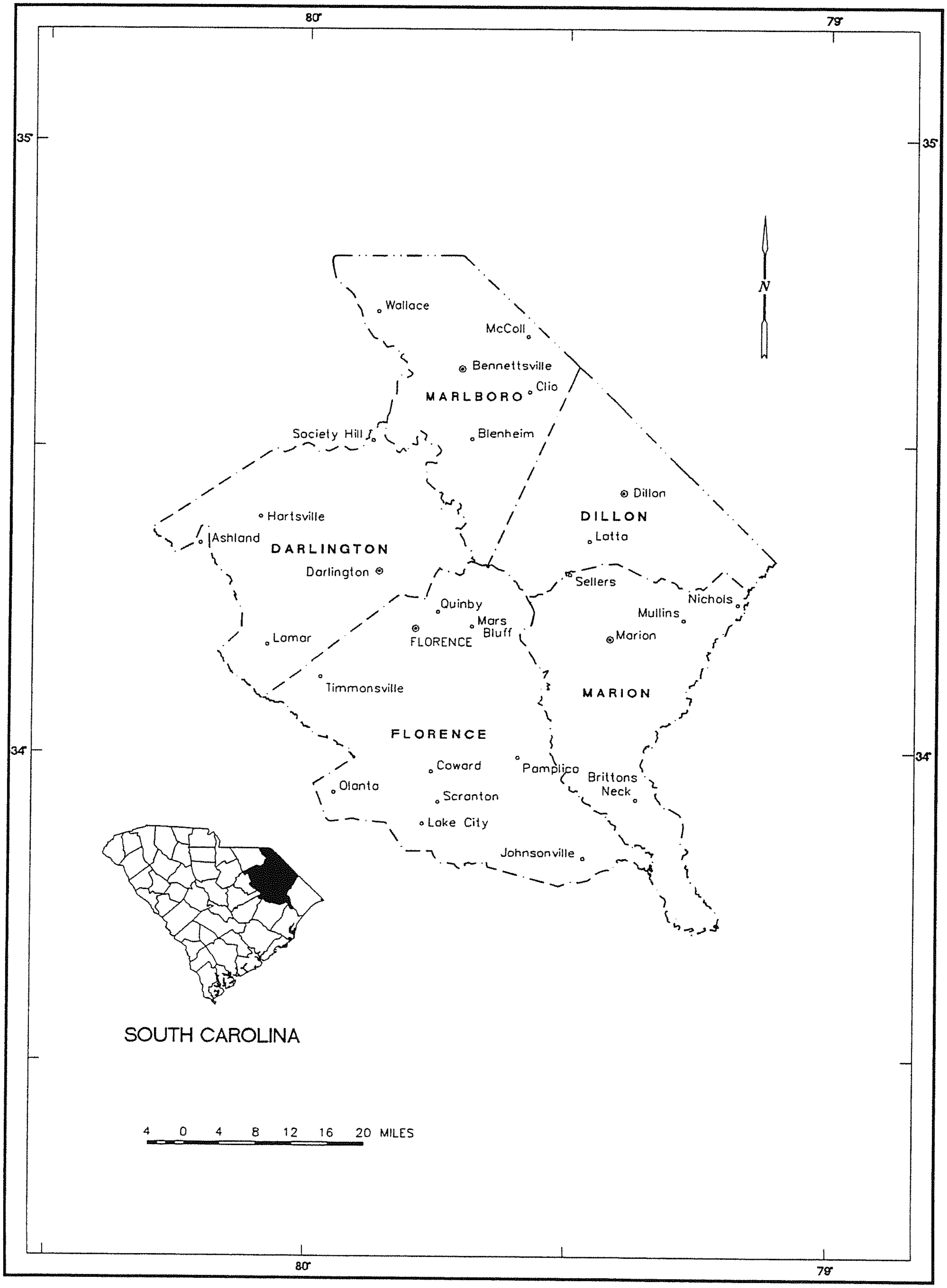

Figure 1. Location of the project area in South Carolina.

where large water-level declines have occurred. The analysis for the five counties outside the city of Florence employed a quasi-three-dimensional ground-water flow model developed in a joint effort under the leadership of Bruce G. Campbell and Marijke van Heeswijk of the U.S. Geological Survey and described in a U.S. Geological Survey report currently in preparation.

The simulations of management alternatives at Florence were carried out with a high-resolution two-dimensional model developed by the Water Resources Commission, using information derived from the U.S. Geological Survey model.

The scope of the following report entails a summarization of the findings and conclusions presented in the preliminary report; additional data obtained from test drilling, aquifer testing, water-level monitoring, and water-quality analysis; and the results of the computer simulations.

WATER USE

The average daily pumpage and population served by the 10 largest municipal water supplies in the project area in 1992 were as follows:

Municipality	Population served	Pumpage (million gallons per day)	Daily per capita usage (gallons)
Florence	58,000	7.78	134
Marion	9,014	2.24	249
Bennettsville	12,172	[a]1.72	141
Lake City	8,034	1.22	152
Darlington	8,500	1.12	132
Dillon	9,095	1.12	123
Hartsville	11,179	1.08	97
Mullins	7,000	.90	129
Timmonsville	2,895	.37	128
Johnsonville	3,167	.43	136
	Total 129,056		Average 142

[a]Includes 0.8 mgd from a surface-water source.

The city of Florence has the State's tenth largest public water supply and the second largest using only ground water. Two rural water systems provide water in Darlington and Marion Counties. The Darlington County Water and Sewer Authority pumped an average of 3.18 mgd in 1992, and the Marco Rural Water Company pumped 1.22 mgd.

Average daily ground-water usage in 1992, by county and type of use, is given in the table below. Use is in millions of gallons per day.

Use type	Darlington County	Dillon County	Florence County	Marion County	Marlboro County	Total
Aquaculture	0	0.08	0	0.15	0	0.22
Golf Course	.01	0	0	0	0	0.01
Industrial	3.22	.98	2.52	0	.73	7.46
Irrigation[a]	.10	.06	.07	0	.68	.92
Nuclear Power	1.16	0	0	0	0	1.16
Public Supply	5.37	1.92	10.40	4.36	1.22	23.27
Rural[b]	2.13	.47	2.51	.99	.37	6.46
Total	12.00	3.50	15.50	5.50	3.00	39.50

[a] Irrigation use calculated on 365-day basis, although its actual use is over a few summer months.
[b] Estimated rural domestic and stock use.

It is apparent from the foregoing that Florence County, with the city of Florence in particular, is far and away the largest user of ground water in the project area. The county's usage was reported to be about 12 mgd in 1975 (Park, 1980). It had increased only a little by 1983 (Harrigan, 1985), but by 1992 it was up to about 15 mgd.

In 1992, about 70 percent of the total usage was in Florence and Darlington Counties. Public-supply and rural use accounted for 75 percent of the water pumped.

GROUND-WATER OCCURRENCE AND AVAILABILITY

AQUIFERS

Nearly all public supply, industrial, and irrigation wells in the five-county area produce water from aquifers in the Black Creek or Middendorf/Cape Fear Formations, some from combinations of these units. These formations consist primarily of alternating sand and clay beds and are of late Cretaceous age. Their lithology was well described by Curley in the preliminary report for this project.

The Middendorf Formation alone and the Middendorf/Cape Fear together are the principal sources for major wells in Darlington and Marlboro Counties. Most Florence County supplies are obtained from the Black Creek Formation, although the largest user, the city of Florence, obtains nearly all of its water from the Middendorf and Cape Fear Formations. Table 1 provides a description of major public water supplies in the region. Dillon County taps the Black Creek and Middendorf or combinations of the two, and Marion County taps mainly the Black Creek aquifers. In this discussion the Middendorf and Cape Fear are considered together because (1) there are practically no wells completed in the Cape Fear alone and (2) where wells are completed in both units it is not known what portion of the yield is from Cape Fear aquifers. Some wells also are completed in aquifers of both the Black Creek and Middendorf Formations.

It should be pointed out here that the unit labeled Cape Fear in Curley's report and the report by Aucott and others (1987) was included in the Middendorf by Park (1980), Colquhoun and others (1983), and Newcome (1989 and 1993).

WELL YIELDS

Of 129 major wells (yield 100 gallons per minute or more), 93 tap the Middendorf Formation alone or the Middendorf together with other units. The range of yields and median yields of these wells are illustrated by Figure 2.

Well yields are only a general indication of an aquifer's capacity to furnish water, because the yields are subject to well design, well efficiency, and pump setting, in addition to aquifer properties.

BASE OF FRESHWATER

On the basis of studies of electric logs and water samples, it appears that freshwater (total mineralization less than 1,000 milligrams per liter) can be found as deep as the base of Cretaceous sediments (top of Paleozoic rocks) throughout the northern half of the five-county area. The base-of-freshwater map in Figure 3 is presented to illustrate the deepest drilling necessary to penetrate the entire freshwater section. It is quite possible that there is some freshwater in the Paleozoic rocks where no saline water occurs in the overlying material, but the amounts available are almost certain to be very small. A U.S. Geological Survey test well near Brittons Neck (Reid and others, 1986) penetrated the deepest freshwater aquifer at a depth of 775 feet (745 feet below sea level), 400 feet above the base of the Cretaceous sediments. Proceeding toward the coast, the base of freshwater rises until it is in the upper part of the Cretaceous sediments (Black Creek Formation).

Because the base of freshwater is within or at the base of the Middendorf Formation throughout the area of this project, a contour map on the top of the Middendorf (Fig. 4) can be used, in conjunction with Figure 3, to estimate the thickness of freshwater-bearing material in the formation. This thickness is about 200 feet at the north and south ends of the project area, but it is 400-500 feet in much of the central part.

WATER LEVELS

MONITOR WELLS

Curley presented hydrographs of four monitor wells in the study area. Three wells are screened in the Black Creek Formation and one in the Middendorf. Curley's hydrograph for 18N-il (FLO-85) is shown as Middendorf but is for the Black Creek. Water-level records have been obtained since 1981-82, and Curley's hydrographs went to late 1988. The extended hydrographs, to 1993, are shown in Figure 5.

The common causes of change in water-level trends are (1) variation in pumping as a result of wet and dry periods, (2) redistribution of pumping, and (3) long-term increase or decrease in ground-water withdrawal.

All of the monitor wells show response to seasonal water use. Water levels almost always are highest early in the year, following and during seasons of high rainfall and low water use, and lowest late in the year, following the low-rainfall, high-temperature period when water use is greatest.

Other than the seasonal effects just described, three of the monitor wells show little net change in the period of record. The fourth, 10Q-p1 (MRN-77) near Brittons Neck, has continued an almost continuous downward trend throughout its period of record. The water level is declining at a rate of 2 feet per year in response to pumping from Black Creek aquifers at Johnsonville, 7 miles to the west-southwest in Florence County. Reduction of pumping at Conway (Horry County) in 1992 apparently had little or no recovery effect on MRN-77.

POTENTIOMETRIC CONDITIONS

Aucott and Speiran (1985) presented potentiometric maps of the Middendorf and Black Creek Formations in South Carolina's Coastal Plain as of 1982 and potentiometric decline maps for the entire period of water-supply development as of 1982. These helpful maps show cones of depression in the Middendorf potentiometric surface at Florence, just north of Dillon, and at Marion. The decline, to 1982, was 150 feet at Florence, 25 feet near Dillon, and 50 feet at Marion. By 1992 the decline at Florence was another 55 feet; it was another 20 feet at Dillon and about 5 more feet at Marion.

Potentiometric declines in the Black Creek Formation in the five-county area have not been as great as in the Middendorf, because withdrawals have been smaller and much less concentrated. The largest decline through 1982 was 50 feet, at Johnsonville. By 1992 there was another 40 feet of decline at Johnsonville. Although it does not show up as a defined cone of depression, it is worth noting that a 20-foot decline occurred at Lake City between 1982 and 1992. At the southern tip of Marion

Table 1. Descriptions of major public water supplies

	Number of wells	Well depths (feet)	Aquifers(s) tapped	Well yield(s) (gpm)	Elec. log(s)	Pumping test(s)	Chemical analyses
DARLINGTON COUNTY							
Darlington	4	305-600	M, M/CF	480-600	Yes	Yes	Yes
Darlington County Water & Sewer Authority	6	408-492	M	550-900	Yes	Yes	Yes
Hartsville	4	215-316	M	300-1,100	Yes	Yes	Yes
Lamar	2	220-486	BC, M	230-626	Yes	Yes	Yes
DILLON COUNTY							
Dillon	6	289-338	BC/M, M	150-686	Yes	Yes	Yes
Lake View	2	255-300	BC	50-160	Yes	Yes	Yes
Latta	2	235-390	BC/M	700	No	Yes	Yes
Trico Water Co.	4	258-433	BC/M, M	415-625	Yes	Yes	Yes
FLORENCE COUNTY							
Coward	2	310-378	BC	210-230	No	No	No
Florence	18	428-745	BC/M/CF,M,M/CF	319-1,123	Yes	Yes	Yes
Johnsonville	3	392-423	BC	250-430	No	Yes	Yes
Lake City	4	431-618	BC	400-850	Yes	Yes	Yes
Olanta	2	225-343	BC	140-219	Yes	Yes	Yes
Pamplico	3	157-300	BC	150-500	Yes	Yes	Yes
Quinby	2	250	BC	130	No	No	No
Scranton	2	430-440	BC	280-320	Yes	No	Yes
Timmonsville	3	260-486	BC/M	300-450	Yes	Yes	Yes
MARION COUNTY							
Marco Rural Water Co.	5	299-507	BC, BC/M	280-530	Yes	Yes	Yes
Marion	7	440-744	BC/M	227-590	Yes	Yes	Yes
Mullins	8	318-386	BC	500-1,000	Yes	Yes	Yes
Nichols	2	171-375	BC	125-340	No	No	No
MARLBORO COUNTY							
Bennettsville	9	190-420	M	95-385	Yes	Yes	Yes
Clio	2	168-311	BC/M,M	150-500	Yes	Yes	Yes
Marlboro County Water Co.	2	135-142	M	435-535	Yes	Yes	Yes
McColl	3	104-217	M	145-244	Yes	Yes	Yes
Wallace Water Co.	4	45-62	M	58-108	Yes	No	Yes

Aquifers tapped: BC, Black Creek Fm; BC/M, Black Creek and Middendorf Fms together; M, Middendorf Fm; M/CF, Middendorf and Cape Fear Fms together; BC/M/CF, Black Creek, Middendorf, and Cape Fear Fms together.

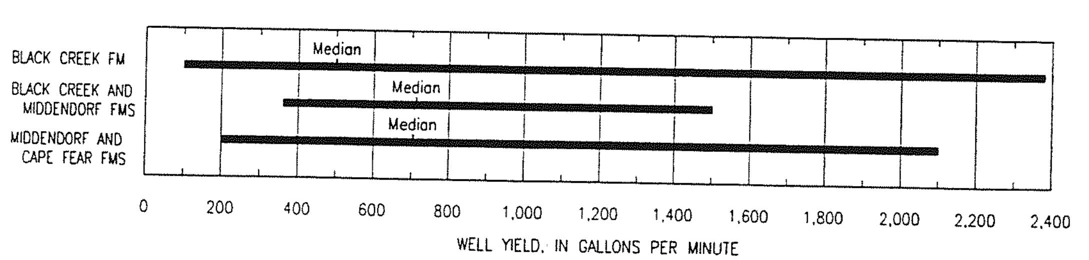

Figure 2. Ranges and medians of major-well yields in the five-county project area.

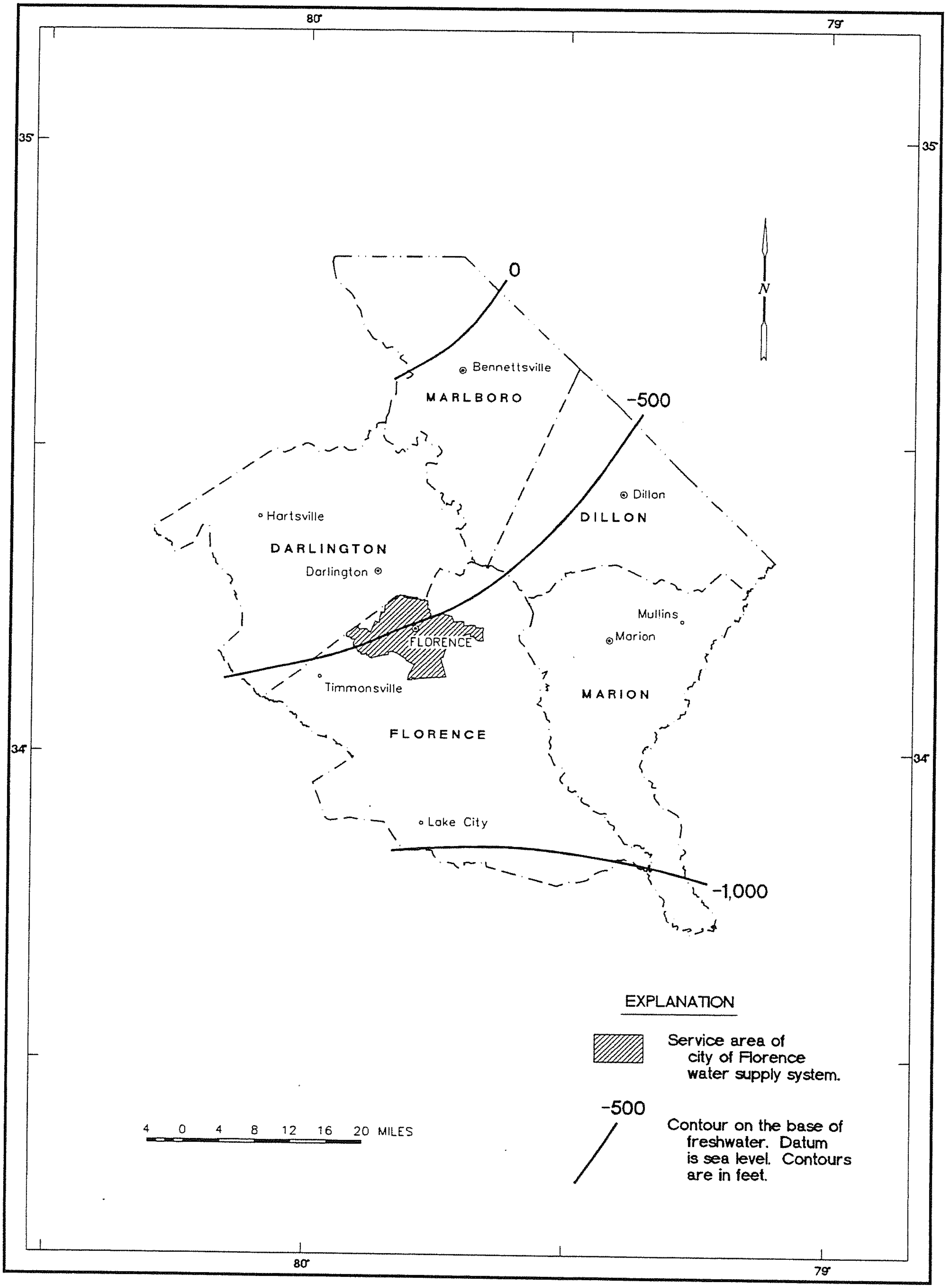

Figure 3. Contours on the base of freshwater (from Newcome, 1989).

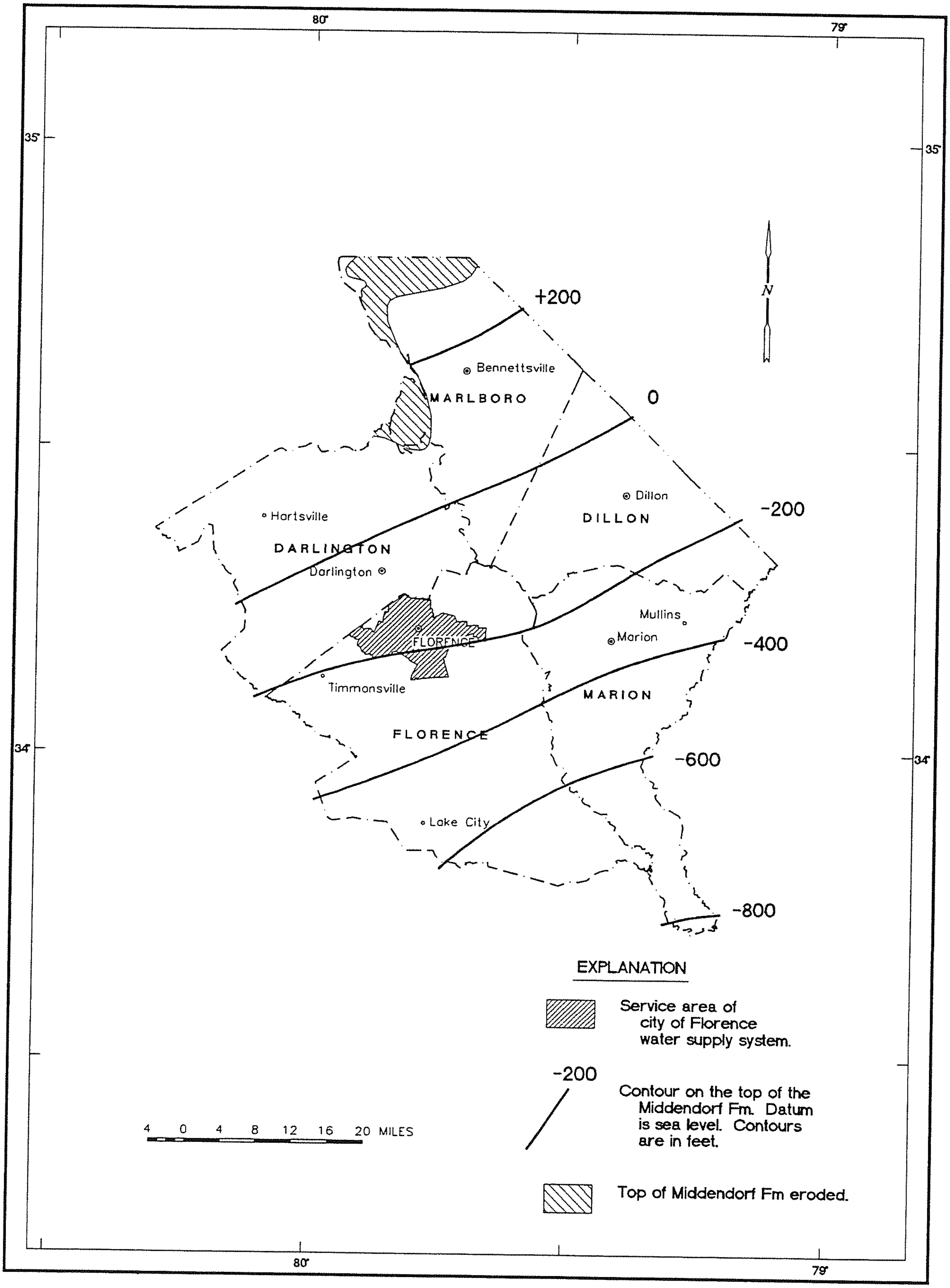

Figure 4. Contours on the top of the Middendorf Formation (from Aucott and others, 1989).

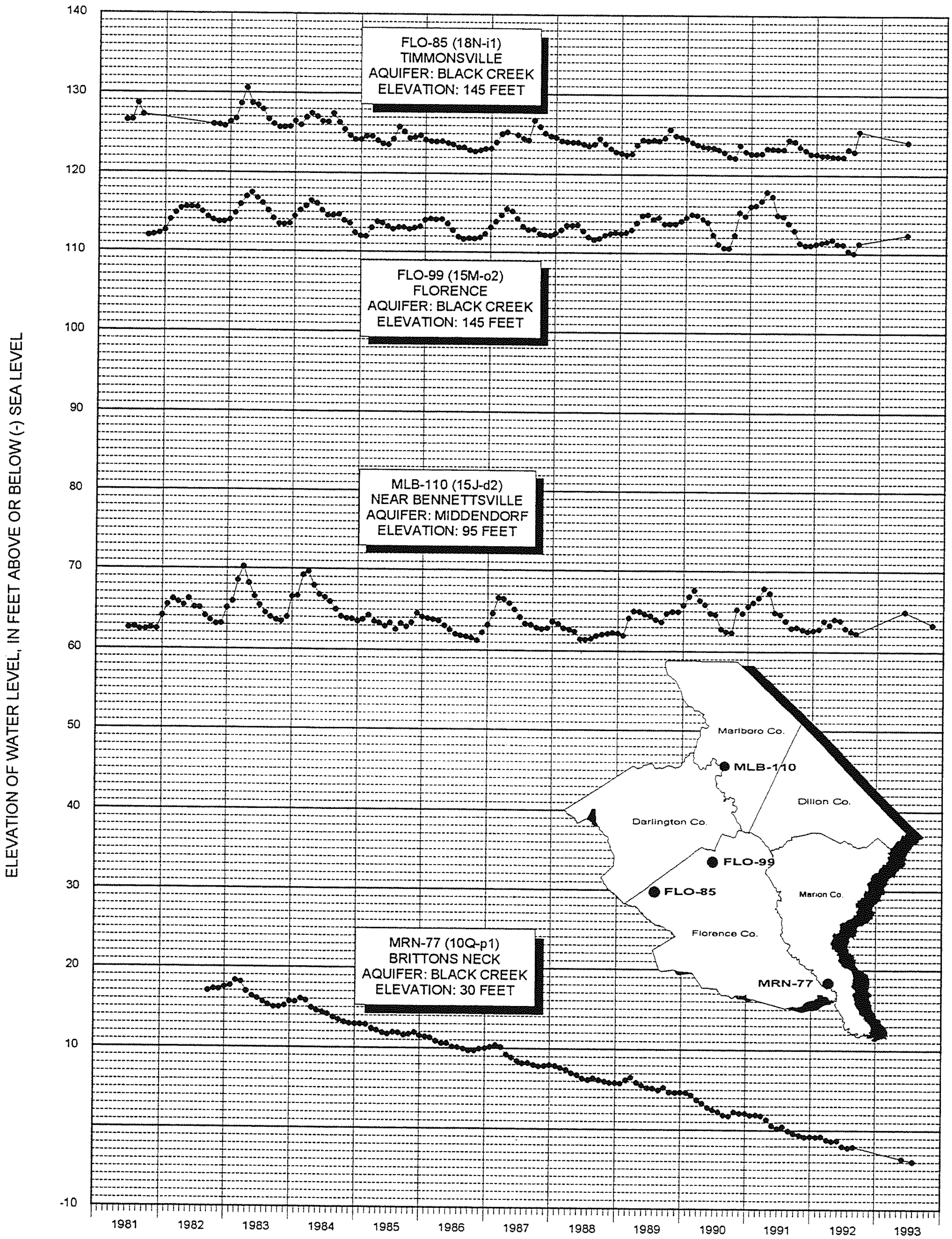

Figure 5. Hydrographs of water-level monitor wells.

County, the Black Creek potentiometric surface was at sea level in 1982, lowered over the years by pumping near the coast. It is currently about 25 feet below sea level even though pumping from Black Creek aquifers in the Myrtle Beach area was greatly reduced in 1990.

Potentiometric maps for the Middendorf and Black Creek Formations are presented in Figures 6 and 7. They reflect conditions in 1992. No attempt has been made to determine the configuration of the potentiometric surface(s) from water levels in wells tapping both Middendorf and Black Creek aquifers.

To summarize the current potentiometric conditions, ground water in the Middendorf Formation in the five-county area is flowing toward Florence from all directions, a consequence of the long-term heavy withdrawals at that city. Total drawdown at Florence since pumping began is about 200 feet. Ground water in the Black Creek Formation is flowing toward the Johnsonville-Hemingway area at the south end of the study area. Here the total drawdown since pumping began is 90 feet.

AQUIFER HYDRAULICS

PUMPING TESTS

Data are available for 79 pumping tests that have been made in the five-county area (Table 2). Ten of the tests are in Darlington County, 9 in Dillon County, 35 in Florence County, 17 in Marion County, and 8 in Marlboro County. The tests are distributed among the formations as follows:

Formation(s) tapped	Number of tests
Black Creek	21
Black Creek/Middendorf	14
Middendorf	27
Middendorf/Cape Fear	13
Black Creek/Middendorf/Cape Fear	3
Cape Fear	1

Figure 8 compares the range and median values of transmissivity determined for the aquifers in the tests just enumerated. This is a more reliable way to compare aquifers than by well yields, because the transmissivity values are not subject to the vagaries of well efficiency and pumping rate. Electric logs of all but one of the 79 wells tested are available to verify the aquifer presence and thickness. These logs indicate that the Middendorf contains major aquifers and the Cape Fear is of minor importance. Of the 13 tested wells producing water from both the Middendorf and Cape Fear, 11 are indicated by electric logs and well-construction records to be obtaining most to nearly all of their water from the Middendorf, and only 2 wells are believed to produce as much as half of their pumpage from the Cape Fear. The test of the one well screened in the Cape Fear alone indicated an aquifer transmissivity of only 9,000 gpd/ft (gallons per day per foot), far below the median of 19,000 for the 27 tests using wells screened in the Middendorf alone.

Curley's report (Table 3.1) listed 85 wells for which either pumping tests or specific-capacity data were available. As he stated (page 3.11), transmissivity values derived from specific capacity "reflect inaccuracies caused by inefficiency." It is encouraging to note, however, that the mean values that Curley reported for transmissivity are not far from the median values obtained from the 79 pumping tests now available. The comparative numbers are presented below.

	Transmissivity, in gallons per day per foot	
Aquifer	Curley's mean value	Median value of this report
Black Creek	14,500	13,000
Black Creek/Middendorf	20,100	16,000
Middendorf	22,700	19,000
Middendorf/Cape Fear	-	12,000

Results of the 79 pumping tests on which the foregoing median values are based are given in Table 2. Median transmissivity values based on about 350 pumping tests throughout the Coastal Plain of South Carolina are 21,000 and 12,000 gpd/ft, respectively, for the Middendorf and Black Creek (Newcome, 1989).

TEST AT EAST FLORENCE TREATMENT PLANT

A pumping test made at the East Florence Water Treatment Plant near Mars Bluff (5 miles east of Florence), provided aquifer-hydraulics information on the Black Creek Formation to the city of Florence. This test is described in the following paragraphs.

Well FLO-288 was screened between the depths of 80 and 130 feet, and observation wells, screened in the same zone, were installed at distances of 50 and 100 feet. A third observation well at a distance of 53 feet, was completed in the Middendorf Formation at a depth of 320 feet to ascertain whether pumping from the Black Creek aquifer would affect the lower unit.

The pumping test began July 1, 1992, and consisted of 24 hours of pumping at 500 gpm (gallons per minute), 3 hours of pumping at the reduced rate of 450 gpm (when the pumping level approached the pump intake), and a recovery period of 16 1/2 hours. Graphs showing the water-level response in the wells are given in Figure 9. There was no response in the Middendorf well.

Analysis of the data to obtain the aquifer-hydraulic characteristics of transmissivity and storage coefficient involved plotting as semilogarithmic and/or logarithmic graphs. The pumped-well data were plotted against cumulative time on semilog paper (Fig. 10) and the straight-line slope of a line through the data points determined by the Jacob (1950) method. This produced a value of 15,000 gpd/ft for transmissivity on the drawdown plot and 12,500 gpd/ft on the recovery plot. An impermeable hydrologic boundary was indicated on both plots, illustrated by a doubling of the slope of the plot. The drawdown plot in Figure 10 is considered more reliable than the recovery plot because the reduction in discharge from 500 to 450 gpm near the end of the test produced erratic water-level data and made analysis of the recovery data questionable. Even so, the transmissivity values obtained are not in serious disagreement.

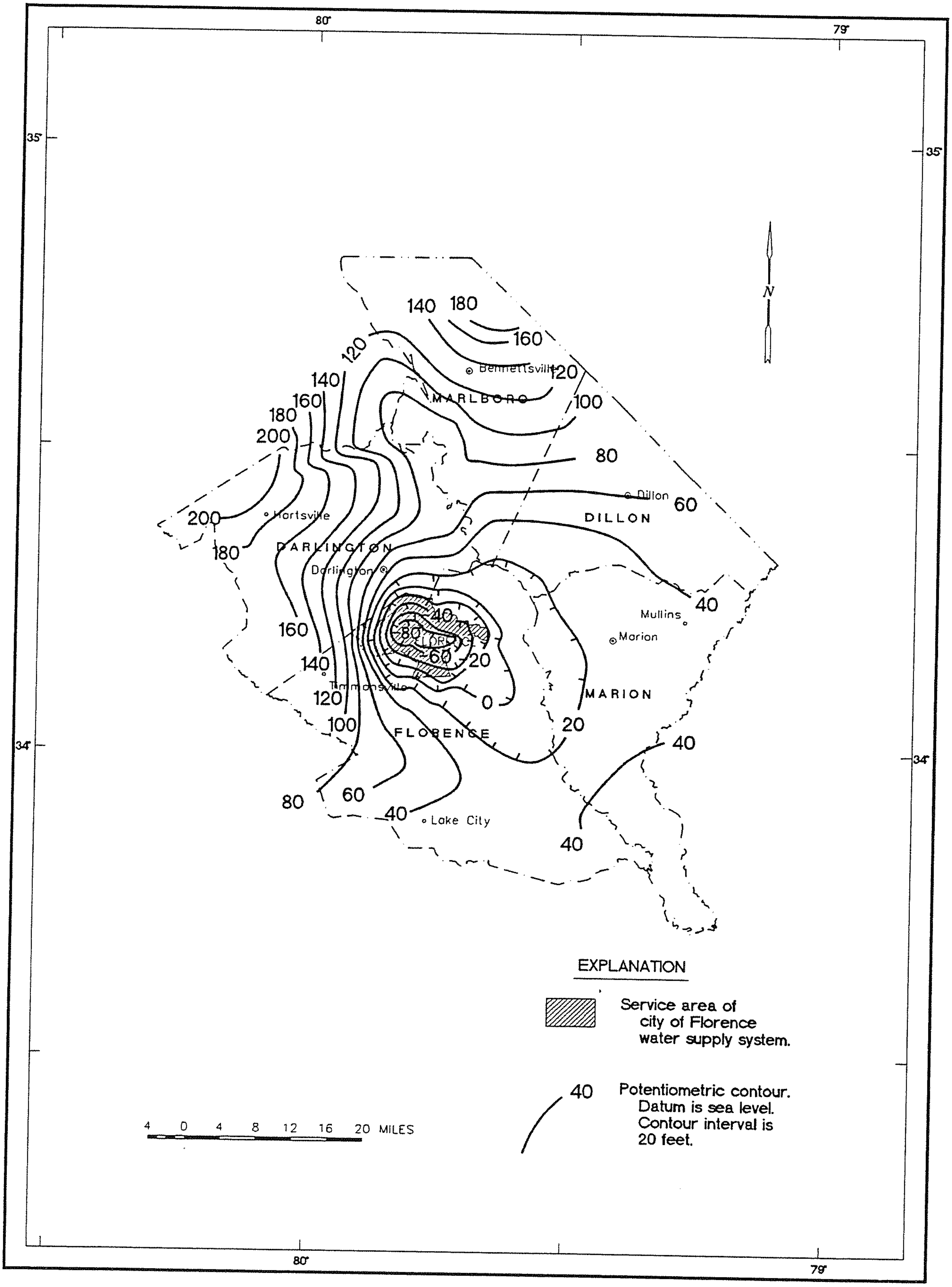

Figure 6. Potentiometric surface of the Middendorf Formation, 1992.

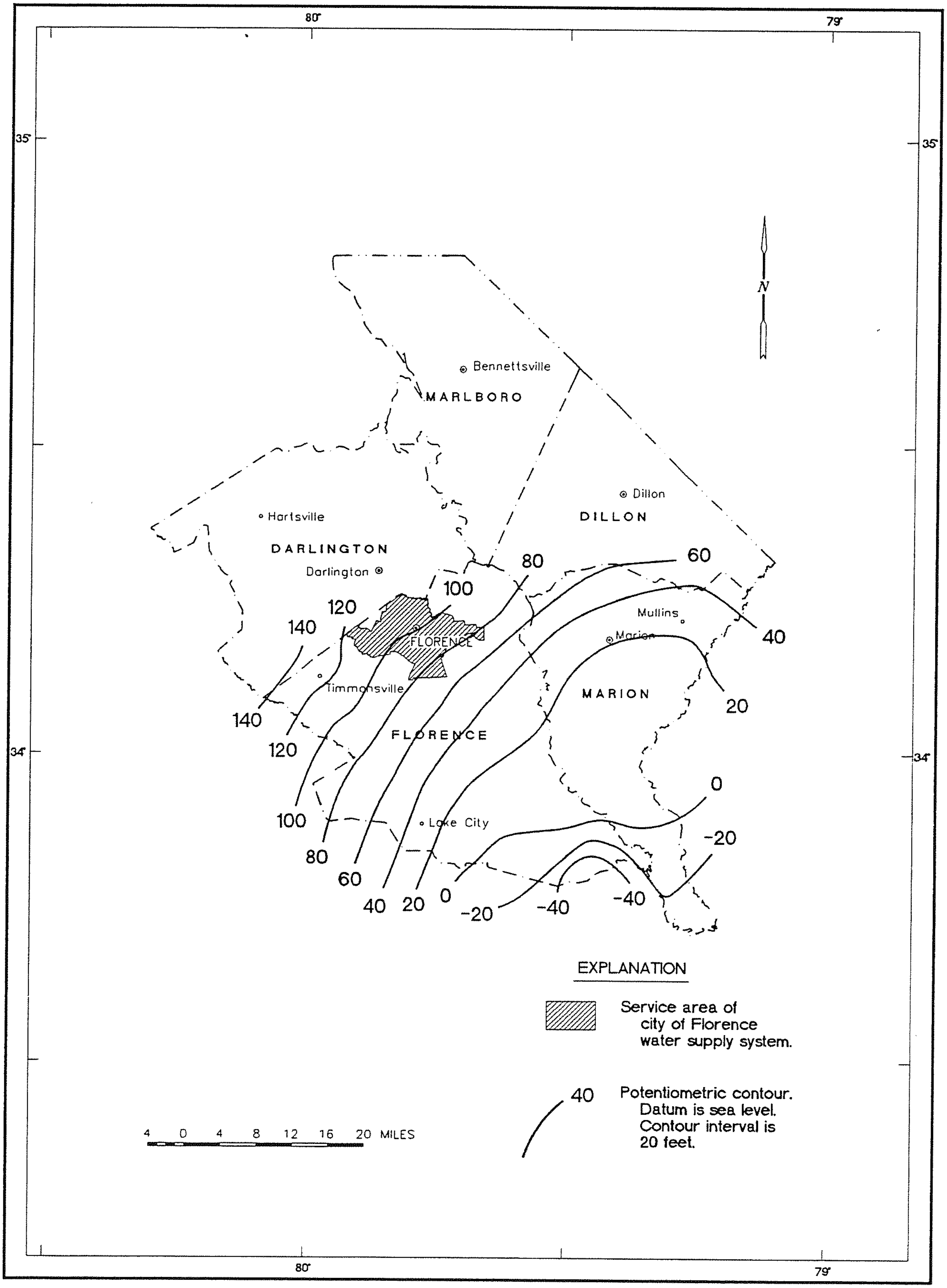

Figure 7. Potentiometric surface of the Black Creek Formation, 1992.

Table 2. Results of pumping tests in the five-county project area (modified from Newcome, 1993)

County well no.	SCWRC no.	Location	Elec. log	Depth (ft)	Aquifer/ thick. (ft)	Date of test	Duration (dd/recov)
DARLINGTON COUNTY							
DAR-71	20K-t1	Hartsville (Magnolia Cemetery)	X	297	M/100	1/3/63	23/
DAR-80	19K-f1	Hartsville (Sonoco Products Company)		239	M/70	3/5/70	14/
DAR-87	19M-y1	Lamar	X	486	M/160	11/10/72	24/48
DAR-89	16L-q1	Darlington, 4 1/2 mi SE	X	663	CF/85	4/16/73	8.5/36
DAR-94	19K-o2	Hartsville (South 5th Street)	X	316	M/150	9/9/76	24/5
DAR-96	17I-v3	Society Hill	X	380	M/125	11/13/75	24/8
DAR-112	16L-x1	Darlington, 4 1/2 mi SE	X	645	M,CF/135	10/13/78	24/41
DAR-222	15L-f1	Darlington, 7 mi E	X	120	M/100	5/24/88	24/
DAR-226	21K-l1	Ashland, 2 mi NNE	X	417	M/135	12/5/89	24/2
DAR-229	17L-m4	Darlington (U.S. 52 bypass)	X	600	M,CF/40	1/28/87	25/37
DILLON COUNTY							
DIL-73	12K-u1	Latta		235	BC/	1/4/61	6.5/
DIL-74	11J-j2	Dillon, 4 mi NNE		415	BC,M/	1/30/56	20/15
DIL-85	11J-k6	Dillon, 4 mi NNE		243	BC/	10/5/65	24/
DIL-86	11J-j5	Dillon, 4 mi NNE	X	323	BC,M/70	12/13/73	24/
DIL-96	11J-j4	Dillon, 4 mi NNE	X	288	BC,M/67	7/16/63	24/
DIL-98	11J-w1	Dillon (First Ave. and Jackson Street)	X	338	M/60	2/11/88	25/7
DIL-111	11J-k9	Dillon, 4 mi NE	X	389	M/80	9/17/92	24/3
DIL-112	11J-q1	Dillon (Wix Road)	X	315	M/130	4/20/93	24/4
DIL-113	11J-o1	Dillon (Wix Road)	X	366	M/80	4/16/93	24/4
FLORENCE COUNTY							
FLO-5	16M-s1	Florence, near center of town		630	M/150±	4/6/54	4/
FLO-33	16M-l1	Florence (Darlington Street)		722	M,CF/	4/5/54	4/
FLO-103	16M-w2	Florence (Treatment Plant)		705	M/	7/29/54	24/18
FLO-112	16M-t3	Florence (Ballard Street)	X	388	BC,M/120	12/11/58	240/
FLO-126	13M-p1	Mars Bluff	X	705	BC,M,CF/80	4/24/59	480/104
FLO-140	16M-v1	Florence (Gully Branch)	X	680	M,CF/150	6/2/61	336/
FLO-146	16M-w1	Florence (S. Edisto Street)	X	660	M,CF/	4/23/62	24/
FLO-147	13P-d1	Pamplico	X	300	BC/65	2/3/65	12/
FLO-154	16M-r1	Florence (W. Darlington Street)	X	712	M,CF/150	12/4/67	26/3
FLO-155	12R-b2	Johnsonville, 1 mi N	X	880	M/50	10/8/76	2/
FLO-156	18P-v1	Olanta (water tank)	X	225	BC/30	5/3/68	36/
FLO-161	16M-x1	Florence (McCown Street)	X	663	M,CF/170	7/13/71	71/1
FLO-178	12R-g1	Johnsonville, 1 1/2 mi SW		391	BC/90±	10/16/73	12/
FLO-187	16N-b2	Florence (Dexter Drive)		460	M/	10/19/79	24/2
FLO-190	15N-o1	Florence, 5 mi SSE	X	550	BC,M/100	10/7/77	24/

Static WL (ft)	Pumping rate (gpm)	Transmissivity (gpd/ft)	Storage coef.	Specific cap. (gpm/ft)	Well effic. (percent)	Hydrol. bound.
29	700	84,000		37	90	
Flowing	530	10,000		< 5		
12	626	57,000		8.0	30	
85	600	9,000	0.0002	3.9	85	
35	1,022	39,000		16	80	
118	250	3,000		2.7	100	
154	951	10,000		4.9	100	
97	823	17,000		11	100	
99	900	68,000		30	90	
94	501	5,100		3	100	R
20	650	34,000		12	70	
36	360	20,000	.0002	13	100	
90	525	33,000		12	75	
70	521	28,000		8.8	70	D
56	626	14,000		9.1	100	
64	704	19,000		17	100	
88	537	28,000		14	100	
58	1,050	45,000		22	100	
58	910	16,000		10	100	
100	520	28,000		4.3	30	D
107	694	32,000		9.6	60	
10	600	22,000		10	90	
39	475	54,000	.002			D
36	510	22,000	.0006			D
49	2,100	40,000	.001	21	100	D
45	1,400	23,000		11	100	
40	536	30,000		7.0	50	
123	1,469	17,000		14	100	
56	620	18,000		10	100	
5	300	7,500		3.3	85	
86	1,250	12,000		9.5	100	
92	408	11,000		4.6	85	
161	855	11,000		6.7	100	
52	759	7,700		8.7	100	

Table 2. Results of pumping tests in the five-county project area -- continued (from Newcome, 1993)

County well no.	SCWRC no.	Location	Elec. log	Depth (ft)	Aquifer/ thick. (ft)	Date of test	Duration (dd/recov)
FLORENCE COUNTY (cont.)							
FLO-194	15M-n4	Florence, 2 mi ENE		386	BC,M/	6/27/69	72/
FLO-201	13N-d2	Peedee, 4 mi SSE	X	123	BC/35	12/8/80	26/
FLO-204	18N-i5	Timmonsville	X	486	M/85	3/12/81	7/3
FLO-221	13N-d3	Peedee, 4 mi SSE		123	BC/	12/20/80	4/
FLO-247	15Q-p3	Lake City (Hwy 341E)	X	618	BC,M/120	8/3/83	24/7.5
FLO-250	16Q-s1	Lake City, 1 1/2 mi SW	X	584	BC,M/	8/12/82	24/14
FLO-265	16M-y1	Florence (Santiago Drive)	X	662	M/60	3/6/89	24/2
FLO-266	14M-p4	Florence, 6 mi E	X	688	M,CF/100	2/13/89	24/16
FLO-267	16M-m1	Florence (Harmony Street)	X	713	M,CF/100	1/23/89	24/6
FLO-269	14M-p5	Mars Bluff, 1 1/2 mi SSW	X	725	M,CF/60	3/20/89	24/6
FLO-270	16M-d7	Florence, 4 mi NW	X	407	M/70	5/2/90	24/3
FLO-271	17M-k1	Florence, 4 mi W	X	428	BC,M/90	7/5/90	24/5.5
FLO-273	14M-x1	Florence, 7 miE	X	737	BC,M,CF/100	9/24/90	24/5.5
FLO-275	16N-c1	Florence (South Park)	X	712	M,CF/100	10/22/90	25/2
FLO-281	17M-w2	Florence, 7 mi WSW		598	M/	6/30/87	24/22
FLO-286	16N-l3	Florence (Green Acres Road)	X	735	BC,M/95	12/3/92	25/2
FLO-288	14M-p6	Mars Bluff, 1 1/2 mi SW	X	130	BC/50±	7/1/92	26/18
FLO-293	16N-i2	Florence (Redbud Road)	X	725	BC,M,CF/100	2/17/93	24/25
FLO-294	16N-j1	Florence (Roberta Drive)	X	735	M,CF/120	1/13/93	24/25
FLO-295	16Q-u2	Lake City (Airport)		565	BC/	11/92	24/7.5
MARION COUNTY							
MRN-9	11M-p2	Marion (Withlacoochee Avenue)	X	633	BC,M/80	6/15/87	24/5
MRN-43	10M-k2	Mullins (Front Street)		375	BC/30	6/9/77	3/1
MRN-60	10M-t1	Mullins (Gapway Street)		375	BC/	6/3/77	5/
MRN-67	9M-p2	Mullins (Springs Mill)	X	365	BC/70	5/10/72	12/9.5
MRN-78	10Q-p2	Brittons Neck, 3 mi S	X	768	M/38	4/24/82	?/.5
MRN-78	10Q-p2	Brittons Neck, 3 mi S	X	537	BC/22	4/30/82	?/60
MRN-81	10M-q1	Mullins, 3 1/2 mi W	X	357	BC/	7/27/67	24/
MRN-83	10M-l1	Mullins, 2 mi W	X	330	BC/75	6/22/78	24/8
MRN-89	9M-p1	Mullins (Cleveland Street)	X	344	BC/65	7/23/79	24/2
MRN-90	13M-b1	Sellers, 3 1/2 mi SW	X	537	BC,M/110	10/20/78	24/2.5
MRN-91	10M-k3	Mullins (Dogwood Street)	X	352	BC/20	6/16/72	3/1.5
MRN-110	9M-h2	Mullins, 3 1/2 mi NE	X	394	BC/165	4/9/89	4/
MRN-116	11N-e4	Marion (Clemson Road)	X	438	BC/65	3/18/92	24/90
MRN-117	11M-w1	Marion (Bluff Road)	X	489	BC/100	5/12/92	24/26
MRN-118	11M-r2	Marion (Rogers Road)	X	555	BC,M/100	6/2/92	24/34
MRN-119	12M-u1	Marion (Beneteau Plant)	X	550	BC,M/90	2/17/93	24/

Static WL (ft)	Pumping rate (gpm)	Transmissivity (gpd/ft)	Storage coef.	Specific cap. (gpm/ft)	Well effic. (percent)	Hydrol. bound.
130	187	16,000		2.0	25	
47	116	14,000	.0003	2.4	35	
54	530	4,000	.0004	3.7	100	
45	118	16,000		2.4	30	
33	751	26,000		15	100	
36	751	47,000		10	45	
175	1,100	18,000		10	100	
97	1,055	10,000		5.7	100	
215	1,000	11,000		7.0	100	
85	1,107	12,000	.0003	8.1	100	
170	506	19,000		9.5	100	
160	710	12,000		9.4	100	
92	1,050	11,000		8.0	100	R
181	1,000	33,000		16	95	D
107	1,708	45,000		20	90	D
130	800	11,000		5.2	100	
0	500	15,000	.0005	6.4	100	D
137	603	5,800		4.4	100	R
132	802	15,000		4.8	65	
56	848	46,000		13	55	
98	650	11,000		7.0	100	
88	402	13,000		6.2	95	
78	305	10,000		2.1	45	D
60	570	21,000		10	100	
25	35	12,000		<1.5	25±	
17	32	7,000		< 1	30±	
50	402	13,000		6.8	100	
60	400	6,000		3.8	100	
60	602	12,000		5.5	95	
22	1,500	18,000		14	100	
61	372	7,000		2.9	85	
54	700	40,000		30	100	
57	525	10,000		5.6	100	
97	480	7,200		5.7	100	
104	460	14,000		6.6	85	
61	400	8,800		2.8	65	

Table 2. Results of pumping tests in the five-county project area -- continued (from Newcome, 1993)

County well no.	SCWRC no.	Location	Elec. log	Depth (ft)	Aquifer/ thick. (ft)	Date of test	Duration (dd/recov)
MARLBORO COUNTY							
MLB-51	15H-s3	Bennettsville (Fleet Street)	X	374	M,CF/170	6/8/77	24/2
MLB-117	15I-W1	Blenheim, 4 mi WSW		167	M/	6/24/59	28/4
MLB-142	15H-j2	Bennettsville, 2 1/2 mi NNE	X	125	M/125	9/13/78	25/2
MLB-143	14G-l2	McColl, 4 mi NW		105	M/	11/2/77	24/
MLB-145	14K-a1	Brownsville, 1 mi NW		250	M/110	4/1/82	24/2
MLB-160	15H-r1	Bennettsville, SW part		145	M/84	1/3/80	24/2.5
MLB-171	13I-c1	Clio	X	311	M/117	5/30/84	24/1
MLB-180	13H-c2	McColl, 3/4 mi SE	X	217	M/78	9/6/84	2.5/1

Static WL (ft)	Pumping rate (gpm)	Transmissivity (gpd/ft)	Storage coef.	Specific cap. (gpm/ft)	Well effic. (percent)	Hydrol. bound.
22	350	4,300		4.0	100	
23	362	36,000		21	100	
42	401	10,000		6.1	100	R
26	151	15,000		5.4	70	
48	1,002	59,000		33	100	
25	200	52,000		12	50	D
63	506	35,000		17	100	
20	403	2,400		2.1	100	

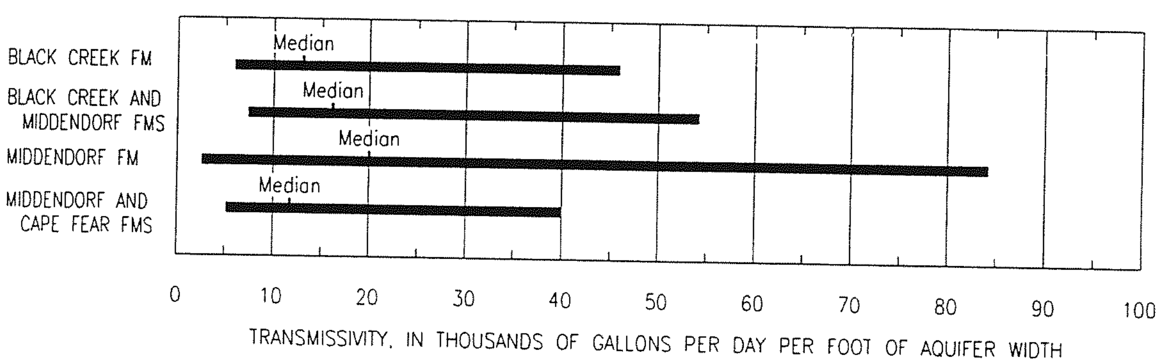

Figure 8. Ranges and medians of transmissivity determined from pumping tests of the aquifers in the five-county project area.

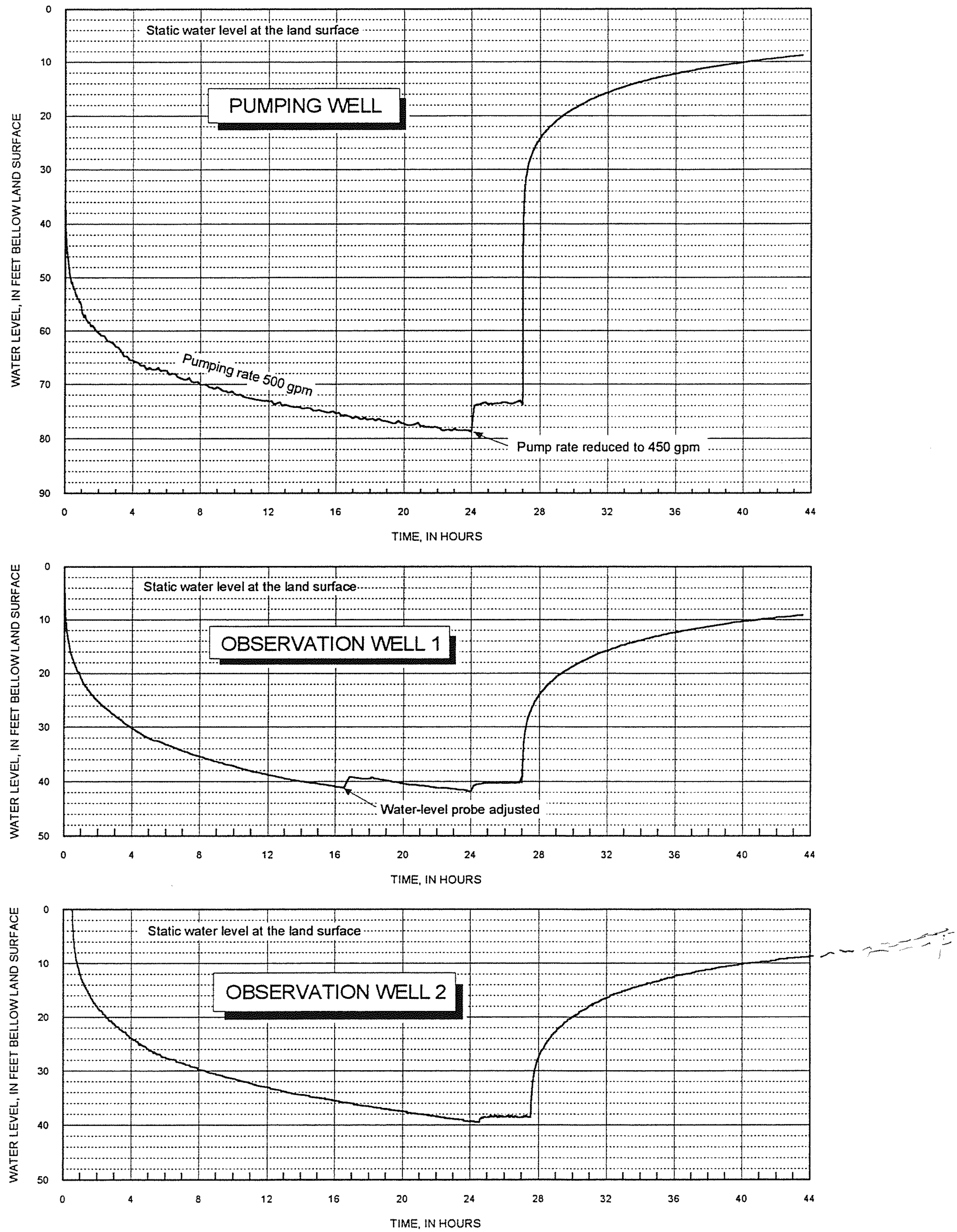

Figure 9. Water levels during the pumping test at the East Florence Water Treatment Plant, July 1-2, 1992.

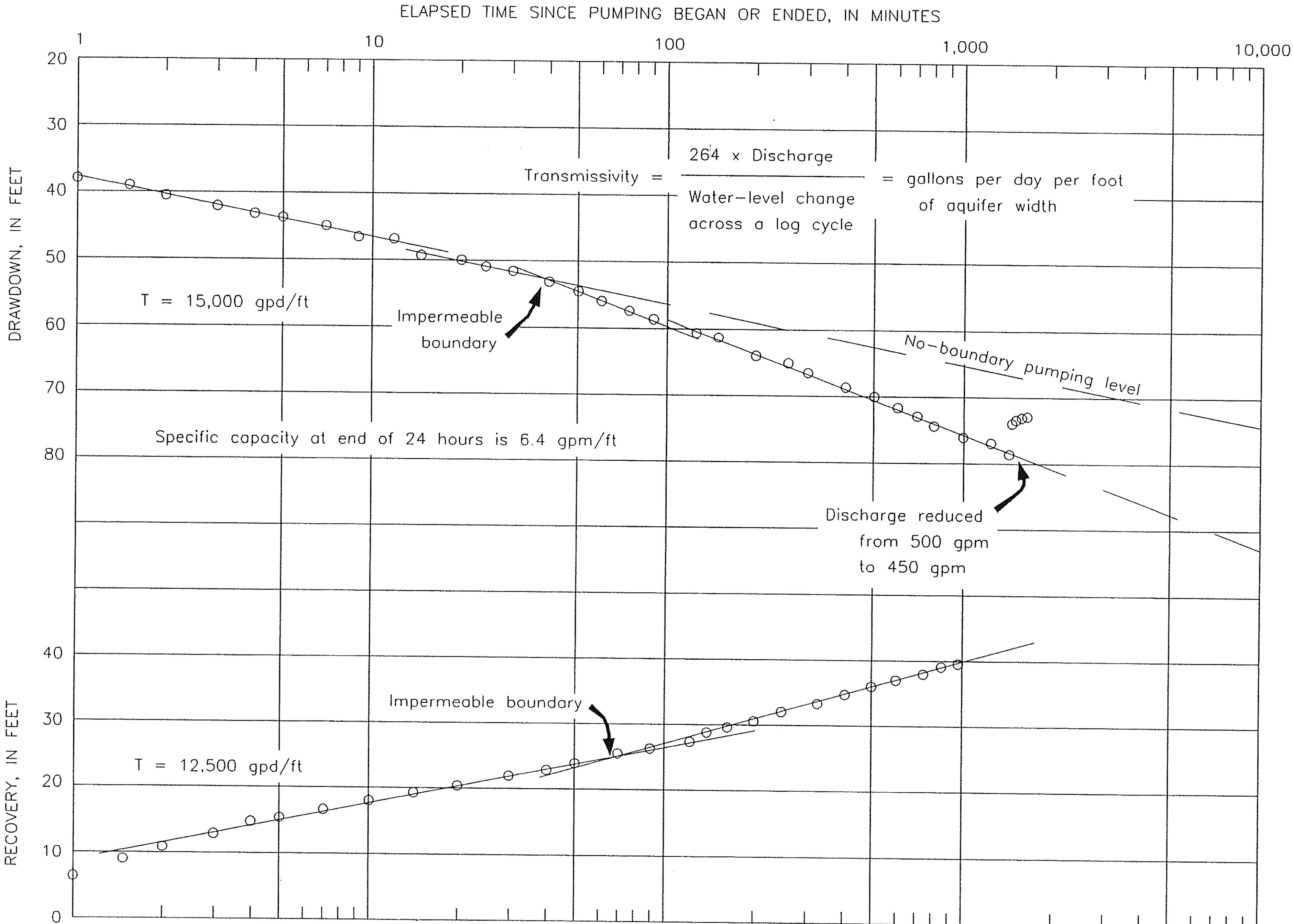

Figure 10. Semilogarithmic graphs of drawdown and recovery in the pumped well during pumping test at East Florence Water Treatment Plant.

The specific capacity of the well was 6.4 gpm per foot of drawdown at the end of 24 hours of pumping. If the hydrologic boundary had not been present, the drawdown at the end of 24 hours of pumping at 500 gpm would have been 67 ft and the specific capacity would have been 7.5 gpm/ft. This is almost exactly what would be expected of a fully efficient well completed in an aquifer having the hydraulic characteristics indicated by this pumping test; hence, the well is considered to have an efficiency of nearly 100 percent.

Observation well 1 (OW1) was analyzed first by plotting the drawdown and recovery against their respective elapsed times on semilogarithmic graph paper (Fig. 11). Because the data plot in straight-line segments when time is on the logarithmic scale, these graphs illustrate clearly the occurrence of extraneous effects, such as hydrologic boundaries, pumping fluctuations, measuring anomalies, and well interference. The data were also plotted as logarithmic graphs and the standard Theis (1935) type curve fitted to them to obtain matchpoints from which the transmissivity and storage coefficient were calculated.

Observation well 2 (OW2) was analyzed in the same way as OW1; the semilog plot is shown in Figure 12. Findings from the test data are summarized in Table 3. In summary, it seems reasonable to conclude that the transmissivity of the aquifers tested is close to 15,000 gpd/ft and confined conditions prevail, with the storage coefficient being about 0.0005. All values indicated by the recovery portion of the test are considered less reliable than those indicated by the drawdown portion.

The impermeable hydrologic boundary indicated on all plots suggests a thinning of the aquifer. This boundary effect was evidenced about 1 hour after pumping began or ended. The distance to the boundary from the pumped well was calculated to be less than 500 feet from the test site and in a direction between east and south. The aquifer thickness at the test site is 38 feet. Electric logs of two wells 0.6 mile to the southeast and the same distance to the south-southeast show the aquifer to be less than 20 feet thick at those locations. There can be little doubt that the marked thinning of the aquifer is the cause of the impermeable boundary effect.

The practical effect, in this case, is that if it had not been for the boundary the pumping level, at 500 gpm, would not have reached the top of the screen (80 ft) until 24 days of pumping. As conditions exist, a pumping rate of 450 gpm would result in drawdown to the top of the screen after 3 days; at 400 gpm it would be 13 days. It should be borne in mind that ground-water flow is induced toward the pumping center from all directions, and the encountering of a boundary does not always portend disaster. Of course, additional boundaries, of either the impermeable or recharging type, may become evident with continued pumping, but their effects are likely to be successively less important as their time of appearance progresses. Interrupting the pumping, as is nearly always the practice, minimizes the boundary effects.

TEST DRILLING

Florence test hole.— Curley (1990) described a test hole (FLO-268) cored to a depth of 716 feet near the Edisto Drive public-supply well in Florence. The test hole was not completed as a well. Curley analyzed the cored material and presented the geophysical logs in his report. Significant water-bearing sand intervals indicated by the electric log are as follows:

Depth, in feet	
135-148 152-188	Black Creek Fm
346-378 388-408 421-436 643-660	Middendorf and Cape Fear Fms

There was considerable sand above the 135-foot depth, but available drawdown probably is insufficient for the development of major wells.

Brittons Neck test well.— A test well installed by the U.S. Geological Survey in 1982 penetrated the entire Cretaceous section at a site 4 miles south-southeast of Brittons Neck in Marion County (Reid and others, 1986). This well (MRN-78) was cored throughout its depth, including 54 feet of pre-Cretaceous basement rock. Casing and screens were set and water samples collected from seven depth intervals. Freshwater samples were obtained from intervals at 325-335, 345-355, 517-537, and 748-768 feet. Saline water (dissolved solids greater than 1,000 milligrams per liter) samples were obtained from 811-831, 1,010-1,030 and 1,120-1,140 feet. Significant water-bearing and intervals indicated by the electric log are as follows:

Depth, in feet	
315-355 372-402 435-445 505-528	Black Creek Fm
720-778	Middendorf Fm

Pumping tests were made for two screened intervals, 517-537 feet and 748-768 feet. See MRN-78 in Table 2 of this report for the pumping-test results. In summary, it can be said that the shallower tested zone, which is in the Black Creek Formation, has a modest transmissivity that probably is capable of supplying 500 gpm to efficient wells equipped to accommodate 200 feet of water-level drawdown. The deeper tested zone, in the Middendorf Formation, is a better aquifer and should be capable of yielding 1,000 gpm to efficient wells equipped to accommodate 200 feet of drawdown.

Probably the most prolific aquifers recorded on the electric log are the 315-355 and 372-402 foot sand zones in the Black Creek Formation, but they were not tested for yield. The upper of these two intervals was sampled for various analyses, and it had by far the best chemical quality of all intervals tested at the site.

Lake City test hole.— Two test holes were drilled in the current investigation after the release of Curley's preliminary report (1990) containing a description of the test hole in Florence. The first of the two newer tests (FLO-274) was installed at the

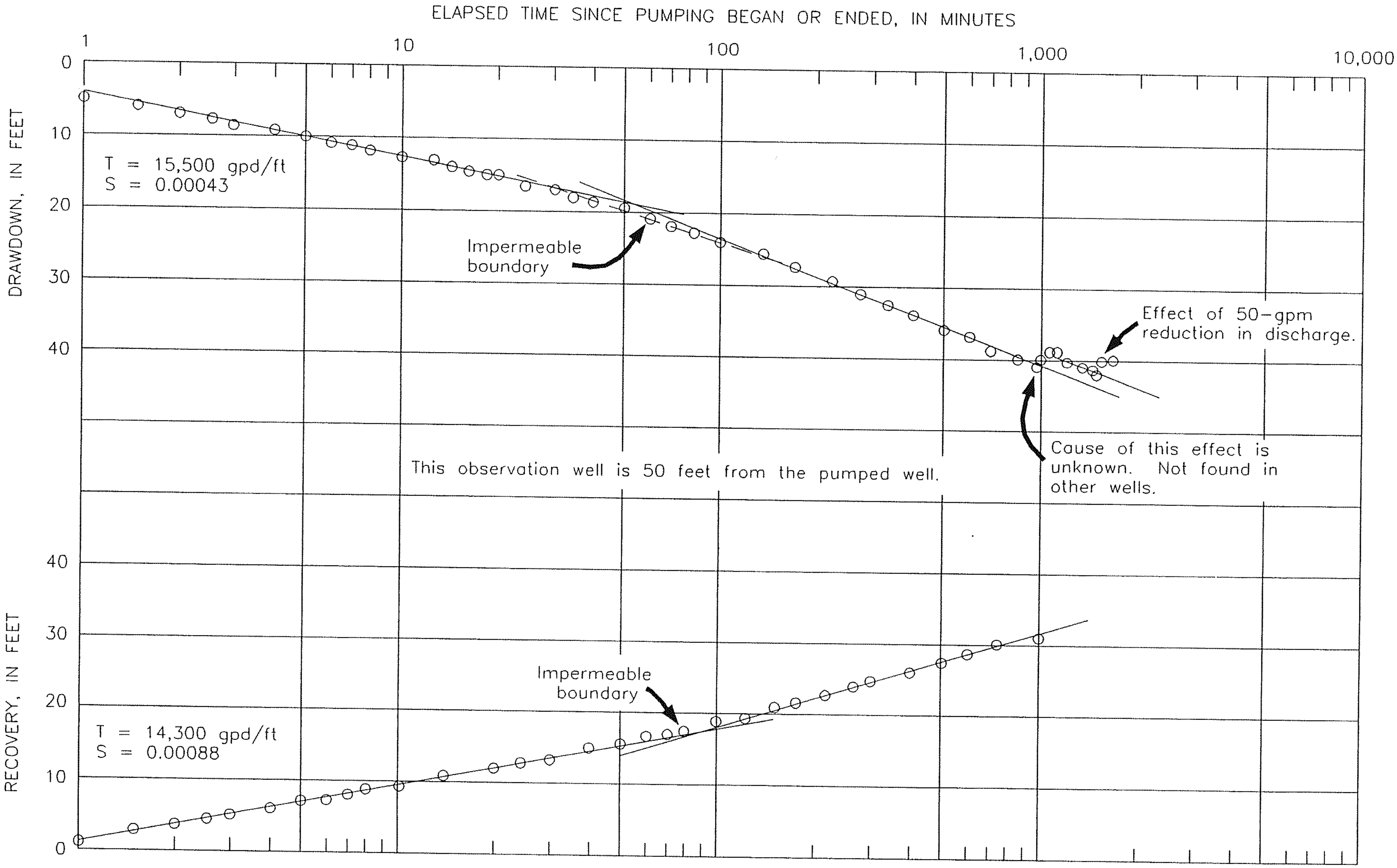

Figure 11. Semilogarithmic graphs of drawdown and recovery in observation well 1 during pumping test at East Florence Water Treatment Plant.

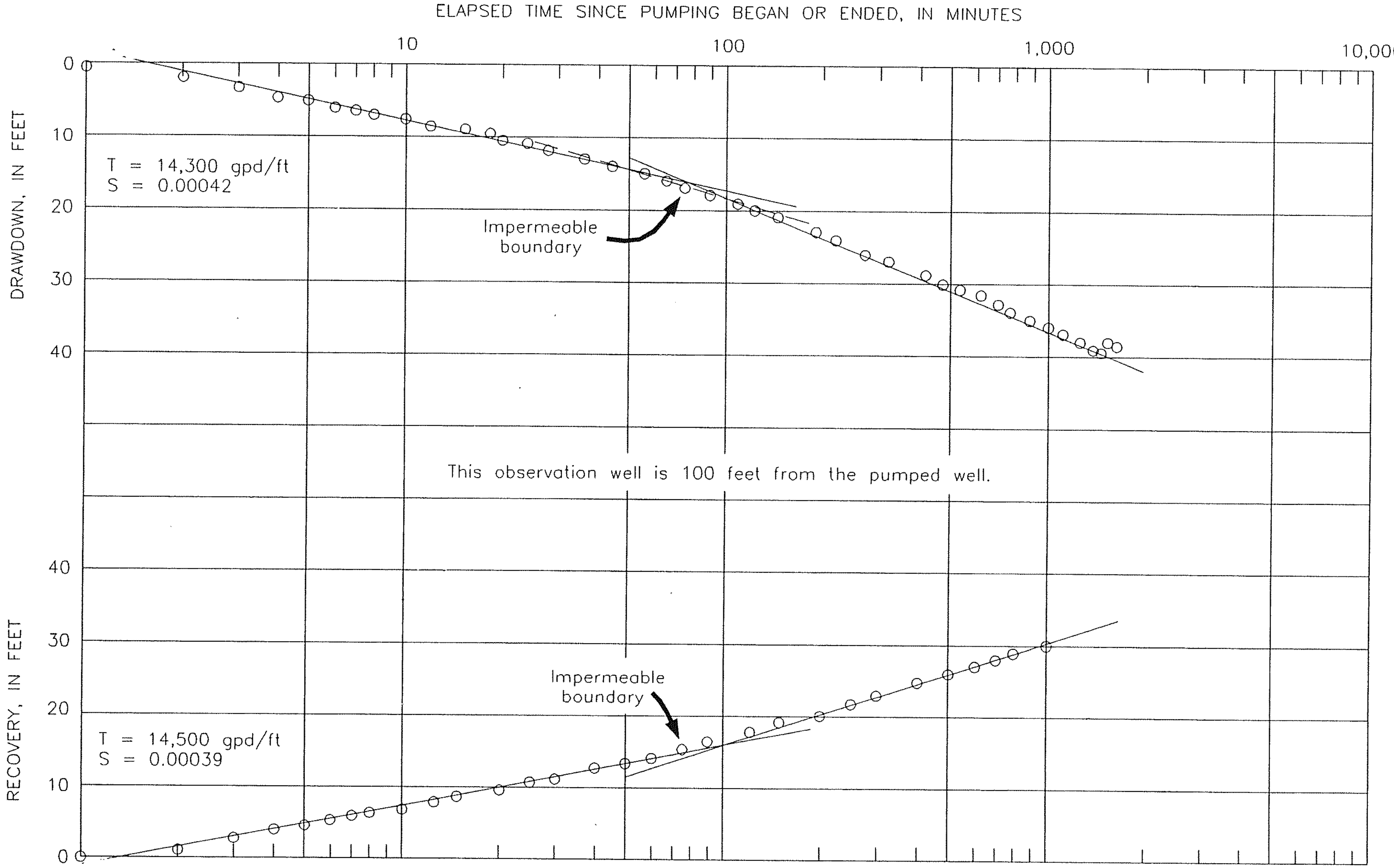

Figure 12. Semilogarithmic graphs of drawdown and recovery in observation well 2 during pumping test at East Florence Water Treatment Plant.

Table 3. Results of the pumping test at the East Florence Water Treatment Plant

WELL	DISTANCE FROM PUMPING WELL (FEET)	TYPE OF ANALYSIS	TRANSMISSIVITY (GPD/FT) BEFORE HYDROLOGIC BOUNDARY DRAWDOWN/RECOVERY	TRANSMISSIVITY (GPD/FT) AFTER HYDROLOGIC BOUNDARY DRAWDOWN/RECOVERY	TIME OF BOUNDARY EFFECT (MINUTES) DRAWDOWN/RECOVERY	STORAGE COEFFICIENT DRAWDOWN	STORAGE COEFFICIENT RECOVERY
PW	0	Semilog (Jacob)	15,000/12,500	7,700/8,500	40/60	-	-
OW1	50	Semilog (Jacob)	15,500/14,300	7,500/8,900	55/85	0.00043	0.00088
		Log (Theis)	15,500/13,200	-	40/80	.00041	.00110
OW2	100	Semilog (Jacob)	14,300/14,500	7,300/8,200	75/75	.00042	.00039
		Log (Theis)	13,300/12,000	-	60/90	.00051	.00058

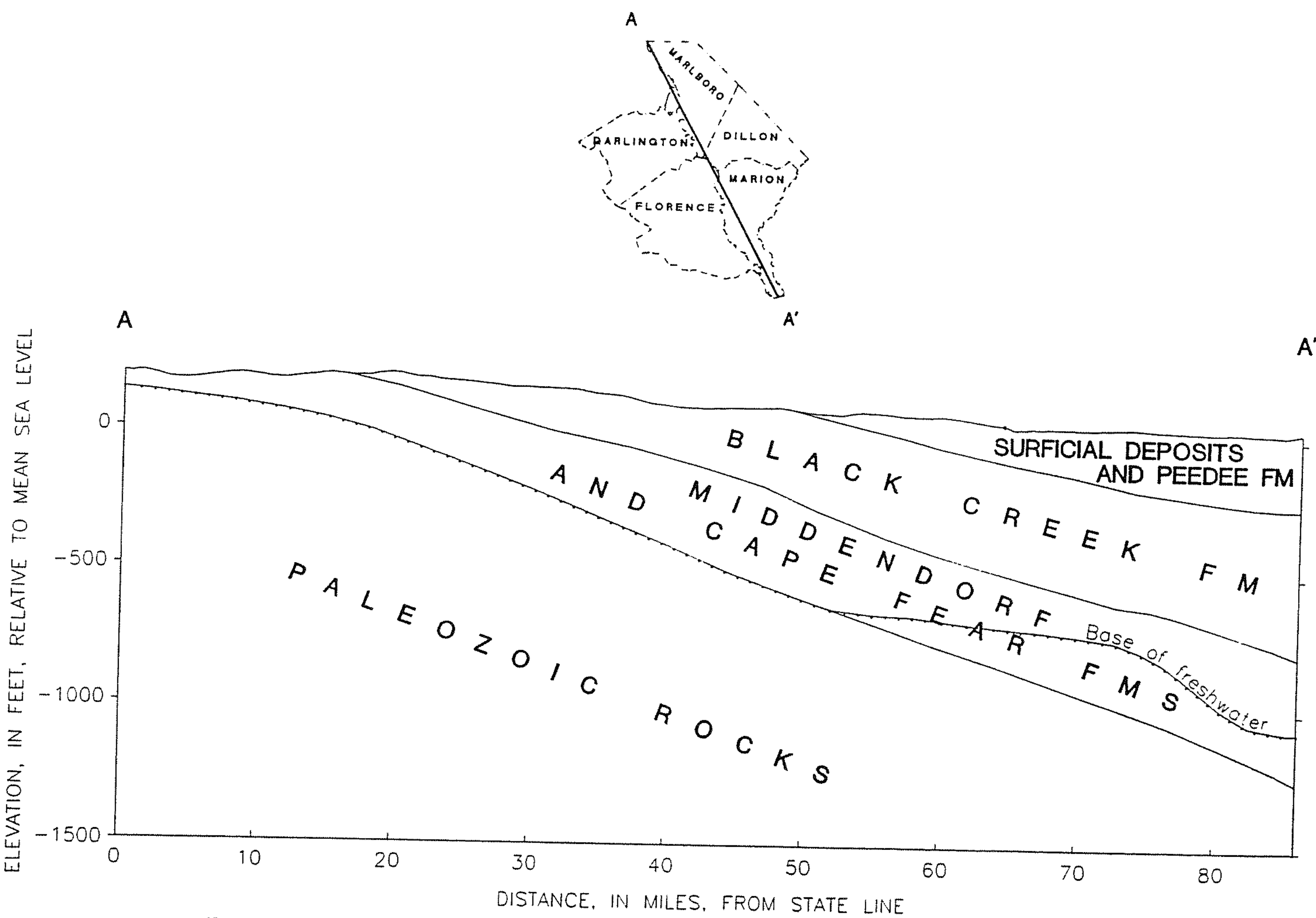

Figure 13. Position of the base of freshwater relative to formation boundaries.

southwest edge of Lake City in July 1990. It was cored to a depth of 1,060 feet and penetrated numerous thin freshwater sand beds above a depth of 700 feet. Although none of the beds is likely to provide much water by itself, the thickest sand intervals indicated by the electric log are as follows:

Depth, in feet	
160-170	Black Creek Fm
249-257	
372-384	
390-397	
508-540	Middendorf Fm
544-553	
672-688	

Saline-water sand beds are evident in the 886-901 and 1,024-1,040 foot intervals.

Lake Darpo test hole.— The second of the two test holes drilled since Curley's report was installed in November 1990. It was cored to a depth of 446 feet closely adjacent to Lake Darpo, which is just north of the Darlington County airport. The electric log of this well (DAR-228) reveals potential aquifers above a depth of 230 feet. They are:

Depth, in feet	
55-80	Middendorf Fm
88-108	
116-132	
154-194	
203-228	

In addition, sand beds in the 258-274 and 302-326 foot intervals may provide water of marginal quality. No samples of water were obtained from this test hole.

Descriptions of the core samples obtained from the Lake City and Lake Darpo test holes are presented in Appendix 1 of this report.

WATER QUALITY

Cretaceous aquifers of the South Carolina Coastal Plain are mostly recharged by rainfall along a narrow band parallel to and east of the Fall Line. Probably less than 10 percent of the precipitation that penetrates the soil recharges the water table, and only a fraction of that eventually recharges the underlying aquifers. Ground water in the recharge areas is similar in composition to rainwater. The water in these shallower aquifers, in western Darlington and Marlboro Counties for example, is characterized by high dissolved oxygen, low dissolved solids, low pH, and low alkalinity. In general, it is soft and corrosive.

By the time the water reaches the deeper aquifers, in eastern and southern Marlboro County for example, the dissolved oxygen has been depleted and the dissolved-solids concentration is about 30 mg/L, pH is less than 6, and the ground water has a high concentration of dissolved ferrous iron. The iron ion is a byproduct of the anaerobic oxidation of organic matter and remains in solution until enough sulfite is available to precipitate the mineral pyrite.

Farther down the gradient, in Dillon and Marion Counties for example, where this water has had a longer time to react with the aquifer, the ground water is characterized by a dissolved-solids concentration of about 150 mg/L, a pH between 7 and 8, an alkalinity of approximately 110 mg/L, and sodium of about 40 mg/L. By the time the ground water has reached these counties a significant amount of sulfate has been reduced to sulfide by anaerobic oxidation of organic matter. Pyrite, moreover, is precipitated, reducing the concentration of sulfide and ferrous iron ions in solution. It has been reported that some wells in these counties have a black precipitate, which could indicate the presence of sulfides in the system.

Once ground water reaches the coastal counties, this water is characterized by a dissolved-solids concentration greater than 600 mg/L, pH about 8.2, alkalinity near 700 mg/L, and sodium of about 250 mg/L. Additionally, the ground water has a high concentration of fluoride from the dissolution of fluorapatite.

Curley's report of 1990 contained a fairly comprehensive analysis of the ground-water quality data then available. It included Piper and Stiff diagrams, along with maps from an earlier report showing areal variations in various constituents and properties. Curley recognized that more chemical-analysis records were needed to better define the water quality in the Pee Dee counties. Consequently, 17 selected wells were sampled between late 1988 and early 1991 and analyses made by the U.S. Geological Survey. The sampled wells are distributed through all five counties of the project area and the three major formations discussed in this report. The analyses are tabulated in Appendix 2. The tabulation does not contain values for the total-dissolved-solids concentration. This is a useful property to know and is easily obtained by adding the concentrations of constituents and subtracting one-half of the bicarbonate. This information is presented below, with the wells in the same order in which they appear in Tables 1-3 of Appendix 2.

Well No.	Depth (feet)	Formation	Dissolved solids in milligrams per liter
DAR-118	110	Black Creek	68
DIL-88	275		132
FLO-105	428		121
FLO-141	400		189
FLO-147	300		79
FLO-156	220		116
FLO-166	126		106
MRN-71	290		661
MRN-91	346		145
DAR-69	305	Middendorf	41
DAR-94	306		15
DIL-98	353		110
FLO-243	425		42
MLB-142	160		28
MLB-600[a]	240		60
DAR-89	624	Middendorf / Cape Fear	170
FLO-149	760	Cape Fear	168

[a]This well is numbered MLB-145 in Water Resources Commission files.

The constituent or property most often exceeding desirable values among the 17 chemical analyses made since Curley's report is iron. Two wells producing from the Black Creek

Formation (DAR-118, 7 miles east of Darlington, and FLO-166, between Florence and Coward) showed iron concentrations of 1.1 and 2.4 mg/L (milligrams per liter), respectively, well above the recommended limit of 0.3 mg/L for drinking water. Three Middendorf wells had high iron concentrations. They are DIL-98 (at Dillon) with 0.7 mg/L, FLO-243 (at Florence) with 0.6 mg/L, and MLB-600 (near the southern tip of Marlboro County) with 2.2 mg/L. One well screened in the Cape Fear Formation (DAR-89 at Darlington) had 1.8 mg/L. This last well also had a high manganese concentration, 0.15 mg/L (maximum recommended is 0.05 mg/L).

Several of the wells produce water with pH below or above the recommended range of 6.5 to 8.5. The low pH values were found mostly in wells producing from the Middendorf Formation (DAR-69, DAR-94, FLO-243, MLB-142, MLB-600). One Black Creek well (DAR-118) had a low pH. High pH was noted only in Black Creek wells (FLO-105, FLO-141, FLO-147). See the map in Appendix 2 for locations of these wells.

Only one of the wells sampled produced water with a dissolved-solids concentration exceeding 500 mg/L, the recommended limit for drinking water. The water from this well (MRN-71, 6 miles southeast of Marion) is a sodium bicarbonate type from the Black Creek Formation. The explanation of the high mineral content lies in the stratigraphic position of the aquifers screened in MRN-71. This well, screened between the depths of 230 and 290 feet, taps the basal sand beds of the Black Creek Formation. An older test well (MRN-77) 16 miles to the south and about the same depth as MRN-71, produced much better water (dissolved solids 284 mg/L), probably because it is screened well above the basal part of the formation. Southern Marion and Florence Counties are far enough down the dip that the lower part of the Cretaceous sediments contains slightly saline water (Fig. 13). At the coastline (near Murrells Inlet, for example) the base of the Cretaceous formations is about 1,500 feet below sea level, but the base of freshwater is only 500-600 feet below sea level.

EFFECT OF SIMULATED INCREASES IN GROUND-WATER PUMPING IN THE PEE DEE REGION

OVERVIEW

To better understand how future increases in ground-water pumping will affect the potentiometric surfaces of the Black Creek and Middendorf aquifers in the Pee Dee Region, a computer model was used to simulate 15 years of pumping (from 1989 through 2003) from the wells of Darlington, Dillon, Florence, Marion, and Marlboro Counties. For each of the five counties, future potentiometric levels were predicted on the basis of the assumption that the wells in that county experience annual increases in pumping while all wells outside that county maintain a constant pumping rate for the duration of the simulation. By increasing the pumping in only one county per simulation, the effect of that county's pumping on the aquifers is more obvious, since the influence of the neighboring counties' pumping is reduced.

Additional simulations were made in which pumping from the wells of all five counties is increased throughout the 15 modeled years. These simulations best demonstrate what effect probable future pumping increases might have on the Black Creek and Middendorf aquifers.

Some simplifying assumptions were made when developing the ground water model. Although both the Black Creek and Middendorf Formations include several distinct aquifers, each formation is assumed to contain only one aquifer; and they are referred to herein as the Black Creek aquifer and the Middendorf aquifer. Also, the wells being pumped in these simulations should be thought of as pumping sites or well fields, rather than individual wells. Although most of the modeled wells do represent individual wells, several represent the aggregate pumping of two or more wells. Additionally, it is assumed that there is no multiaquifer screening; each modeled pumping site taps only one aquifer. The terms "water level" and "potentiometric level" are used interchangeably in the discussion following.

MODELING GROUND WATER LEVELS

The potentiometric levels of an aquifer can be determined by solving a three-dimensional partial differential ground-water flow equation. Unfortunately, in all but the most simple and idealized cases this equation cannot be solved analytically. There are methods of approximating a solution to this equation, however, that involve the use of computer models.

One commonly used approximation technique, the finite-difference method, involves using a grid of rows, columns, and layers to divide a study area into many small blocks, or cells, each of which is considered to be homogeneous and isotropic. After making some simplifying assumptions, the potentiometric level of each cell can be calculated for a given time and given hydrologic conditions. Because the number of cells used in the calculations tends to be large—there are almost 60,000 cells in the model used for the simulations in this report—computer programs are used to solve for the approximated potentiometric levels.

There are two parts to this model: a description of the study area's hydrologic conditions; and a computer program that solves the finite-difference equations and calculates the potentiometric levels.

Each cell in the finite-difference grid must be assigned specific values for several hydrologic parameters, such as transmissivity, storage coefficient, and initial potentiometric level, which are variables in the ground-water flow equation. The model used to describe the hydrologic properties of the South Carolina Coastal Plain for the simulations in this study is essentially that developed by Campbell and van Heeswijk of the U. S. Geological Survey. Refer to Appendix 3 for a more detailed description of this finite-difference model. The computer program used to actually solve for the potentiometric levels, developed by the U. S. Geological Survey (McDonald and Harbaugh, 1984) and commonly referred to as MODFLOW, is a widely used ground-water modeling program.

The output of the modeling program is the potentiometric level for each cell in the grid, calculated for some elapsed simulated time, such as after every simulated day or every simulated year. An example of the model's output is illustrated in Figure 14, which shows the predicted water level decline for the Middendorf aquifer at a site near Lake City during a 15-year simulation.

These modeled water levels for a given aquifer and time can be contoured to produce a potentiometric surface map similar to those of Figures 6 and 7. These maps are useful for describing regional aquifer conditions, but because of their relatively large contour interval (in this case 20 feet), these maps are not very useful for illustrating the smaller changes in an aquifer's potentiometric surface that occur during the simulations made for this study.

A better way to study the effect of increased pumping on the Pee Dee Region's aquifers is to observe the areal water-level decline that occurs during these simulations; it is more instructive to study the changes in an aquifer's potentiometric surface rather than the final shape of that surface. The decline, as illustrated on the hydrograph in Figure 14, is the net distance that the potentiometric level descends at a given site over a given period of time. A contour map showing an aquifer's potentiometric decline during a period of simulated pumping effectively illustrates how, on a regional basis, that aquifer is affected by the modeled pumping. In this study, potentiometric-decline maps are used to show the changes in the potentiometric surfaces of the Black Creek and Middendorf aquifers that would occur from 1993 through 2003 as a result of various pumping scenarios being modeled.

MODELING AQUIFER RESPONSE TO PUMPING RATE INCREASES

Estimating Future Pumping Rates

Each well in the model was assigned a pumping rate that represented that well's average daily pumping for the year being simulated. The 1989-92 pumping rates assigned to most of the wells in this model were based on reported water use information; the 1993-2003 pumping rates for wells not held at their 1992 rates were predicted on the basis of each well's pumping history, type of water use, and water use projections provided by county, city, and public utility officials. When available, water use projections provided by well owners or users were employed to determine future pumping rates. Otherwise, the following scheme was used to estimate annual pumping rates.

Irrigation wells were not given annual pumping rate increases. For the years after 1992, each of these wells was assigned a pumping rate approximately equal to the average rate at which the well pumped during the period 1989-92. After 1992, pumping rates for industrial wells were increased by about 1 percent annually, and pumping from most public supply wells was increased from 1 to 4 percent per year.

Details of each county's estimated future pumping rates are described in the following sections of the report. A listing of all the wells modeled in the five-county study area is located in Appendix 3. This listing includes the well owner, location and aquifer (layer), and pumping rate used for each of the 15 simulated years.

Constant Future Pumping Rates in the Pee Dee Region

The simulations presented in the following sections are designed with the idea that, by increasing the pumping rates of some wells and keeping all other wells at constant pumping rates throughout the simulation, the effect of the increased pumping on an aquifer can be determined by studying the changes in that aquifer's potentiometric surface during the simulation.

Before simulating any increasing pumping rates, however, it is important to determine how the aquifers will respond to holding all of the wells at constant pumping rates. The results of this zero-growth simulation serve as a reference to which the results of other simulations can be compared. The difference between the results of this constant-pumping simulation and an increasing-pumping simulation can be attributed to the differences in pumping rates of the two scenarios, since all other aspects of the simulations are identical.

For this simulation, the 1993-2003 pumping rates for all the wells in the model were set equal to the 1992 pumping rates. For both the Black Creek and Middendorf aquifers, the difference between the predicted water levels for 1993 and those for 2003 is shown in the potentiometric decline maps of Figure 15. It is clear from these maps that the water levels of both aquifers are virtually unchanged after 10 years of modeled pumping, implying that both aquifers can sustain pumping at 1992 rates for a long period of time with little or no change in their potentiometric levels.

Darlington County

Estimated Future Pumping Increases

The 28 Darlington County wells used in these simulations consist of 7 irrigation wells, 3 industrial wells, 5 wells used in electricity generation, and 13 public supply wells. All the irrigation wells pump from the surficial aquifer, and all the other wells pump from the Middendorf aquifer; no Black Creek pumping in Darlington County occurs in these simulations.

The irrigation wells, located mostly in the northeastern part of the county, produce only minor amounts of water annually and have fixed pumping rates throughout the simulation after 1992.

The Sonoco Products well, located in the city of Hartsville, produces more water than any other Darlington County well in the model. On the basis of that company's projections for future water use, this well's pumping rate was increased annually by about ½ percent after 1992. No projected water use estimates were available for the other two industrial wells, belonging to Fiber Industries and the Dixie Cup Corporation, both located near Darlington, so each well's pumping rate was also increased by about ½ percent annually after 1992.

The five wells used by Carolina Power & Light at its plant northwest of Hartsville are all located at essentially the same site. Because these five wells show little change in pumping rates from 1989 through 1992, the 1992 rate for each well is used as that well's pumping rate for the duration of the simulation.

Darlington County's largest ground-water user, the Darlington County Water and Sewer Authority, has seven wells in this model, all located in the Hartsville area. Lacking any official water use projections, a 4-percent annual increase in water demand was

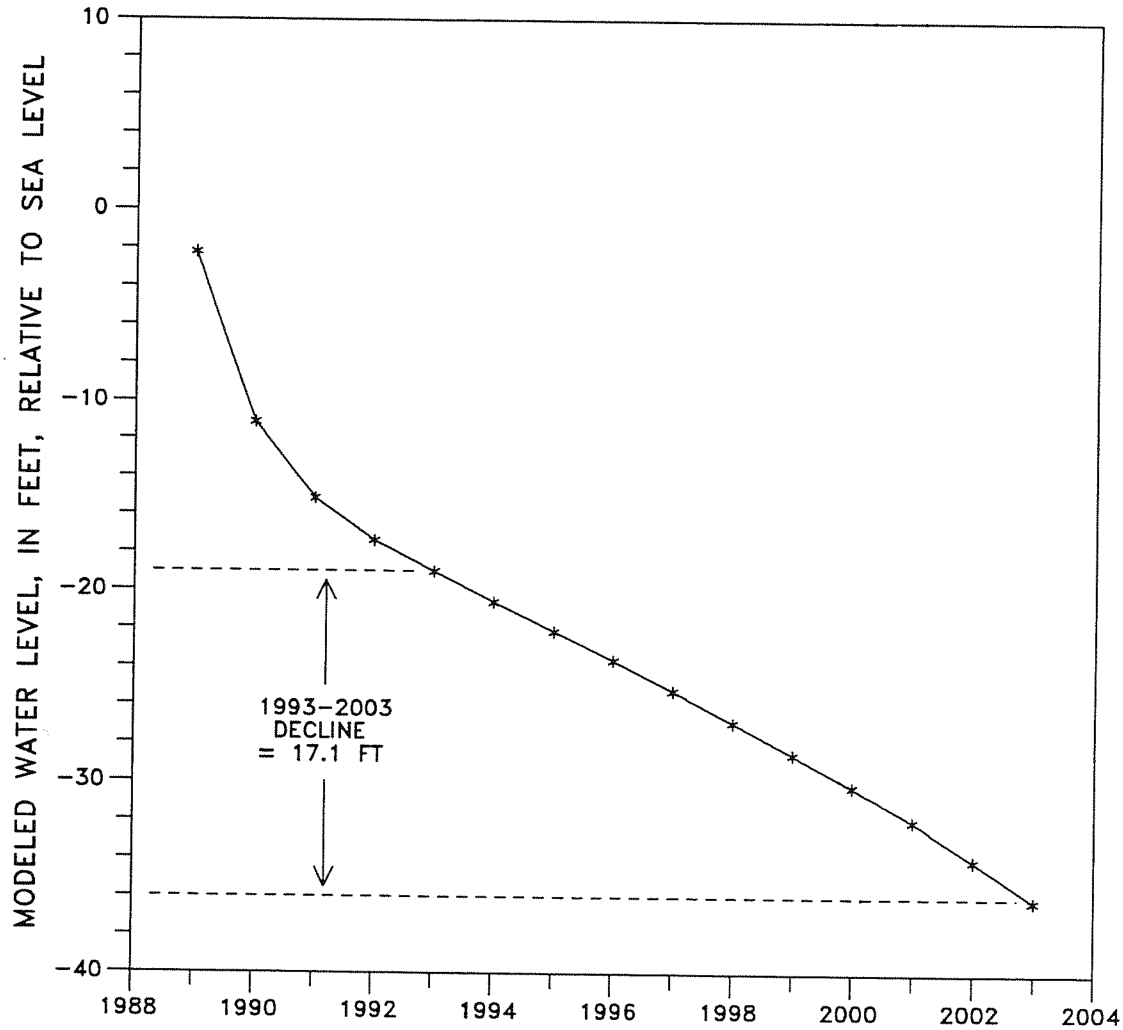

Figure 14. **Predicted Middendorf aquifer water levels at a site near Lake City, from a simulation of annually increasing pumping of Florence County wells.**

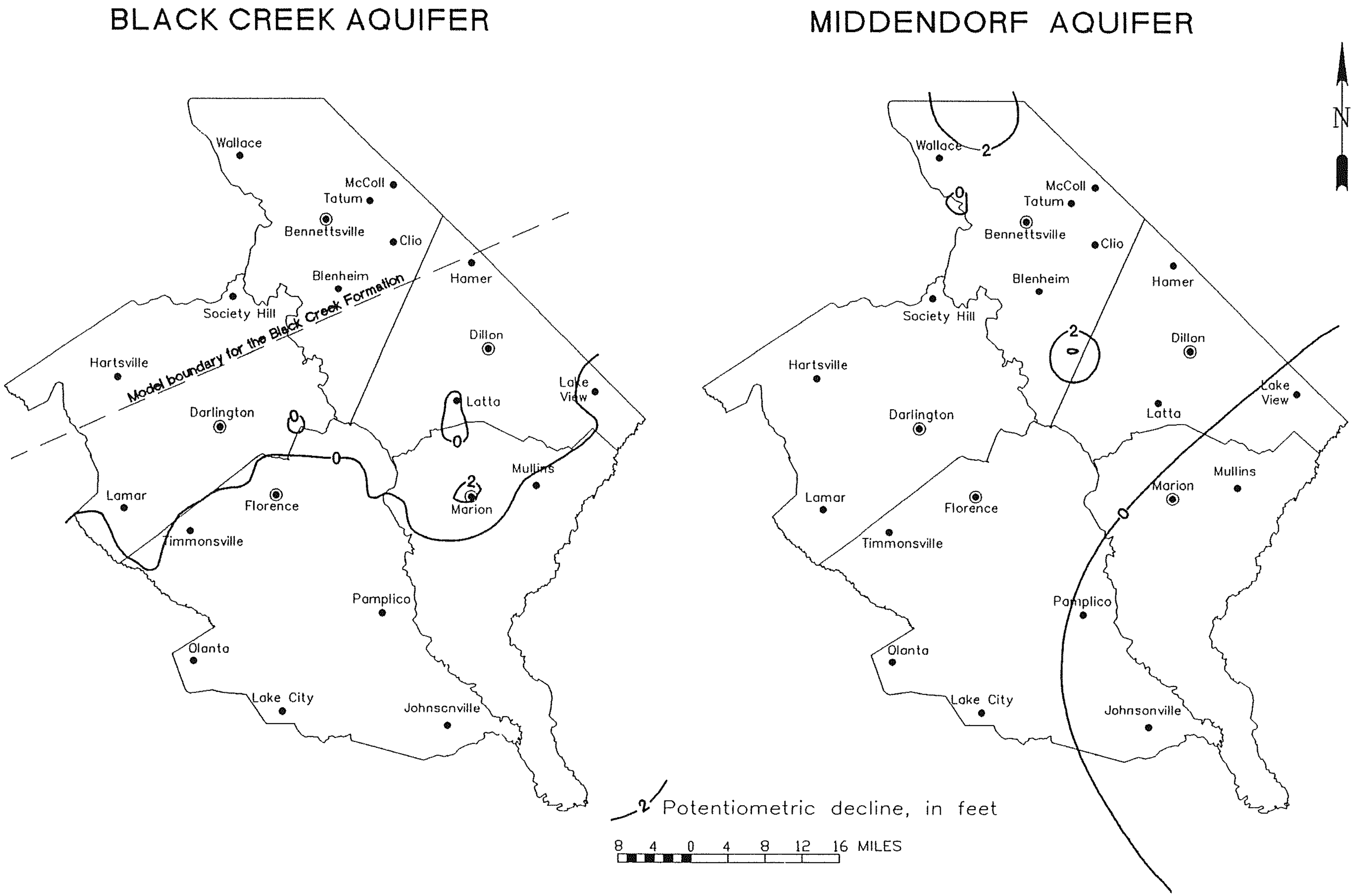

Figure 15. Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with no increased pumping in any county after 1992.

assumed and the wells' pumping rates increased accordingly. One of the water company's modeled wells does not become active in the model until 1996. Located a few miles south of Hartsville, this well represents a new well likely to be drilled in the near future in order to accommodate the increasing demand on the company's system.

The city of Darlington provided water use projections that indicated expected pumping rate increases of 1 percent annually for each of the city's four wells. Lacking official projections from either the city of Hartsville or the town of Society Hill, each of these communities was given an annual pumping rate increase of 1 percent after 1992.

Effect of Future Pumping Increases on the Black Creek Aquifer

Because none of the Darlington County wells in this model pump from the Black Creek aquifer, and because Darlington County is a recharge area for that aquifer, there is no appreciable decline of the potentiometric surface after 10 years of increasing pumping of the Darlington County wells (Fig. 16).

Effect of Future Pumping Increases on the Middendorf Aquifer

Ten years of annually increasing pumping from the Middendorf aquifer in Darlington County results in a noticeable decline in the aquifer's water levels throughout the county (Fig. 16). The decline exceeds 12 feet in the Hartsville area and is greatest at the well site which the Darlington County Water and Sewer Authority is planning to begin pumping in 1996. The city of Darlington is less affected, with about 8 feet of decline, and the decline extends into Florence County, lowering water levels in the city of Florence by almost 4 feet.

Dillon County

Estimated Future Pumping Increases

All 18 modeled wells in Dillon County—1 irrigation, 5 industrial, and 12 public supply wells—tap the Middendorf aquifer.

The one irrigation well, located west of Latta, is a relatively minor water user and was given a constant pumping rate for the years 1993-2003.

The five industrial wells, all belonging to Dixiana Mills, are located northeast of the city of Dillon, near the North Carolina border. The combined pumping from these wells, which are assumed to increase production by 1 percent annually after 1992, make Dixiana Mills the third largest ground-water user in the county.

The city of Dillon has three wells in the model, each in close proximity to the other two. Estimated pumping rates for the years 1993-2003 were based on population growth estimates and average daily per capita water use estimates presented in the report Preliminary Engineering Report for Water Supply System Improvements for the City of Dillon, South Carolina (Hussey, Gay, Bell, & DeYoung, 1992). The increase in pumping needed to meet the projected growth, which amounted to about 1 percent per year, was applied to each of the three wells in proportion to their 1992 pumping rates.

The Trico Water Company is Dillon County's largest user of ground water, having seven wells active in our model and clustered around three water treatment plants. Water use projections provided by D. C. Barbot & Associates, Inc., indicate that the water company will increase production by about 4 percent per year throughout the time period of the simulation.

The town of Latta's one modeled well was increased by a fixed amount each year, increasing the pumping rate by about 1¼ percent annually.

The town of Lake View stopped pumping from its wells in 1992 and began to purchase its water from the Trico Water Company. As a result, pumping from the Lake View system is set to zero for all years after 1992.

Effect of Future Pumping Increases on the Black Creek Aquifer

Because all the Dillon County wells in this simulation pump from the Middendorf aquifer, the increased pumping during 1993-2003 has little effect on the Black Creek aquifer. Figure 17 shows that only a small section of this aquifer, northwest of the City of Dillon, experiences more than 2 feet of drawdown. This drawdown is almost certainly the result of water leaking out of the Black Creek and into the Middendorf aquifer, owing to the much larger drawdown of the Middendorf in this area.

Effect of Future Pumping Increases on the Middendorf Aquifer

The annually increasing pumping of Dillon County wells impacts the Middendorf aquifer throughout most of the county, with the greatest drawdown exceeding 16 feet around the two new Trico wells located northwest of the city of Dillon (Fig. 17). In Dillon, Middendorf water levels decline 10 feet; in Latta, 8 feet. The effect of this increasing pumping extends into the neighboring counties, causing just under 2 feet of drawdown at the cities of Marion and Florence.

Florence County

Differentiating City of Florence Pumping from Other Florence County Pumping

In an effort to differentiate between the effect of increasing pumping of the Florence city wells and the effect of increasing pumping of all the other Florence County wells, two scenarios were modeled for Florence County: one in which the city of Florence wells were kept at constant pumping rates, and one that annually increased the pumping rates of the city's wells. All wells other than those belonging to the city of Florence used the same pumping rates during both simulations.

Estimated Future Pumping Increases

Of the five counties in the study area, Florence County has the largest number of modeled wells and pumps the most ground water. Thirty-one Florence County wells were used in the simulations: 4 irrigation wells, 6 industrial wells, and 21 public supply wells.

The four irrigation wells, located in the center of the county, are relatively small-yield wells and were given constant pumping rates for the years 1993 through 2002. These fixed rates

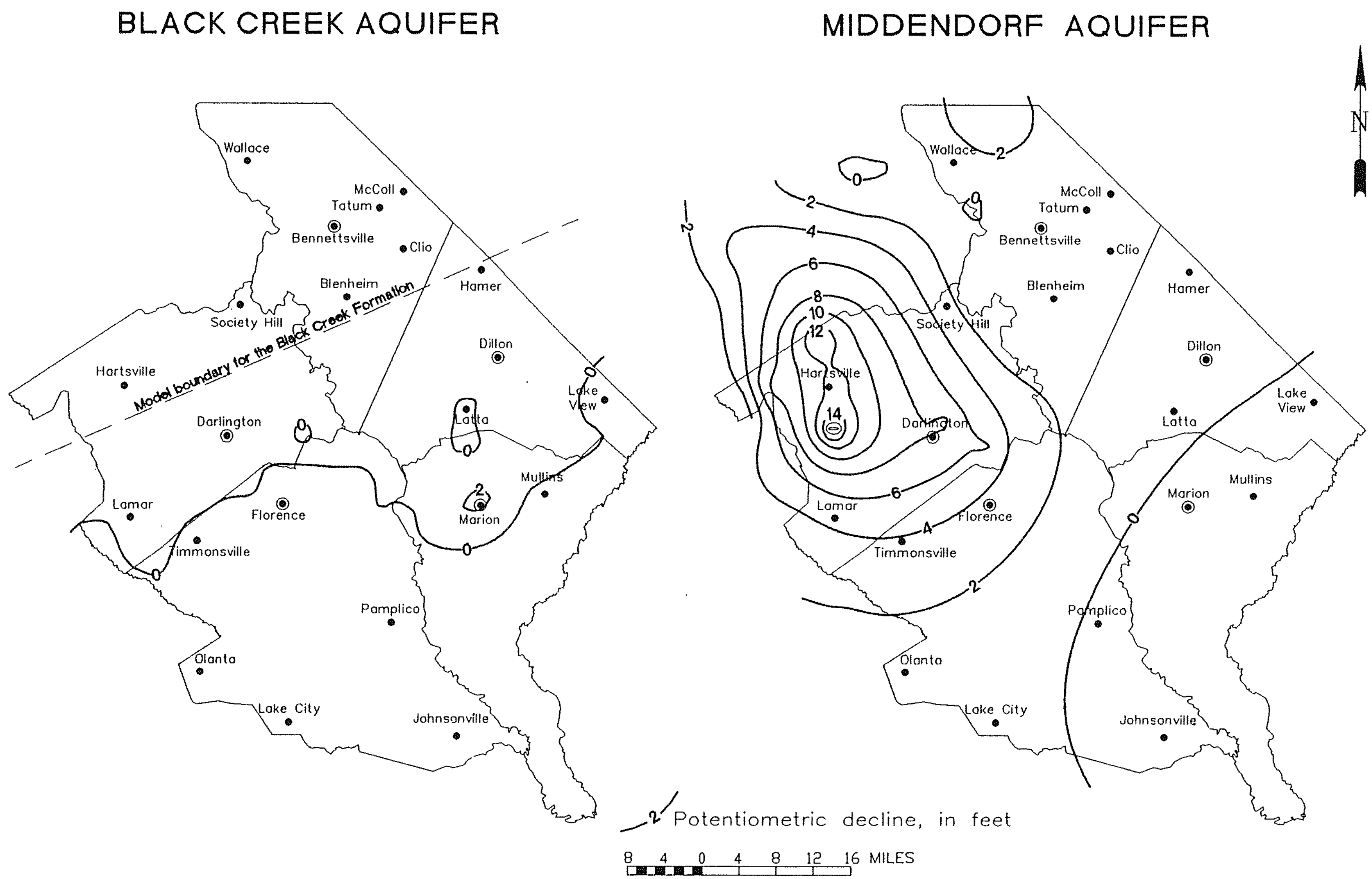

Figure 16. Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with increased pumping in only Darlington County wells after 1992.

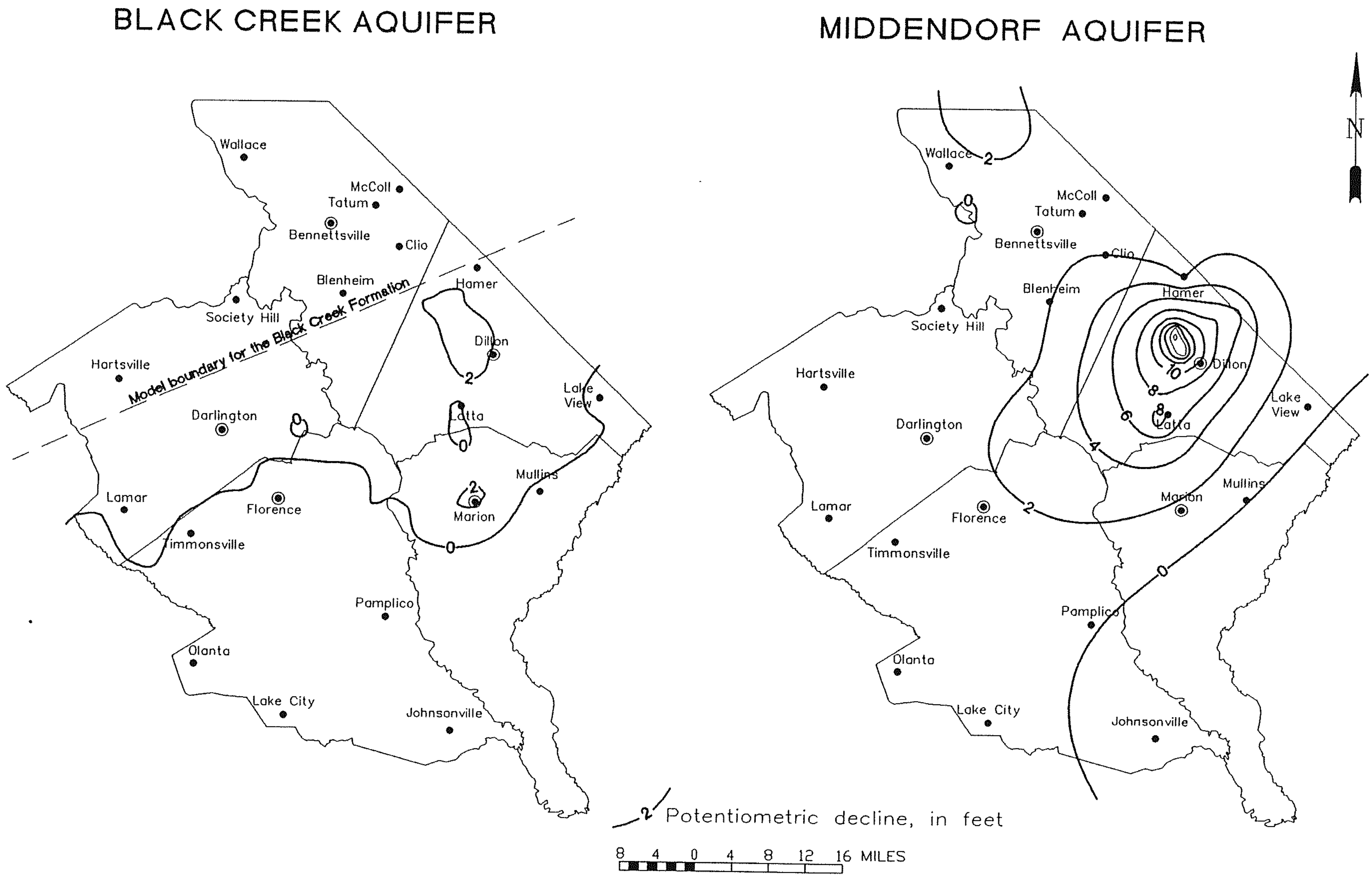

Figure 17. Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with increased pumping in only Dillon County wells after 1992.

approximate each well's average pumping rate during the period 1989-92.

Four of the industrial wells, belonging to Wellman Industries and located in Johnsonville, pump from the Middendorf. The other two industrial wells, located northeast of Pamplico and along the Marion County border, are Black Creek wells and pump considerably less water than the Wellman Industries wells. The pumping rate for each of these six wells was increased about 1 percent annually, starting in 1993.

The 18 public supply wells belonging to the city of Florence are represented by 11 pumping sites, and the 1993-2003 pumping rates for these modeled wells, which all pump from the Middendorf aquifer, depend on which of the two scenarios is being modeled. For the scenario in which the city wells have constant pumping rates, each well is assigned a rate equal to that well's average pumping rate during the period 1989-92. For the scenario in which the city wells have increasing pumping rates, each well's pumping rate is increased 3 percent annually after 1992, without regard to the actual maximum yield of the wells. (By the last year of this simulation, several of the Florence wells have pumping rates that probably far exceed the actual production capacity of those wells.)

Pumping rates for the remaining public supply wells—4 Lake City wells, 3 Johnsonville wells, 1 pumping site representing all of Timmonsville's wells, and 1 pumping site representing all of Olanta's wells—were increased 4 percent annually after 1992. The town of Pamplico began purchasing its water in 1991, so for each year after 1991 the town's one well in the model is assigned a pumping rate of zero.

Seventeen of the 21 modeled public supply wells pump from the Middendorf aquifer; only the three Johnsonville wells and the one Olanta well pump from the Black Creek aquifer.

Effect of Future Pumping Increases on the Black Creek Aquifer

Because most of the Florence County wells pump from the Middendorf aquifer, there is almost no change in the potentiometric surface of the Black Creek aquifer from 1993 to 2003 (Figs. 18 and 19). No modeled wells in the city of Florence system pump from the Black Creek, so increasing Florence's pumping each year has no effect on this aquifer. Only near Johnsonville, which pumps its water supply from this aquifer, is any water-level decline predicted, and this decline may be partially offset by recharging of the cone of depression centered in the Myrtle Beach area.

Effects of Future Pumping Increases on the Middendorf Aquifer

When the city of Florence wells are held to a constant pumping rate similar to their 1992 rates, only about 5 feet of water-level decline of the Middendorf aquifer occurs in the Florence area after 10 years (Fig. 18). Pumping in nearby Timmonsville results in about 10 feet of decline for that town, and the most significant decline—about 16 feet— occurs in the Lake City area. Most of Florence County experiences 4 to 8 feet of decline, and the increased pumping of all the county's wells (other than the city of Florence wells) causes only minor declines in the Middendorf water levels in Marion and Darlington Counties.

When pumping of the city of Florence wells is increased along with the county's other wells, the results of 10 years of pumping are dramatically different (Fig. 19). The decline of the Middendorf water levels in the Florence area exceeds 50 feet, and this decline affects the entire county's water levels. The drawdown in Timmonsville is 25 feet, and at Lake City, the water levels drop more than 20 feet. The increased pumping at Florence also impacts on neighboring counties. The western half of Marion County has 5 to 15 feet of water-level decline, virtually all of Darlington County experiences water-level declines of 5 feet or more, and in the city of Darlington the water levels drop by about 15 feet during the 10 years of pumping.

Marion County

Estimated Future Pumping Increases

Pumping from the 19 modeled wells in Marion County is fairly evenly distributed among the Black Creek and Middendorf aquifers. Public supply wells account for virtually all the modeled pumping in Marion County, which is the second largest ground-water user of the five counties in the study area. There are no industrial wells included in this county's modeled pumping.

The five irrigation wells, located in the central part of the county, pump a relatively insignificant amount of water (less than 1 percent of the county's total pumping) from the Black Creek aquifer, and were given constant pumping rates from 1993 through 2003. Two wells, located about 10 miles south of the city of Marion, pump water from the Middendorf at an assumed constant rate from 1993 through 2003 to supply water for catfish farm ponds.

The town of Mullins has five modeled wells, all of which pump from the Black Creek aquifer. Water use in the Mullins system was assumed to increase by 4 percent annually after 1992, since the town did not supply any specific water use projections.

The city of Marion is the county's largest ground-water user. All of the city's wells, grouped together in the model as one well representing the combined pumping of all the city's wells, are assumed to pump from the Black Creek aquifer. The city did not provide specific water use projections through the year 2003; therefore, pumping was assumed to increase by about 4 percent annually.

The Marco Rural Water Company, the second largest ground-water user in the county, pumps primarily from the Middendorf aquifer. D. C. Barbot & Associates, Inc., provided projected water use for the Marco Rural Water Company through the year 2004, but these projections, which called for about an 8 percent annual increase in water use, did not indicate how the increased pumping was expected to be distributed among the five Marco wells in service as of early 1994.

Marco's projected annual water use from 1993 through 2003 was met by increased pumping from the Marco wells. Increases in pumping were applied fairly evenly to all the Marco wells until a well reached its estimated maximum production capacity. These capacities, determined by calculating how much water a well would produce if it were pumped at its maximum yield for 16 hours per day, were calculated from information in the South Carolina Water Resources Commission well records. After a well

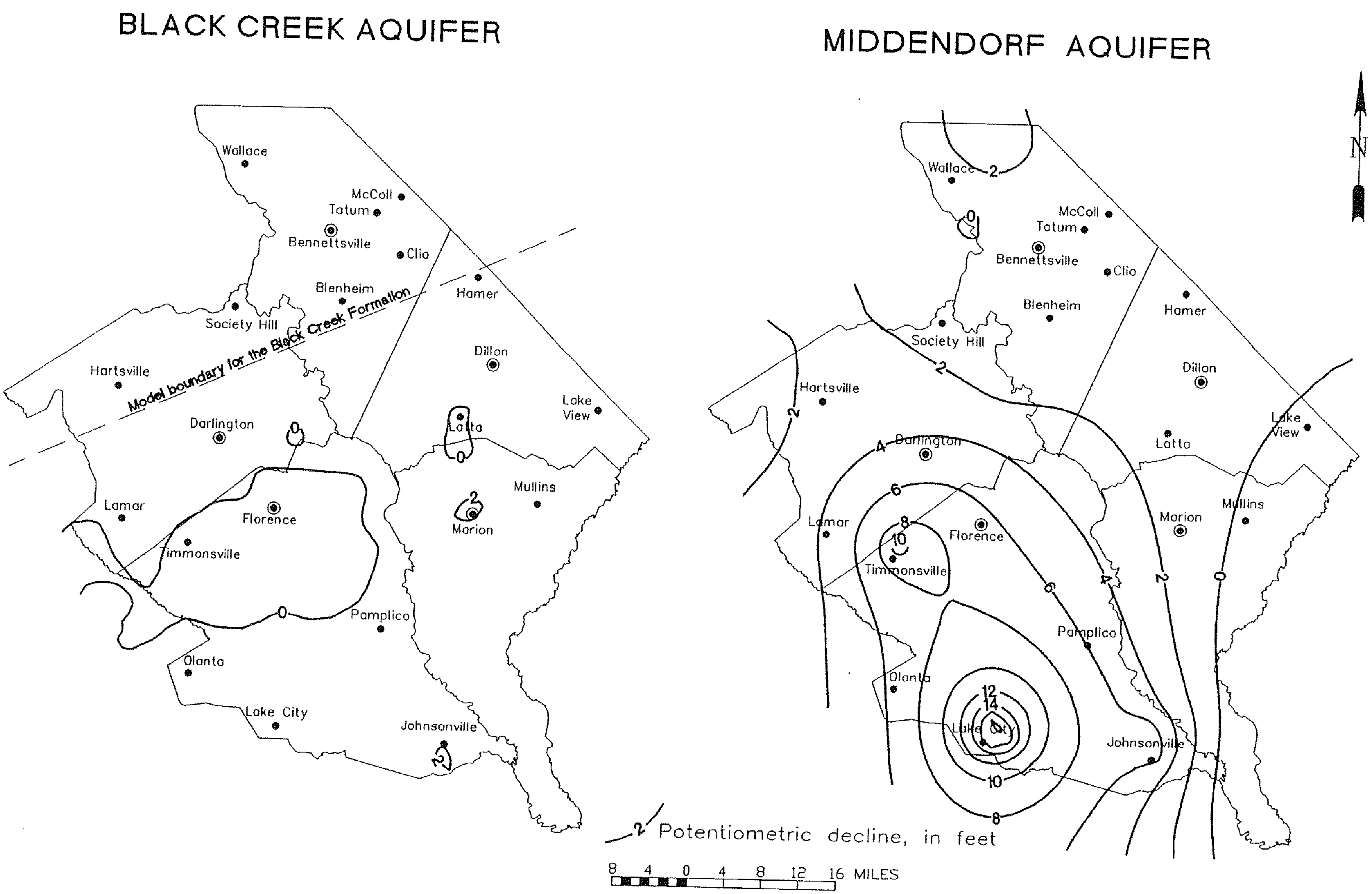

Figure 18. **Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with annually increased pumping in only Florence County wells after 1992 and no increased pumping in the city of Florence wells.**

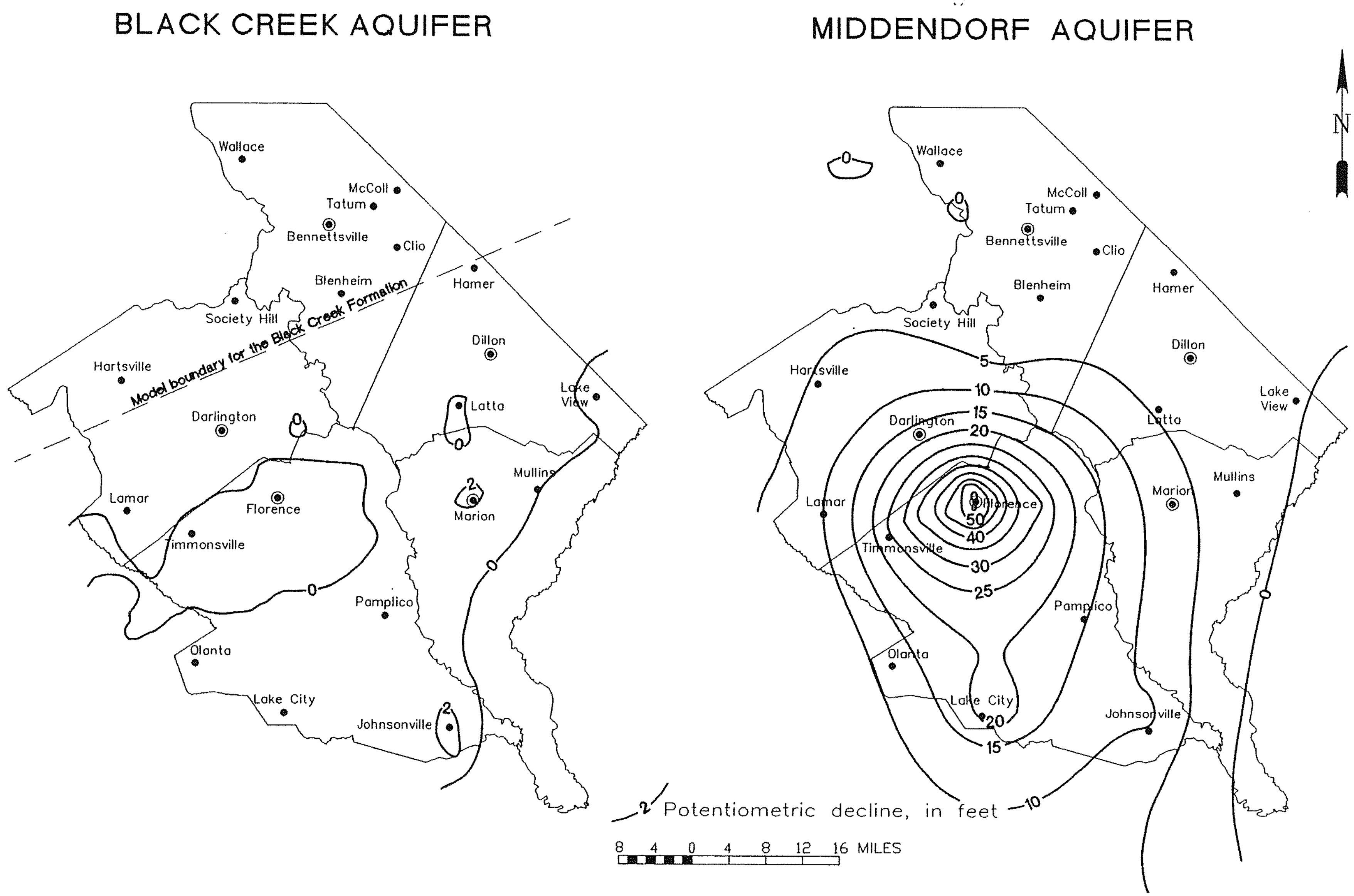

Figure 19. **Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with annually increased pumping in only Florence County wells after 1992 and increased pumping in the city of Florence wells.**

had reached its maximum capacity, the pumping rate for that well was not increased; other wells were pumped more to meet the projected demand.

The addition of Marco Well 6 to the system in 1995 allows Marco to meet the projected water use demand until about the year 2001, at which time another well is needed. A hypothetical new well (Marco 7), arbitrarily located about 7 miles southeast of the city of Marion and assumed to be a Middendorf well, allows the Marco system to meet projected water use through the year 2003.

Effect of Future Pumping Increases on the Black Creek Aquifer

Figure 20 shows that 10 years of increasing pumping of the city of Marion's wells has a significant effect on the Black Creek aquifer in the Marion area. The potentiometric decline of this aquifer exceeds 22 feet at the site of the modeled city wells, but this decline is limited in its areal extent. About half of the 6 feet of drawdown predicted in Mullins is due to the Marion pumping; the rest is due to increased pumping by the town of Mullins. The increased pumping from the Black Creek aquifer in Marion and Mullins appears to have no effect on the aquifer outside Marion County.

Effect of Future Pumping Increases on the Middendorf Aquifer

The only increased pumping from the Middendorf during this simulation occurred in the Marco wells, and almost all of this aquifer in Marion County is affected by those increases (Fig. 20). Although the potentiometric decline of this aquifer, centered at the two newest modeled Marco wells, was not as great as the decline of the Black Creek aquifer at Marion, it is much more widespread. This aquifer has declines of about 15 feet in Mullins, 11 feet in Marion, and about 5 feet in much of the area where Marion County borders Dillon County and Florence County. The cities of Dillon and Florence both experience almost 2 feet of Middendorf water-level decline owing to the increased pumping of the Marco wells.

Marlboro County

Estimated Future Pumping Increases

Eleven irrigation wells, three industrial wells, and six public supply wells account for all of Marlboro County's modeled pumping. Four of the wells tap surficial aquifers; the rest pump from the Middendorf. No modeled wells pump from the Black Creek aquifer.

Eight of the 11 irrigation wells pump from the Middendorf aquifer, and only one well, near Bennettsville, pumps more than 100 gallons per minute. All 11 wells were set to constant pumping rates throughout the simulation after 1992.

The three industrial wells, owned by Oak River Mills, are located together at a site just west of Bennettsville. Considered together, these three wells are the second largest user of ground water in the county. Pumping rates for these wells were assumed to increase by 1 percent per year after 1992.

The city of Bennettsville, whose wells are all grouped together as one well in the model, is the largest water user in the county. Due primarily to the city's use of Lake Wallace as an additional water source, a practice begun in early 1991, Bennettsville's 1992 pumping rate is roughly half that of 1990. Because of this surface water supply, near-future increases in the city's pumping rates are unlikely, so the modeled pumping rates for Bennettsville's well for 1994-2003 were held constant at a rate approximately equal to the 1993 rate, which was derived from the city's reported ground-water pumping for that year.

The wells belonging to the Wallace Water Company, the town of McColl, and the Marlboro Water Company were each assigned pumping rate increases of 1 percent annually, starting with the 1993 model year. The one well belonging to the town of Clio was set to a constant pumping rate for 1992-2003 which approximately equaled the town's reported pumping rates for 1989-1991.

Effect of Future Pumping Increases on the Black Creek Aquifer

Because no wells in Marlboro County pumped water from the Black Creek aquifer during this simulation, and because of this aquifer's limited extent in Marlboro County, this aquifer is essentially unaffected by the increases in pumping from Marlboro County wells, as illustrated in the potentiometric decline map of Figure 21.

Effect of Future Pumping Increases on the Middendorf Aquifer

The increases in pumping rates of the Marlboro County wells also had very little effect on the Middendorf aquifer. The most significant water-level decline, occurring in the northernmost part of the county (Fig. 21), is not due to any increases in Marlboro County pumping, as there are no pumping wells within that area, and this same drawdown can be seen on the drawdown map produced from the simulation in which all five counties' pumping rates were held constant after 1992 (Fig. 15). This drawdown may result from changes in the aquifer's recharge rate in this area. Elsewhere in the county, the aquifer has negligible water-level declines.

Three factors may contribute to the apparent stability of this aquifer in Marlboro County: the generally low total volume of water being pumped by all the county's wells each year; the very small (zero- and 1-percent) annual increases in the two largest users' pumping rates; and the fact that the Middendorf aquifer is in a recharge zone in Marlboro County.

Predicting 10-Year Water-Level Declines in the Pee Dee Region

Combined Future Pumping Increases for all Five Counties

Each of the previous simulations isolated one county's pumping increases in order to determine how those particular increases affected the Black Creek and Middendorf aquifers. By keeping the other counties' pumping rates constant, the influence of these other counties' wells on the one county being studied was minimized. A more realistic prediction of how the estimated future pumping increases will affect the aquifers can be obtained by modeling all five counties' predicted pumping rate increases in one simulation.

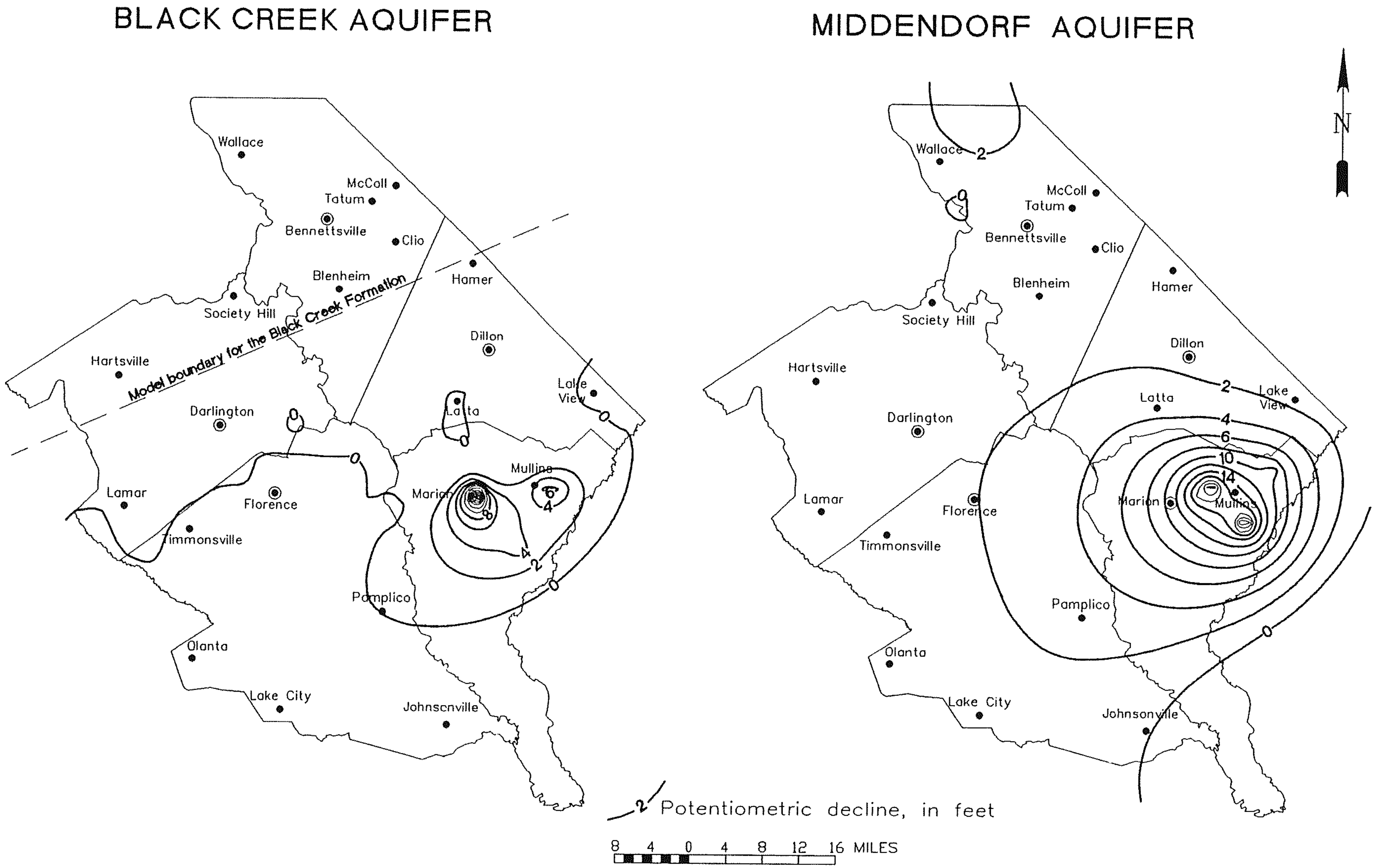

Figure 20. **Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with increased pumping in only Marion County wells after 1992.**

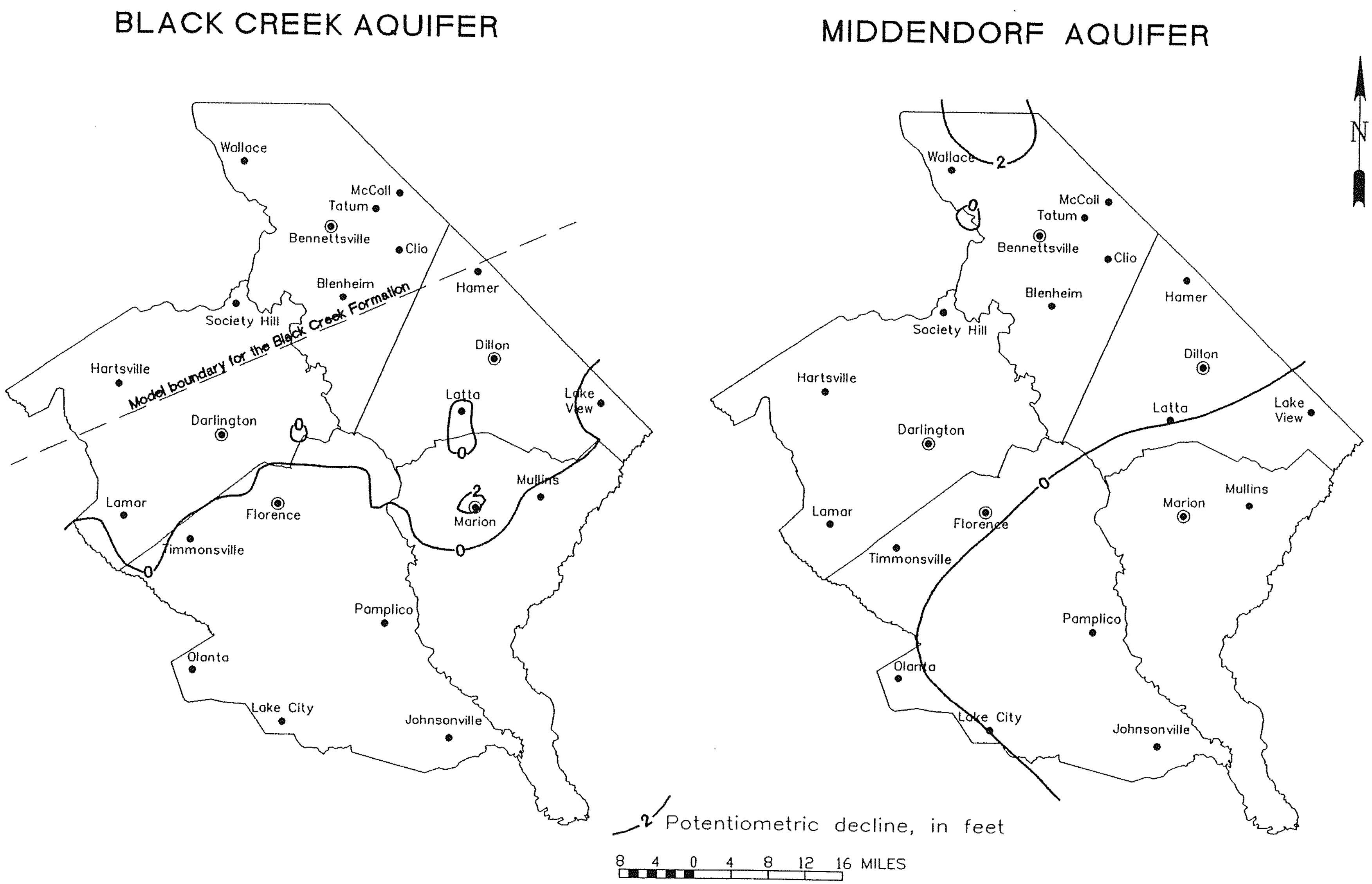

Figure 21. Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with increased pumping in only Marlboro County wells after 1992.

Two scenarios were modeled in which all five counties increased their pumping: one in which the city of Florence wells remained at a fixed pumping rate; and one in which the city of Florence wells experienced annual pumping rate increases. In these two simulations, the pumping rates for the Florence wells were the same as those used in the two simulations in which only the Florence County wells had annually increasing pumping rates.

Predicted Water-Level Declines: No Increased Pumping in the City of Florence

The effect of 10 years of anticipated pumping increases in all five counties (except in the city of Florence) on the Black Creek and Middendorf aquifers is shown in Figure 22.

The Black Creek aquifer is affected primarily by the increased pumping of the city of Marion and town of Mullins wells, and this decline is limited to the Marion County area.

The decline of the Middendorf water levels in each county is primarily the result of that county's pumping increases, but the combined effect of all the counties increasing their pumping is to lower the potentiometric surface of this aquifer an additional amount, from about 2 feet near most of the study area's perimeter, to about 6 feet in northern Florence County, an area influenced by the pumping in each of the five counties. Northern Marlboro County, which is a recharge zone for the Middendorf aquifer, is essentially unaffected by increased pumping of the wells in this study area.

Predicted Water-Level Declines: Increased Pumping in the City of Florence

A comparison of Figures 22 and 23 reveals how future increases in the pumping rates of the city of Florence wells will affect the Black Creek and Middendorf aquifers.

The Black Creek aquifer's water-level decline predicted in this simulation (Fig. 23) is almost identical to the water-level decline predicted in the previous simulation (Fig. 22), indicating that, in this model, the city of Florence pumping has little effect on the Black Creek water levels.

The potentiometric decline of the Middendorf in the city of Florence area exceeds 60 feet, and the entire area of Lake City, Hartsville, Dillon, and Marion experiences at least 20 feet of decline after 10 years of the predicted pumping increases. The declines at these cities are only slightly greater than the regional decline in the aquifer's potentiometric surface. Only the northern part of Marlboro county is unaffected by the city of Florence pumping increases.

CONCLUSIONS

A computer model simulated anticipated pumping from wells in Darlington, Dillon, Florence, Marion, and Marlboro Counties, from 1989 through 2003, in order to predict the impact of the anticipated pumping increases on the Black Creek and Middendorf aquifers.

Both the Black Creek and Middendorf aquifers appear capable of sustaining long-term pumping at 1992 rates with little change in either aquifer's potentiometric levels.

The only significant influence on the Black Creek aquifer appears to be the city of Marion's pumping. More than 20 feet of water-level decline is predicted from 1993 to 2003 at Marion, but this decline is restricted to a relatively small area; outside Marion County, the city of Marion's pumping has no appreciable effect on the Black Creek aquifer.

Pumping increases in Marlboro County will have little impact on the Middendorf aquifer, but pumping from this aquifer in other counties may produce several feet of water level decline in the southern part of Marlboro County. From 1993 to 2003, increases in Middendorf pumping in Darlington, Dillon, and Marion Counties will cause a regional lowering of 2 to 6 feet in the Middendorf's potentiometric surface, with additional localized declines of 10 to 20 feet at pumping sites near Hartsville, Dillon, and Marion.

In Florence County, the pumping increases anticipated for Timmonsville and Lake City will cause localized declines of about 12 feet and almost 20 feet, respectively, between 1993 and 2003. The city of Florence's future pumping rate will have the most impact on the Middendorf aquifer in this five-county region. If the city maintains its 1992 pumping rate through the year 2003, the aquifer will undergo about 10 feet of decline throughout most of Florence, Darlington, and Marion Counties. A 3-percent annual increase in the city's pumping from 1993 to 2003, however, would cause an additional 50 feet of decline at Florence, and an additional 10 feet or more throughout much of Darlington, Florence, Dillon, and Marion Counties.

GROUND-WATER MANAGEMENT ALTERNATIVES FOR THE CITY OF FLORENCE

The city of Florence, situated 75 miles east of Columbia, S.C., and 95 miles southeast of Charlotte, N.C., is considered the center of commercial, medical, transportation, and cultural activities in the Pee Dee Region. With a population of approximately 30,000, it is the primary urban center in the region and the seventh most populated city in the State. The climate is mild, with the average temperature ranging from 48°F in the winter to 78°F in the summer. Normal annual rainfall is approximately 48 inches, with July and August being the wettest months. Winds blow most frequently from the south and southwest; average wind speed is 8 miles per hour.

Florence's strategic location and mild climate have attracted many industries and people to the area, spurring substantial growth. This growth, however, has caused considerable stress to the present water system that relies heavily on the aquifers of the Middendorf Formation. As a result, these aquifers are experiencing severe potentiometric-level declines. In an attempt to alleviate this problem, the city is considering several alternatives. Some of these alternatives involve the redistribution of pumpage and the reconfiguration of the current well system. To analyze these alternatives, a ground-water management modeling package was developed. This package consists of two parts: (1) a ground-water flow simulation model and (2) an optimization model. The simulation model evaluates the response of the aquifer to pumping, and the optimization model determines the magnitude and distribution of pumping that causes the minimum impact on the aquifer.

Following are an overview of the Florence well system and a

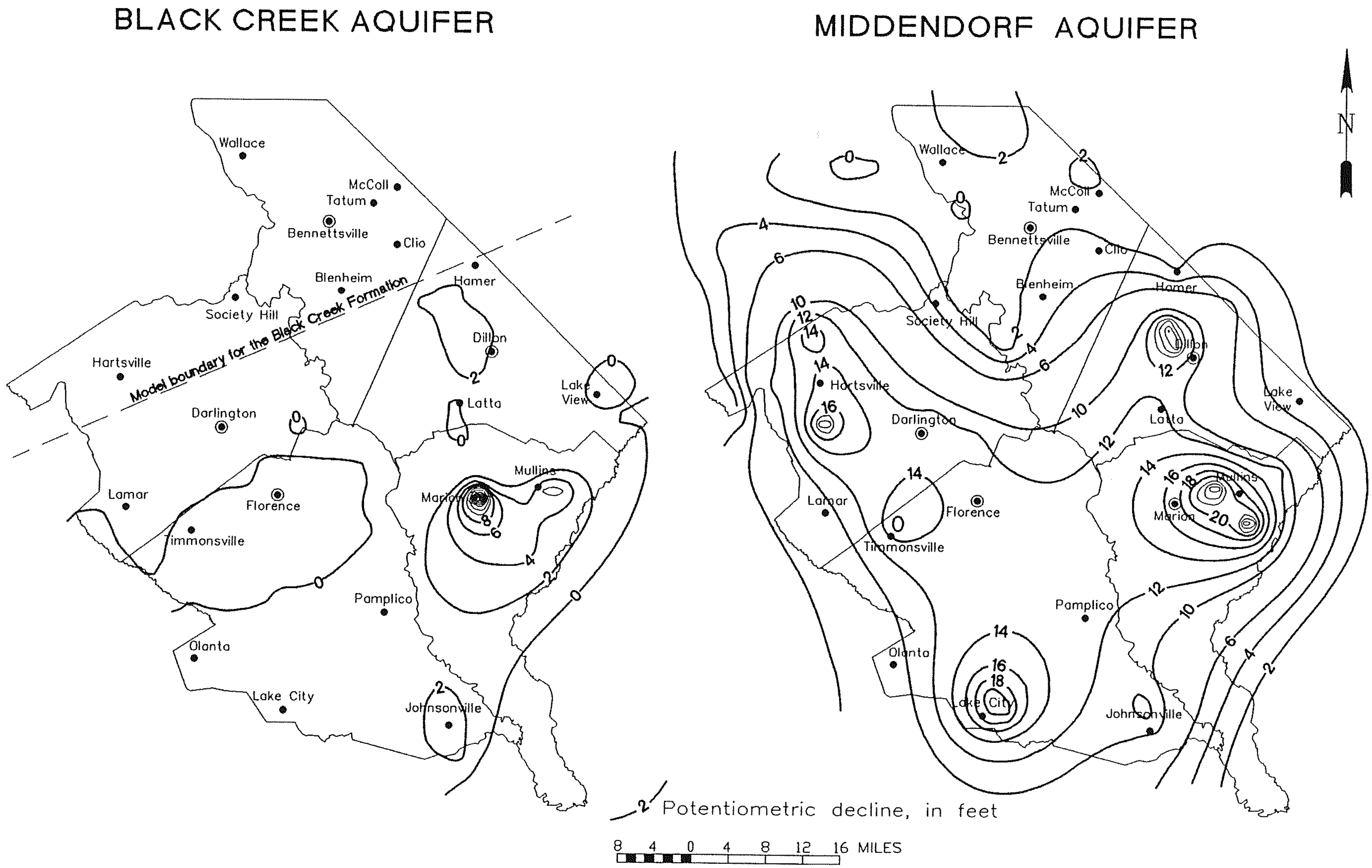

Figure 22. **Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with increased pumping in all five counties' wells, except the city of Florence wells, after 1992.**

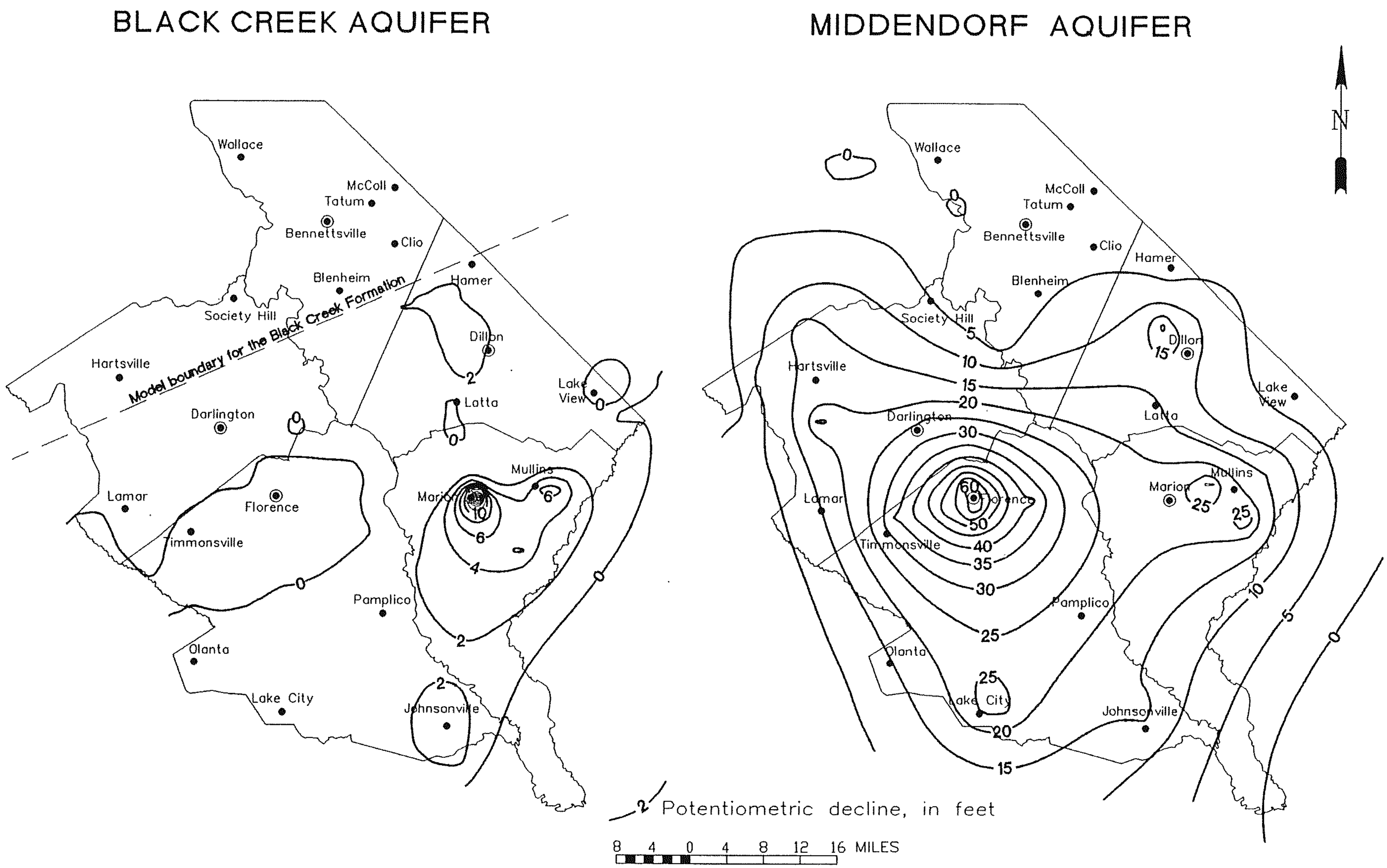

Figure 23. Predicted potentiometric decline for the Black Creek and Middendorf aquifers from 1993 to 2003, with increased pumping in all five counties' wells, including the city of Florence wells, after 1992.

description of the models. A discussion of the results of the simulation of several management alternatives is provided later.

WATER- SUPPLY SYSTEM

The city of Florence water-supply system is the second largest ground-water based system in the State and serves a population of more than 67,000 spread over an area of approximately 70 square miles that includes the city and unincorporated county areas. The system, which has more than 16,000 connections, consists of 12 water treatment plants, 18 wells, and 9 elevated tanks. Seven treatment plants are fed by a single well each, four receive water from two wells each, and one is fed by three wells. Table 4 lists the treatment plants along with their associated wells. The location of each well is shown in Figure 24.

Table 4. City of Florence water-supply system facilities

Facility	Treatment capacity (mgd)	Well[1]	Pump capacity (mgd)
Pine Street Plant	1.5	16 on site	1.10
Boatwright Plant	1.0	17 on site	0.8
Gulley Branch Plant	1.5	18 on site	1.50
Edisto Plant	2.0	33 off site	1.30
Ballard Street Plant	1.0	20 on site	0.65
Darlington Street Plant	2.5	21 on site	1.30
		27 off site	1.00
McCown Drive Plant	2.5	22 on site	0.80
		28 off site	1.10
Lucas Street Plant	2.0	24 on site	1.50
Oakdale Plant	2.0	25 on site	1.50
G. E. Plant	2.5	26 on site	0.75
		32 off site	0.75
East Florence Plant	3.0	30 on site	1.50
		31 off site	1.50
South Florence Plant	3.0	34 on site	0.43
		35 off site	1.14
		36 off site	1.14
Total	24.5		19.76

[1]City numbers of wells serving plants.

The quantity of water produced by the system from 1972 to 1993 is shown in Figure 25. A steadily growing trend can be noticed. Marked declines occurred in 1991 and 1992. These declines probably can be attributed to a water-price increase and wetter than usual summers. In 1993,however, the rising trend in water production was resumed. Data from 1972 to 1982 were obtained from engineering reports to the city. After 1982, data were obtained from water-use reports to the Water Resources Commission.

WATER SOURCE

The main source of water at Florence is the Middendorf Formation, which consists of interbedded layers of sand and clay. See Curley (1990) for a lithologic description of the material. Recharge to the aquifers occurs directly from precipitation on the outcrop area of the formation. (Fig. 26). The Pee Dee River and tributaries that traverse this area drain a substantial part of the recharge (Aucott and others, 1987). Leakage from the Black Creek and Cape Fear Formations also contributes to the recharge of the aquifer. This recharge accounts for 15 percent of the total ground water flow in the Pee Dee region (approximately 12 percent comes from the Black Creek Formation and 3 percent from the Cape Fear Formation). These estimates were obtained from preliminary simulations of the regional flow made with the U.S. Geological Survey (USGS) model and may be overestimated because comparison of potentiometric levels in the Black Creek and Middendorf Formations (Figs. 6 and 7) does not indicate leakage effects.

The average transmissivity indicated by pumping tests of Middendorf wells at Florence is about 21,000 gpd/ft. Values ranging from 4,000 gpd/ft to 45,000 gpd/ft have been reported (Newcome, 1993). The aquifers are confined. Few values for storage coefficient are available, but an average of 0.0005 is indicated for the Middendorf in the five-county area of this project. This is a typical confined-aquifer storage coefficient.

GROUND-WATER MANAGEMENT MODELING

The ground-water management framework for modeling the Florence well system is based on the "total available drawdown" concept. Under this concept, water production in a well is restricted by the total available drawdown. This drawdown is defined as the difference between the static level and a minimum level specified for each well (Fig. 27). The minimum level may be at the pump intake, at the top of the well screen, or at any higher level considered practical for the operation of the system.

A simulation package consisting of a ground-water flow model and an optimization model is used to simulate the management framework. Simulation results indicate the best combination of withdrawal rates that complies with the minimum-level requirements and satisfies, for as long as possible, the estimated future water demand.

Ground-Water Flow Model

The ground-water flow model was derived from the USGS three-dimensional regional model, using only the portion that corresponds to the Middendorf Formation in the area (Fig. 28). In the new model, the aquifer is represented by a single layer and a computational grid consisting of 78 rows and 85 columns (Fig. 29). The grid is a mathematical artifact used to represent a continuous space with a discrete space formed by a finite number of rectangular cells. To simulate more accurately the distribution of wells in the Florence area, the size of the cells was set equal to 1/4 mile per side (Fig. 30). Outside the city, to save computation time, the cell size was increased gradually to 4 miles per side.

Two types of boundaries were included in the model: no-flow and constant-head boundaries. No-flow boundaries were defined for the northern part of the modeled area that coincides with the edge of the aquifer, and constant-head boundaries were defined elsewhere. Inasmuch as the heads at some of the constant-head boundaries actually may change with time (because they do not coincide with any hydrologic boundary), results from the model

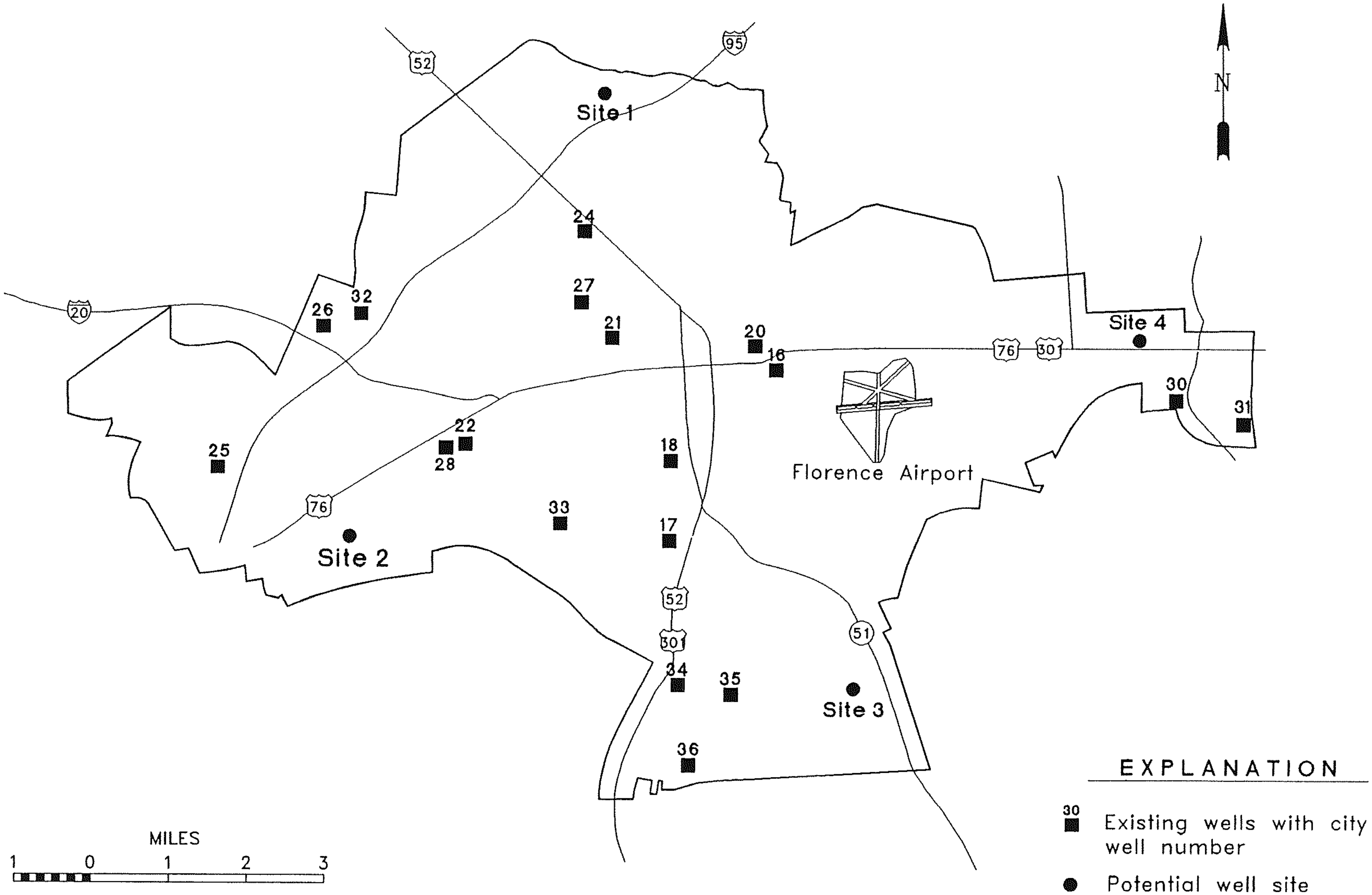

Figure 24. Location of wells in the city of Florence water system service area.

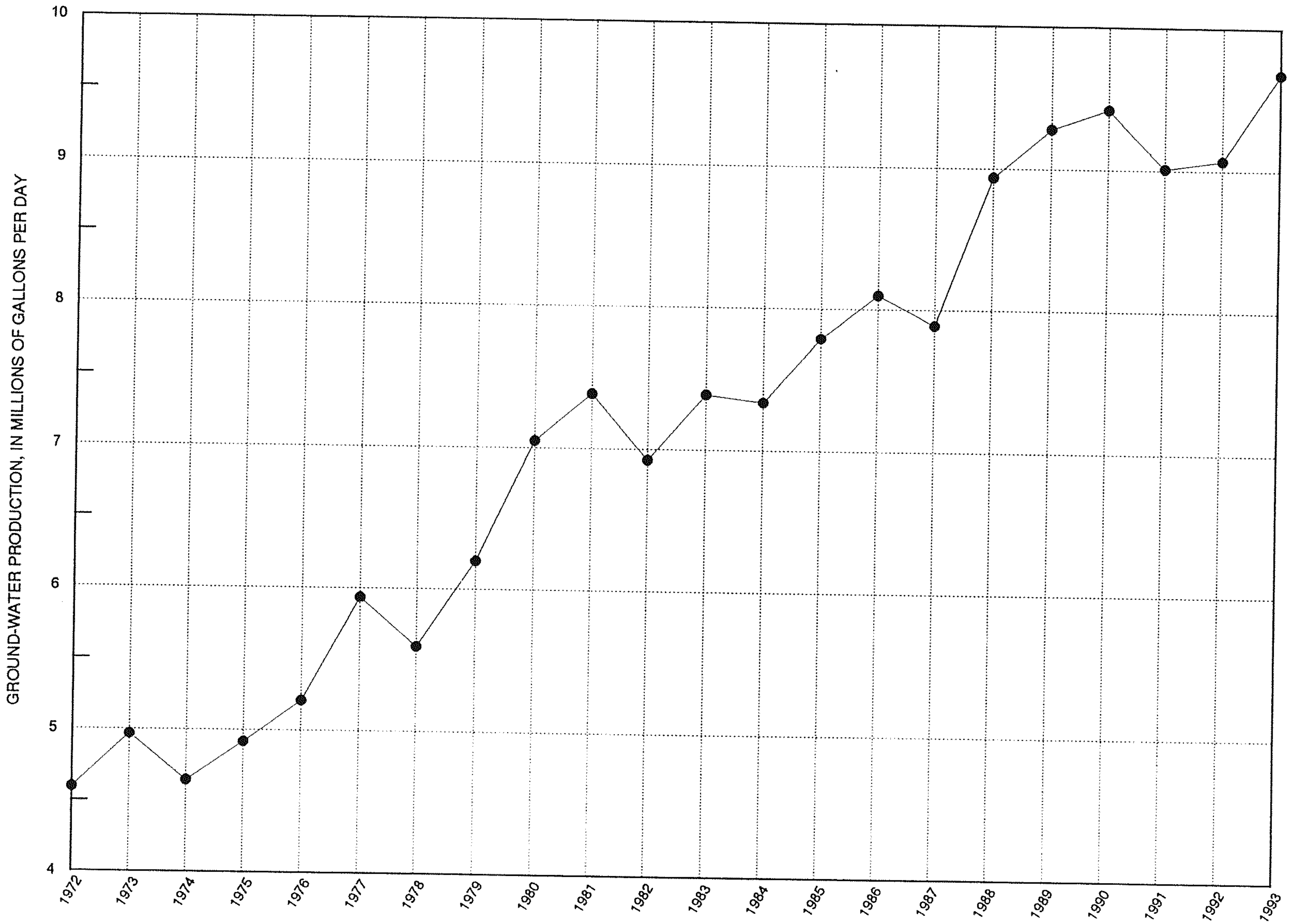

Figure 25. **City of Florence water system production, 1972-93.**

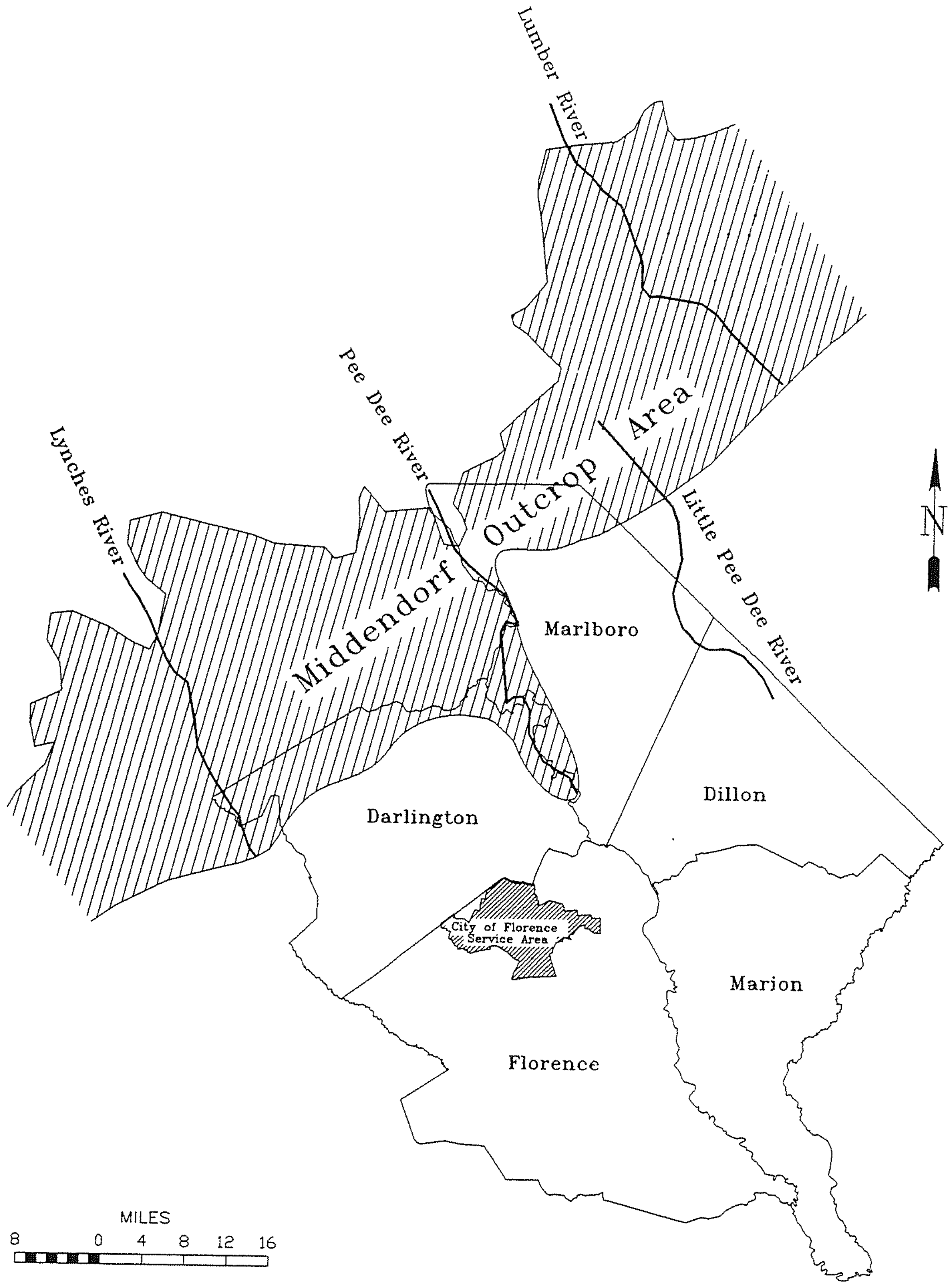

Figure 26. Location of the outcrop area and traversing rivers of the Middendorf Formation.

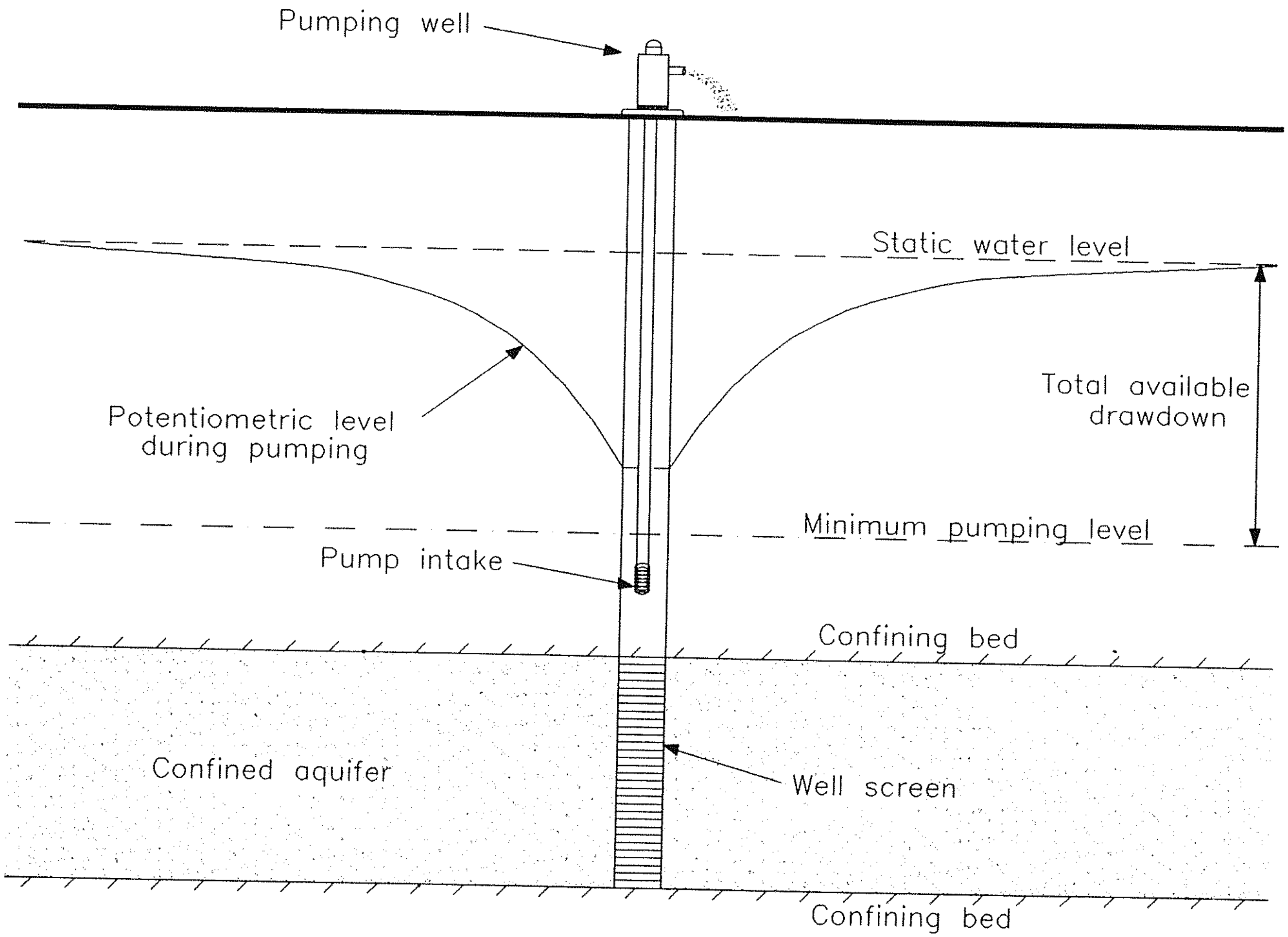

Figure 27. The basic elements of ground-water management.

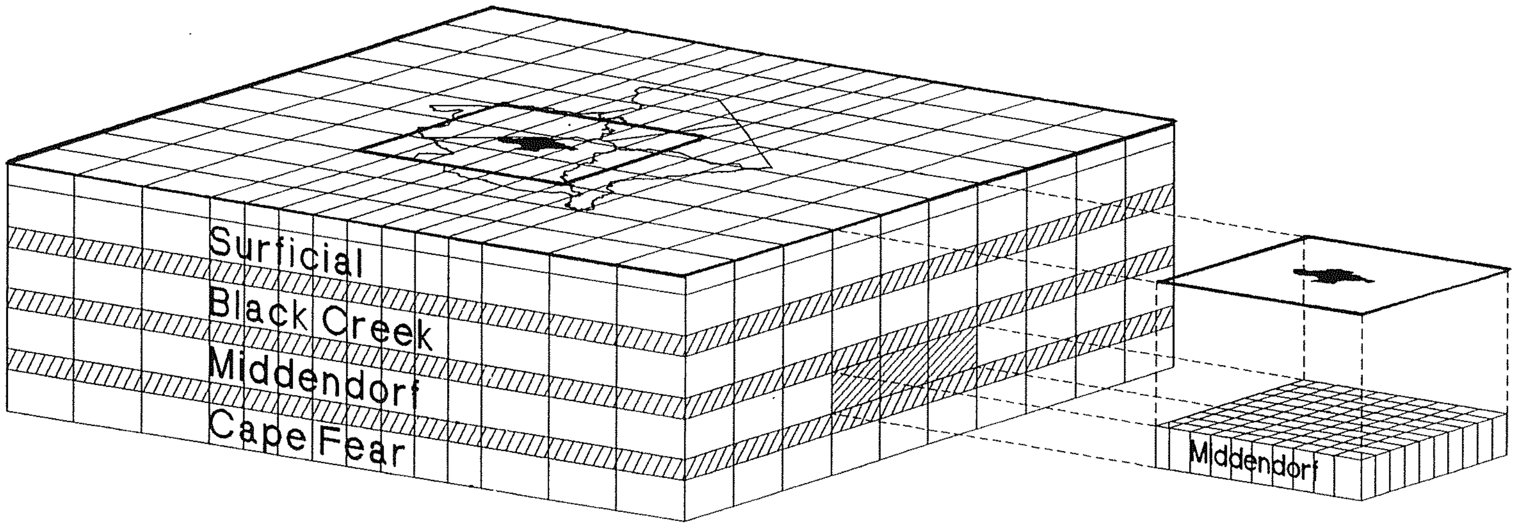

Figure 28. Schematic representation of the ground-water model for the city of Florence.

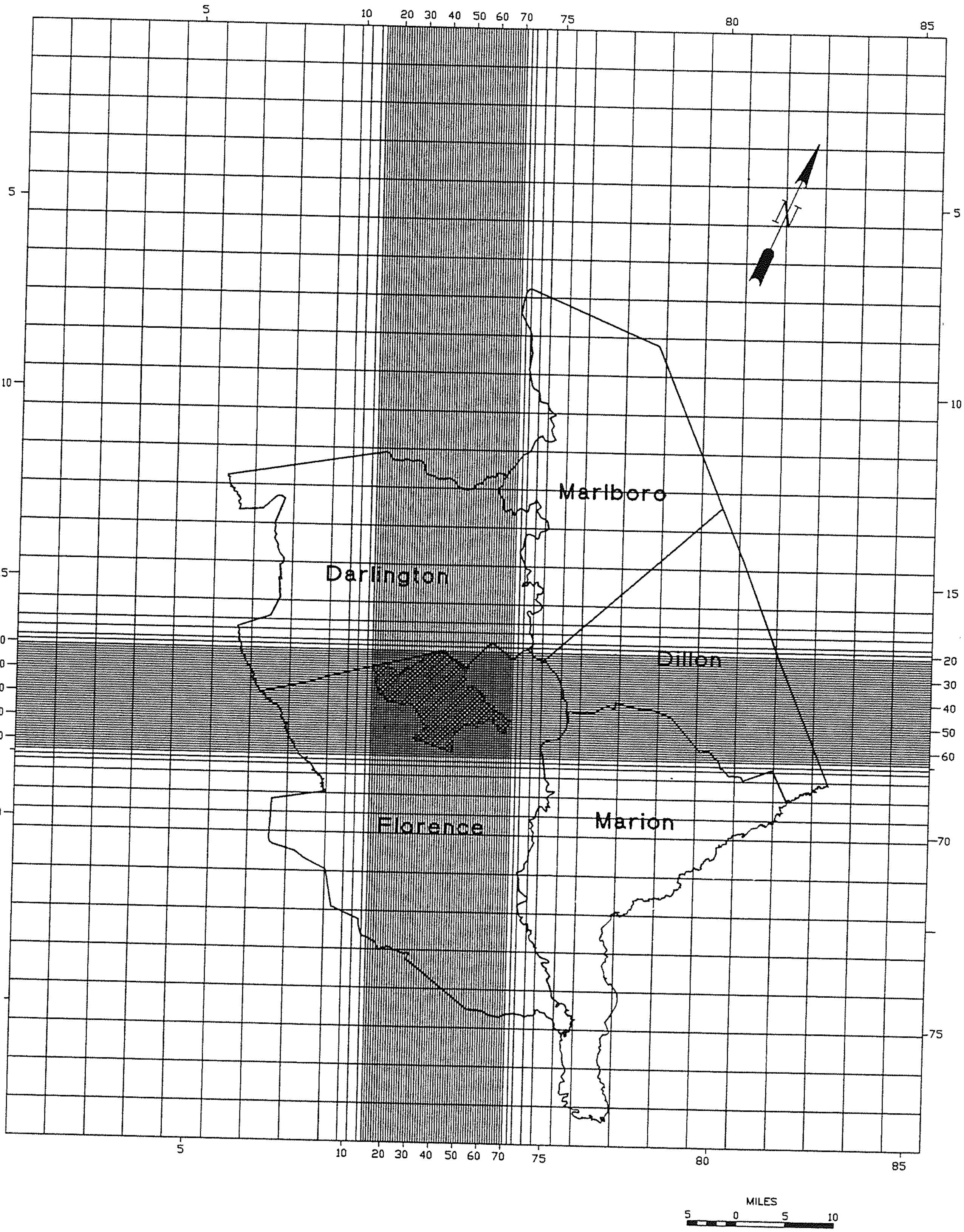

Figure 29. Computational grid for the city of Florence ground-water flow model.

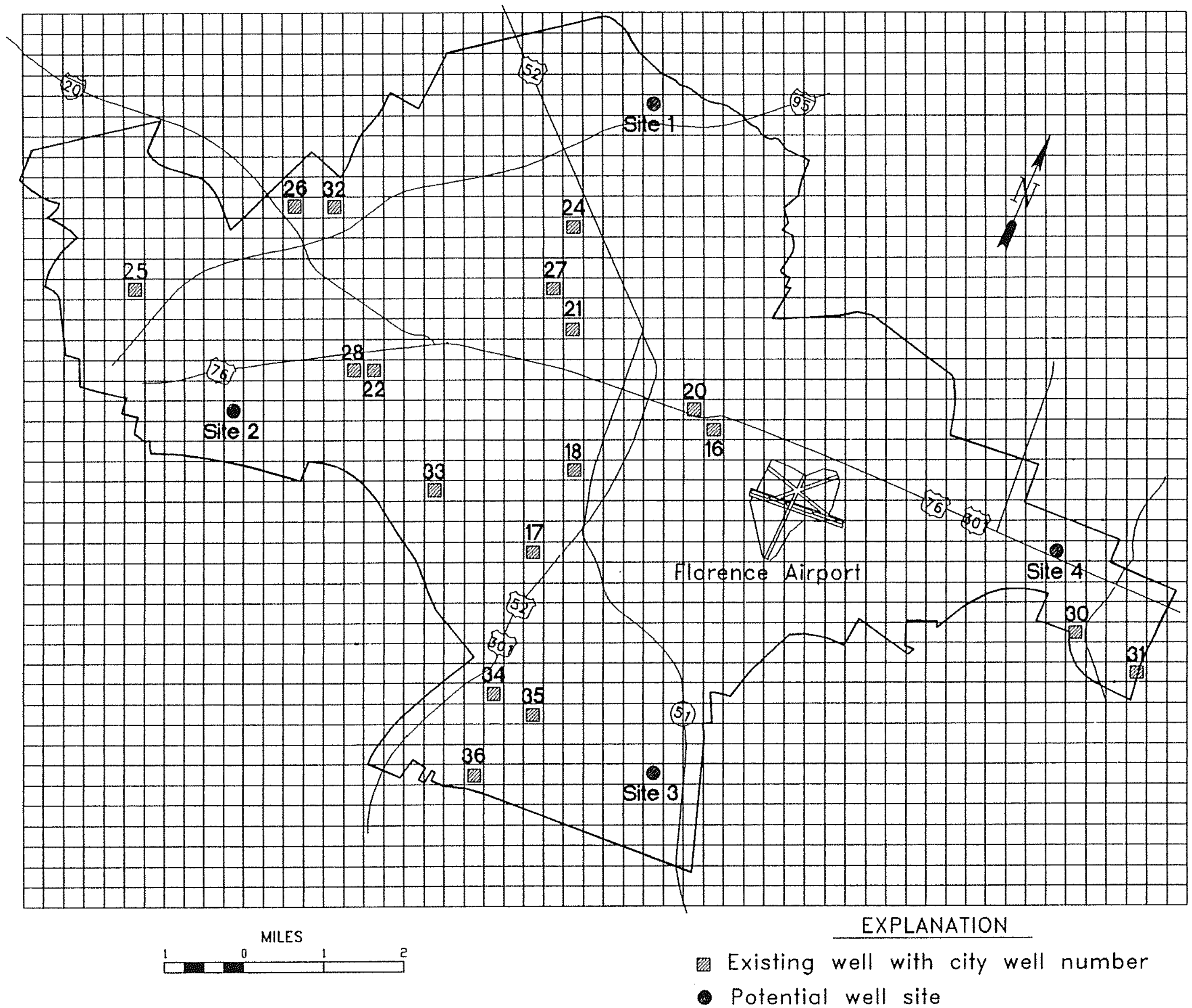

Figure 30. Portion of the computational grid corresponding to the city of Florence area.

may not be accurate near these areas. To minimize their impact on the simulations, these types of boundaries were located far from the city (at least 40 miles away).

Starting heads for the model were defined arbitrarily as the 1987 potentiometric levels. Because there were not enough measurements to define the head at each cell of the model, the starting heads were computed by using the USGS three-dimensional model.

Model Input

Input for the ground-water flow model consisted of river stage, river-bed conductance, recharge rates, transmissivity, storage coefficient, starting heads, and pumping rates. Most of this information was obtained directly from the USGS model, but other data were gathered from topographic maps and existing wells records.

The rivers that were included in the model are the four rivers that traverse the recharge area (Fig. 26). These are the Lumber, Pee Dee, Lynches, and Little Pee Dee Rivers. The Lumber and the Little Pee Dee Rivers are located in the northeastern part of the area, the Pee Dee runs across the middle of the recharge areas for the Middendorf and Black Creek Formations, and the Lynches River is located in the northwestern part of the region. Stage, cross-section, and reach-length data were obtained from topographic maps and information provided by the USGS. This information was then used to compute the initial estimates of river-bed conductance.

Recharge rates for the model were obtained from the results of a study carried out by the USGS as part of the Regional Aquifer Systems Analysis (RASA) program (Aucott, 1988). Recharge due to vertical leakage from the Cape Fear Formation was neglected because of the small fraction of the total regional flow that this represents. Leakage from the Black Creek Formation also was ignored because of the large differences in potentiometric levels observed in the Black Creek and Middendorf Formations (Figs. 6 and 7).

Pumpage in the area was calculated from records maintained by the South Carolina Water Resources Commission as part of the Water Use Reporting Program. Because reporting is voluntary in this program, some of the records were incomplete; therefore, numerical interpolations had to be carried out to fill the gaps.

Transmissivity values for the modeled area were obtained from the USGS three-dimensional model. Inside the city of Florence area, this information was expanded with records from pumping tests conducted at many of the city's wells. Since little information exists about the aquifer storage coefficient, a constant value of 0.0005 was used.

Model Calibration

Calibration of the model consisted of adjusting transmissivity, recharge, and river-bed conductance until a good agreement between observed and simulated values of head and base river flow occurred. The parameters that were adjusted the most during the calibration were recharge rates and river-bed conductance. Because the initial estimates of these parameters were poor, more adjustments were necessary. Transmissivity values, on the other hand, were minimally changed.

Simulated and observed heads were compared for the 1989 potentiometric conditions described in a map report by Stringfield and Campbell (1993). Figure 31 shows potentiometric contours for observed and simulated heads. In general, the shape of the potentiometric surface and the direction of flow are well simulated. In some areas, however, it appears that the simulation is not as good, especially in the recharge areas. Because some observed water levels in these areas are affected by river-stage fluctuation and well pumping, an exact match is not to be expected. Also, the small cones of depression shown by the model in the southern part of the region are not represented by the observed heads, because of the lack of observation wells in that area.

Simulated river flows and the observed base flow are included in Table 5. No records were available for the Little Pee Dee River in the modeled area, consequently this river was not included in the comparisons.

Table 5. Observed and simulated river base flow

River	Reach length (miles)	Base flow (cfs/mi)	
		Observed[1]	Simulated
Lynches	22	3.0	1.86
Pee Dee	34	1.1	1.05
Lumber	31	0.53	0.60

[1] From Aucott and others (1987).

It is clear from this table that a good agreement between observed and simulated base flow was achieved for the Pee Dee and Lumber Rivers. For the Lynches River, however, the base flow could not be well reproduced. Even after varying the river-bed conductance outside reasonable ranges, the model still yielded smaller base-flow values. This probably happened because the model does not account for the effect of local shallow-flow systems, which in this case may be significant.

Optimization Model

An optimization model is formed basically of an objective function and a set of constraints. The objective function represents the goals of the optimization and the constraints define physical and operational restrictions. The goal for the city of Florence well system is to maximize the amount of water produced over a period of 10 years. This goal is represented by the objective function

$$Z = Max \sum_{m=1}^{M} \sum_{n=1}^{N} Q_{m,n} \tag{1}$$

in which $Q_{m,n}$ is the annual withdrawal at well site m and year n and Z is the sum of the withdrawals for all the wells M and years N.

The objective represented by Equation 1 is subject to restricted by various constraints. A constraint restricting the drawdown at each well or specific site of interest to less than or equal to the total available drawdown is defined by

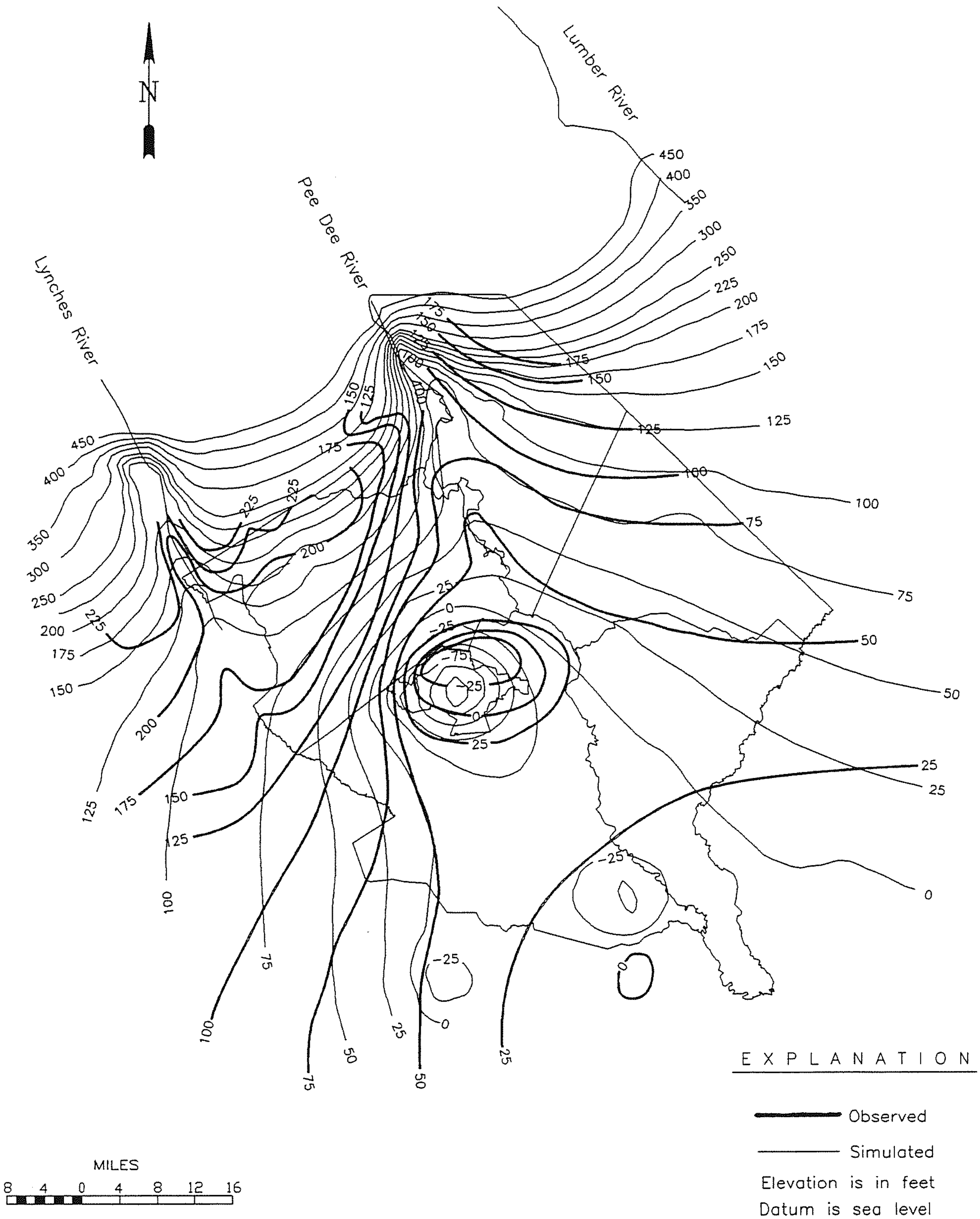

Figure 31. Comparison of observed and simulated potentiometric levels, 1989.

$$d_{l,n} \leq TAD_{l,n} \qquad (2)$$

where $d_{l,n}$ is the drawdown at a well located on site l during year n and $TAD_{l,n}$ is the total available drawdown at the same site and year.

Because the model computes drawdowns as an average cell value, at the cells where the wells are located the drawdown is underestimated. To compensate for the averaging effect, test simulations were performed to determine a correction factor and the total available drawdown was reduced by 20 percent at each well.

Maximum-withdrawal rate constraints are imposed by the capacity of the pumps and by the predicted water demand. The pump-capacity constraints are represented by

$$Q_{m,n} \leq QP_m \qquad (3)$$

where QP_m is the capacity of the pump at well m. This capacity was reduced by one-third to comply with the South Carolina Department of Health and Environmental Control (DHEC) guidelines, which specify that pumping of a well should not continue for more than 16 hours in a day.

The city of Florence water supply system does not have the capacity to store water over years; therefore the annual production of the system is limited by the demand every year. This condition is represented in the model by a set of constraints that specifies the annual production of the system during a year to be less than or equal to the estimated demand for that particular year. These types of constraints are represented by

$$\sum_{m=1}^{M} Q_{m,n} \leq WD_n \qquad (4)$$

where WD_n is the estimated demand during year n, and the summation of withdrawal rates is the well production for that year.

Because the aquifers in the city of Florence area are confined and leakage is low, the drawdowns in Equation 2 can be computed by using unit-response functions of the form

$$d_{l,n} = \sum_{m=1}^{M} \sum_{i=1}^{n} \beta_{l,m,n-i+1} \, Q_{m,i} \qquad (5)$$

where β known as unit response coefficient, is the drawdown at a specific site l resulting from a unit withdrawal (or pumpage) occurring at well m during a time period n. After substitution, the drawdown constraints become

$$\sum_{m=1}^{M} \sum_{i=1}^{n} \beta_{l,m,n-i+1} \, Q_{m,i} \leq TAD_{l,n} \qquad (6)$$

Several methods are available for computing unit-response coefficients. These include analytical, analog, and numerical techniques. In this investigation, a numerical technique was employed. This technique consists of the following steps:

- For a specific well site, a unit withdrawal rate (1 mgd for example) is put into a calibrated ground-water model.
- Drawdowns at the end of the first stress period (1 year for example) are recorded at all the wells in the system.
- The unit withdrawal is then turned off and recovery is recorded at all the wells for the remaining stress periods.
- The procedure is repeated for each well in the system.

After substituting these coefficients into Equation 6, the problem becomes a simple linear programming problem that can be solved with commercial optimization packages. The package used in this investigation is MINOS, which is a general-purpose linear and nonlinear optimization program developed at Stanford University (Murtagh and Sanders, 1987).

ANALYSIS OF ALTERNATIVES

Three alternatives for managing the city of Florence well system were analyzed for a 10-year period with the developed model. These alternatives are (1) redistributing pumpage, (2) increasing the current total available drawdown, and (3) adding new wells to the system.

In the first alternative, the existing configuration of wells and current pump settings are kept unchanged throughout the simulation period, in the second alternative the total available drawdown was increased by lowering the pump intakes, and in the third alternative the pumping capacity of the system is increased by adding new wells to the system. Owing to uncertainty in defining future water demand, annual growth rates ranging from zero to 5 percent were considered in the analysis of alternatives. Table 6 shows the predicted water demand for the various growth rates considered.

Table 6. Predicted water demand for selected annual growth rates at Florence

Year	Water demand, in millions of gallons per day					
	0 %	1%	2%	3%	4%	5%
1994	9.66	9.76	9.85	9.95	10.05	10.14
1995	9.66	9.85	10.05	10.25	10.45	10.65
1996	9.66	9.95	10.25	10.56	10.87	11.18
1997	9.66	10.05	10.46	10.87	11.30	11.74
1998	9.66	10.15	10.67	11.20	11.75	12.33
1999	9.66	10.25	10.88	11.53	12.22	12.95
2000	9.66	10.36	11.10	11.88	12.71	13.59
2001	9.66	10.46	11.32	12.24	13.22	14.27
2002	9.66	10.56	11.54	12.60	13.75	14.99
2003	9.66	10.67	11.78	12.98	14.30	15.74

Note: The figures in this table are based on a compounding rate of growth. The zero-percent growth values correspond to the water production in 1993.

Alternative 1

In this alternative the number of wells and the current positions of the pump intakes are maintained constant for the entire simulation period (1994 to 2003). By redistributing pumping, it was sought to maximize water production and minimize drawdowns. Figure 32 shows the annual water production computed with the model for each of the water-demand growth scenarios considered. After increasing for a few years, water production begins to decrease. This happens because of the cutbacks needed to maintain water levels within the available drawdown. When the production is decreased, water deficits (the difference between the computed production and the estimated water demand) occur, as shown in Figure 33. Note that for the zero-demand growth the water deficits still occur (after the year 1999). This indicates that the present well system cannot maintain the current level of production indefinitely if potentiometric levels are to be kept above the current pump intakes.

The distribution of pumping that generated the water production shown in Figure 32 is included in Appendix 4-1. This appendix contains the annual pumping rate for each well in the system for every year of the simulation period. Pumping at well 18 was zero throughout the simulation. This indicates that the well causes excessive interference and should be discontinued to maximize the production from other wells. Pumping at wells 20, 21, 24, and 27 was gradually reduced. This, again, was done to reduce well interference.

The pumping shown in Appendix 4-1 represents the operation of the well system that has the least impact on the potentiometric level of the aquifer. This operation, however, does not take into account certain practical considerations such as well accessibility and maintenance.

Alternative 2

In this alternative the total available drawdown of the system is increased by hypothetically lowering the pump intakes to the top of the well screen. The purpose of this change is to raise the water production achieved with the existing well system configuration (Alternative 1). The increases accomplished with this alternative are shown in Figure 34. The largest increase obtained is 0.85 mgd. This increase corresponds to the zero percent water-demand growth in the year 2002. For the rest of the water-demand growth conditions, the maximum increase obtained ranges between 0.7 and 0.8 mgd. Note that for all the scenarios there is a period when there are no water production increases. For the zero-percent growth scenario, for example, no gains occur before the year 2000. In this period the amount of water produced by the system is sufficient to satisfy the demand. Therefore, the increase in the total available drawdown becomes irrelevant.

A definite increase in the system's production is achieved with this alternative. The magnitude of this increase, however, is not sufficient to satisfy the predicted demand, as shown in Figure 35. Water deficits still occur for all the considered water demand growths. These deficits, nevertheless, occur at a later time. For example, water deficits occur 3 years later than in Alternative 1 for zero-percent water demand growth. For 1 and 2 percent, water deficits occur 2 years later and for 3 to 5 percent these deficits occur only 1 year later.

The computed pumping rates for this alternative are included in Appendix 4-2. Again in this alternative, pumping at well 18 is discontinued and pumping at wells 21, 24, and 27 is drastically reduced.

Alternative 3

This alternative consists of adding wells to the system in four areas chosen by city administrators as potential sites for well construction (Fig. 24). The purpose of this alternative is, again, to increase the production of the existing well system. The following well-placement options were considered:

1. Adding a well at site 1.
2. Adding a well at site 2.
3. Adding a well at site 3.
4. Adding a well at site 4.
5. Adding wells at all four sites.

As these wells do not exist, the available drawdowns are not known. Therefore, it was assumed that the difference between the static water level and the top of the aquifer is the available drawdown. Table 7 lists the assumed pump capacity and total available drawdown for these wells.

Table 7. Hydraulic description of the potential wells

Site	Pump capacity (mgd)	Anticipated capacity (mgd)	Total available drawdown (ft)
1	2.0	1.33	204
2	1.5	1.0	211
3	1.5	1.0	195
4	1.5	1.0	198

The pump capacities in this table were provided by city administrators, and the anticipated capacities are the volumes of water that the pumps produce during a 16-hour period of operation.

Figure 36 shows the increases in water production achieved with each of the well- placement options. As expected, the larger increases occur when a well is added in each of the four potential sites. Also, the larger increases in water production are obtained for higher water-demand growths. For example, an increase of 1.3 mgd is achieved for a 5-percent growth in water demand when adding a well at all the sites. An increase of only 0.95 mgd, however, is achieved for the zero-percent growth for the same option.

Although some increase in the total water production of the system is achieved when adding new wells, these increases, again, are not sufficient to satisfy the demand for the entire simulation period, as shown in Figure 37. Severe deficits still occur, especially in the last years of the simulation period. In these years, deficits of more than 7 mgd are observed. The earliest year that a water deficit occurs is 1995, which is observed for the 5-percent water demand growth in all the well-placement options. The latest year is 2001, which corresponds to the zero-percent growth scenario for adding a well at sites 1 or 3. Note that after year 2001 the water deficits in all the well-placement options are about the same. This indicates the time when the well system tops the capacity of the aquifer, which is restricted by the total available drawdown. If water production were increased to satisfy the demand after this year, water levels would experience substantial declines.

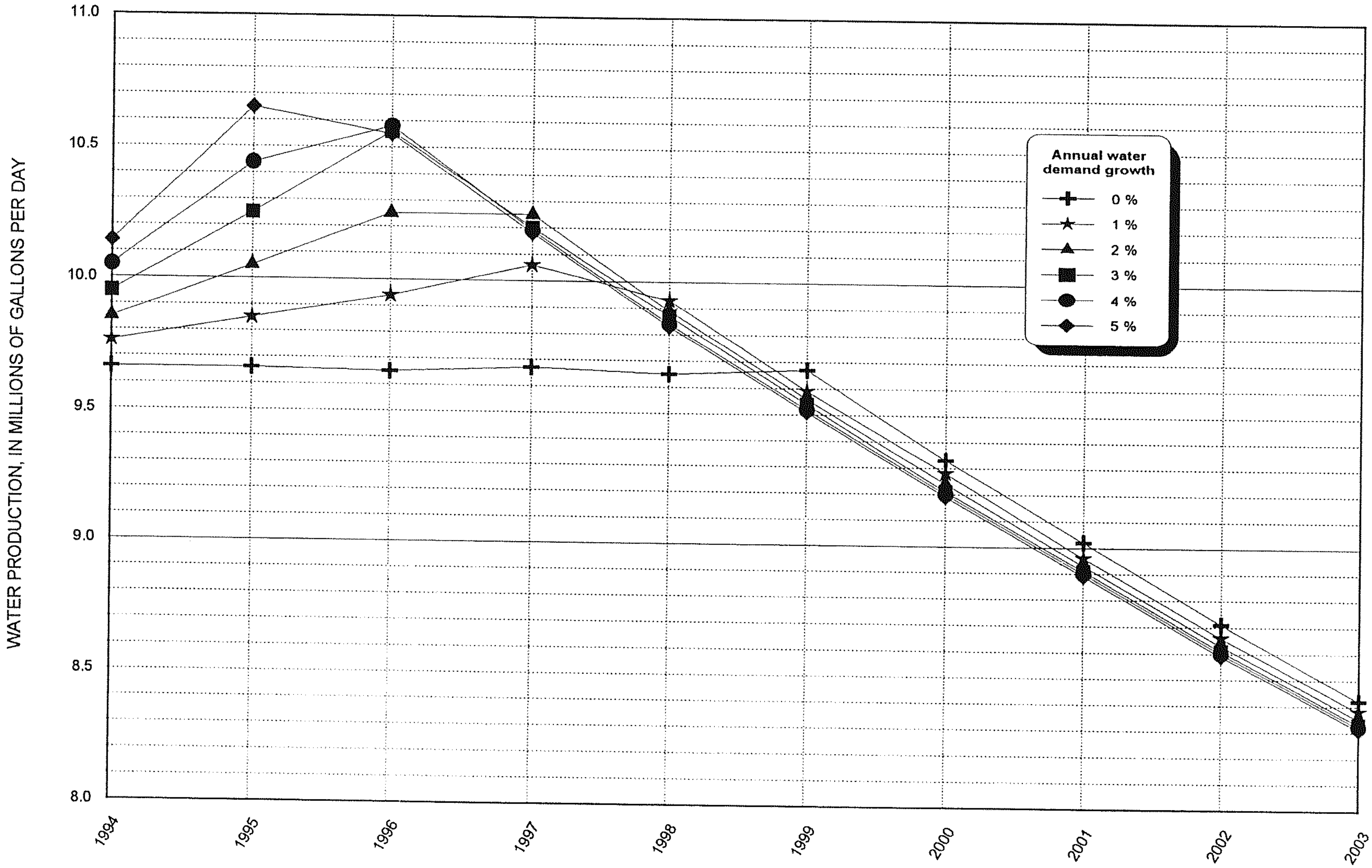

Figure 32. **Water production for the various water-demand growth rates considered in Alternative 1 (existing well-system configuration).**

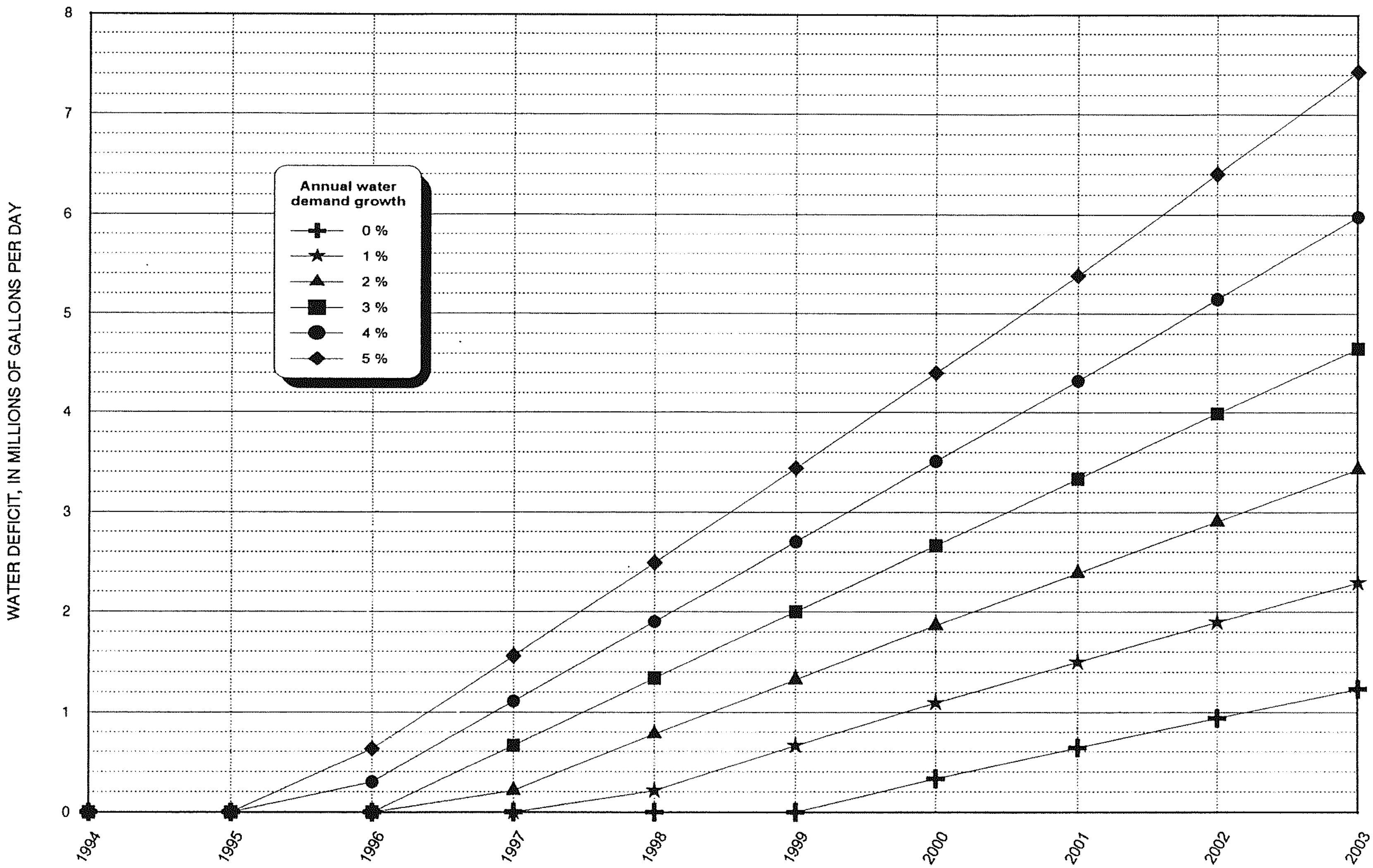

Figure 33. Water deficits for the various water-demand growth rates considered in Alternative 1 (existing system).

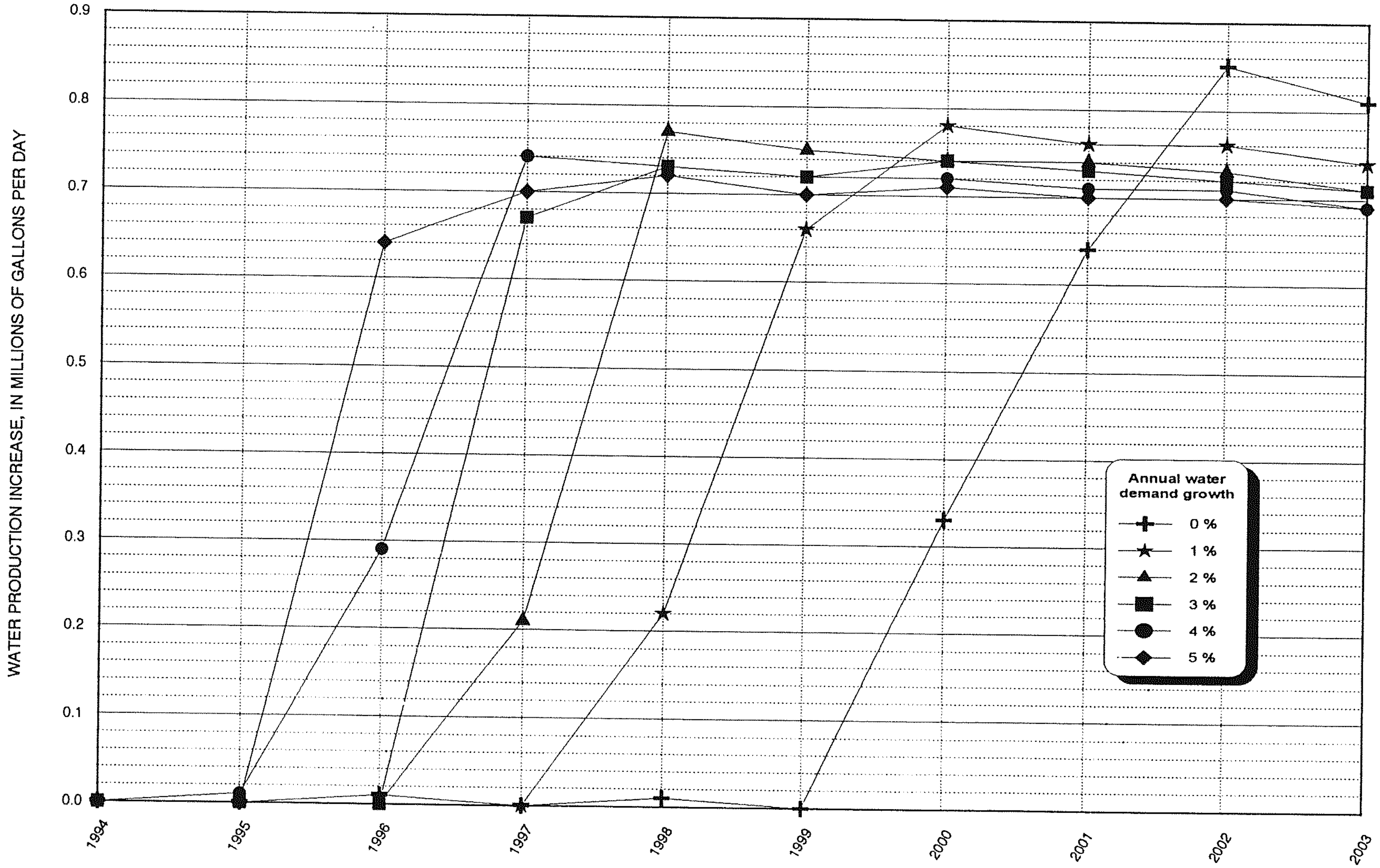

Figure 34. **Increases in water production for the various water-demand growth rates considered in Alternative 2 (increase in total available drawdown).**

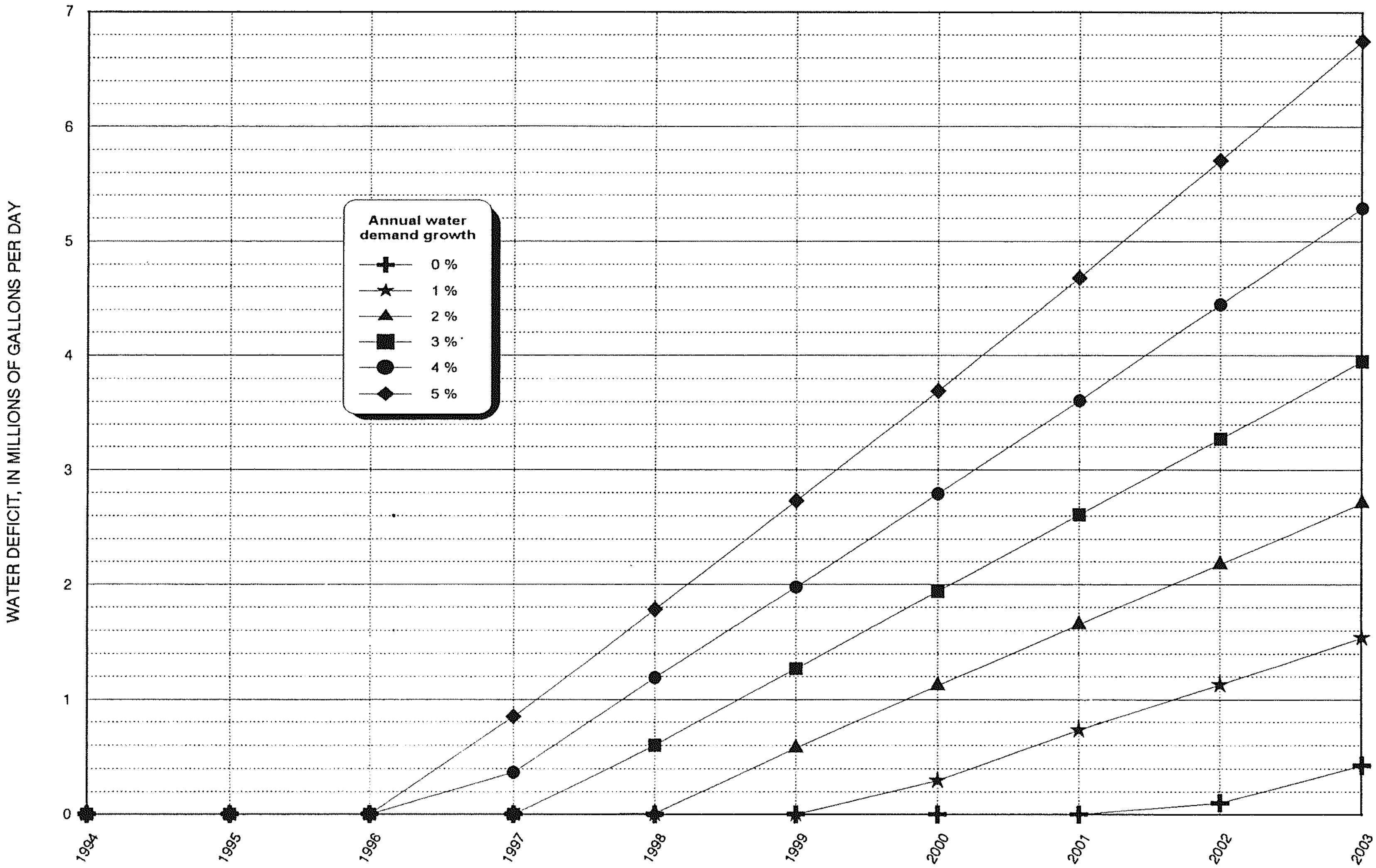

Figure 35. Annual water deficits for the various water-demand growth rates considered in Alternative 2 (increase in total available drawdown).

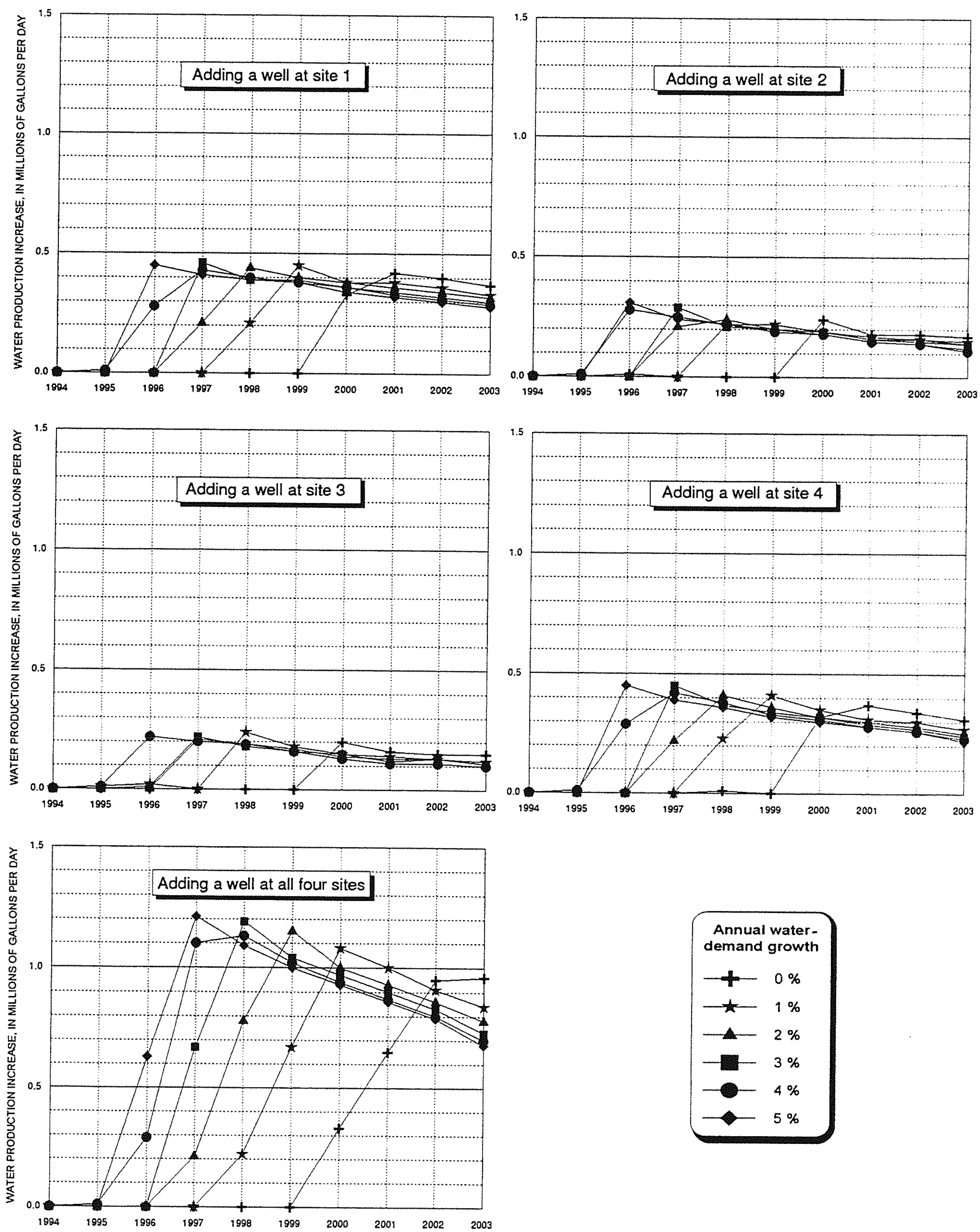

Figure 36. Increases in water production for the various well-placement options and water-demand growth rates considered in Alternative 3 (adding wells).

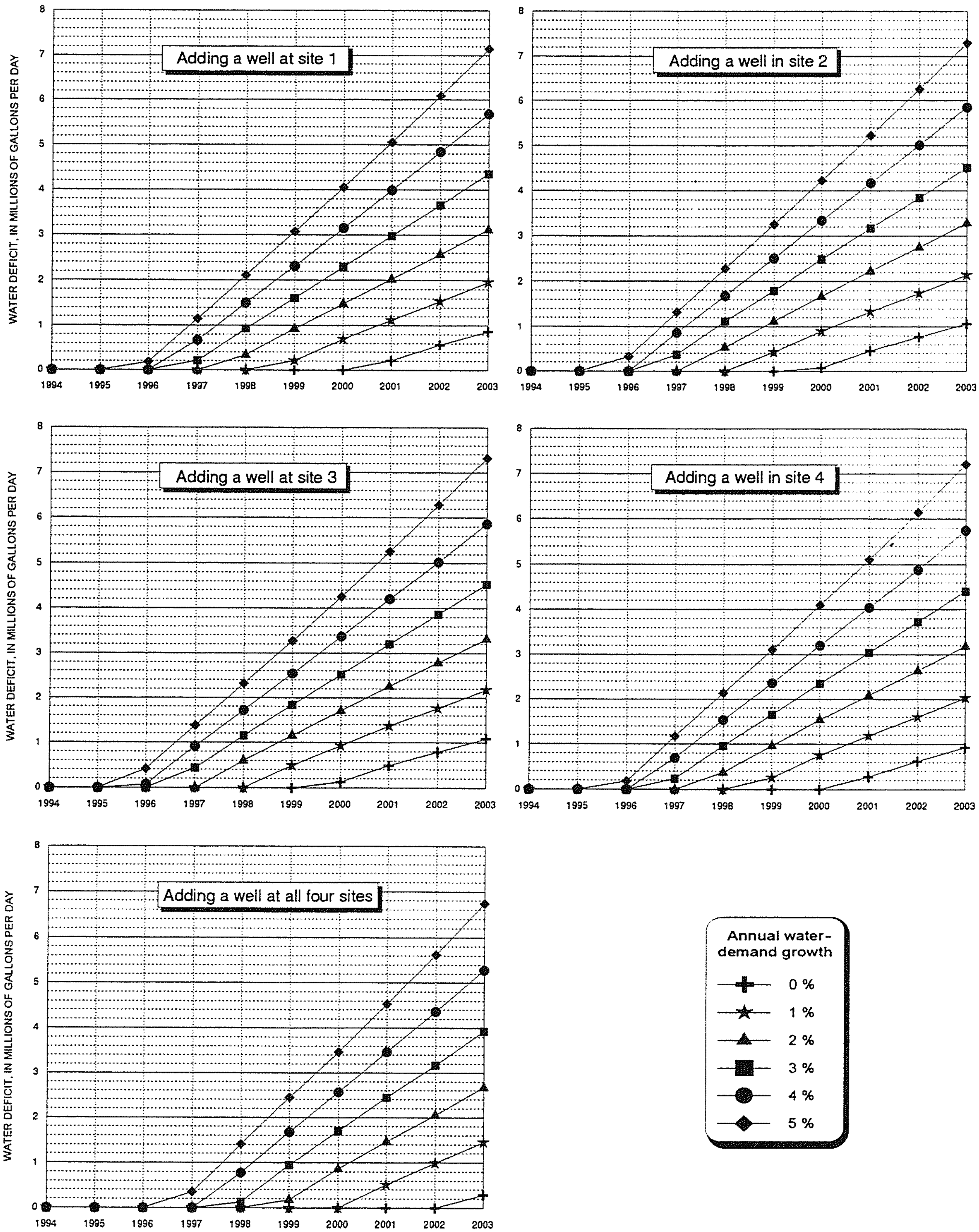

Figure 37. Annual water deficits for the various well-placement options and water-demand growth rates considered in Alternative 3 (adding wells).

The simulated pumping rates for all the well-placement options of this alternative are included in Appendix 4-3. As the new wells were located away from the center of the well system, their interference with the other wells is minimal. For this reason, the best combination of pumping rates is achieved by pumping the new wells at their specified maximum capacity. The existing wells that are located close to the center of the well system have their current pumping rates considerably reduced and in some cases discontinued.

Comparison of Alternatives 2 and 3

A comparison of the increases in water production achieved with Alternatives 2 and 3 is shown in Figure 38. It is clear that the best alternative is to add a well at all four sites; however, the alternative of increasing available drawdown, which is probably less expensive, is almost as good. Adding a single well to the system results in a modest increase in production. For this option, the best places to add a well are sites 1 and 4. The maximum increase achieved with wells at these sites is 2.8 and 2.6 mgd, respectively.

SUMMARY AND CONCLUSIONS

A ground-water management model based on simulation and optimization techniques was developed to analyze different alternatives for modifying the configuration and operation of the city of Florence well system. The ground-water part of the model was based on a previously developed three-dimensional model of the Coastal Plain aquifer system and was calibrated with water levels observed in 1989. The calibrated model was then used to determine the aquifer unit response coefficients used in the evaluation of drawdowns.

The operation of the system was represented in the model as an optimization problem in which the objective was to maximize the water production of the well system while satisfying restrictions on drawdowns and pumping rates.

Various alternatives were investigated. These included (1) increasing the total available drawdown by lowering the pump intakes and (2) increasing the system capacity by adding new wells. Annual water production for the next 10 years was calculated for each alternative. To asses the effectiveness of each alternative, the computed water production was compared with the predicted water demand. Since it is uncertain how water demand will grow in the next 10 years, several annual water demand growths, ranging from zero to 5 percent, were considered.

Results of the simulation of alternatives showed that the aquifers, under the current well system configuration, could not satisfy the demand for the entire 10-year period, even if pumping were optimally distributed. If water demand remained unchanged, for example, by the year 2000 a deficit (approximately 0.3 mgd) would occur. For 1-percent annual growth, the system would satisfy the water demand for about 3 years. This period would be reduced to 2 years if the growth were 3 percent. If water demand increased by 4 or 5 percent annually, water deficits would be experienced in 1 year.

Although some improvement is achieved by increasing the total available drawdown in the system, the predicted water demand is not satisfied for the entire period of simulation. Even for a zero increase in water demand, a small deficit still occurs in the year 2002. Nevertheless, some time is gained in the process. If the demand increases by 1 percent annually, for example, the system satisfies the demand until 1999. This represents a gain of 1 year when compared to the previous alternative. If the demand increases by 3 percent, however, no gain in terms of time is attained.

The alternatives investigated in this study represent only a portion of the array of possible methods of alleviating the water-level decline problems in the Florence area. Other potential solutions could involve additional tapping of aquifers in the Black Creek Formation, development of surface-water sources, or a combination of ground-water and surface-water supplies. Any chosen alternative, however, must be carefully analyzed and evaluated to maximize the benefits and minimize the impact on the water resources of the region.

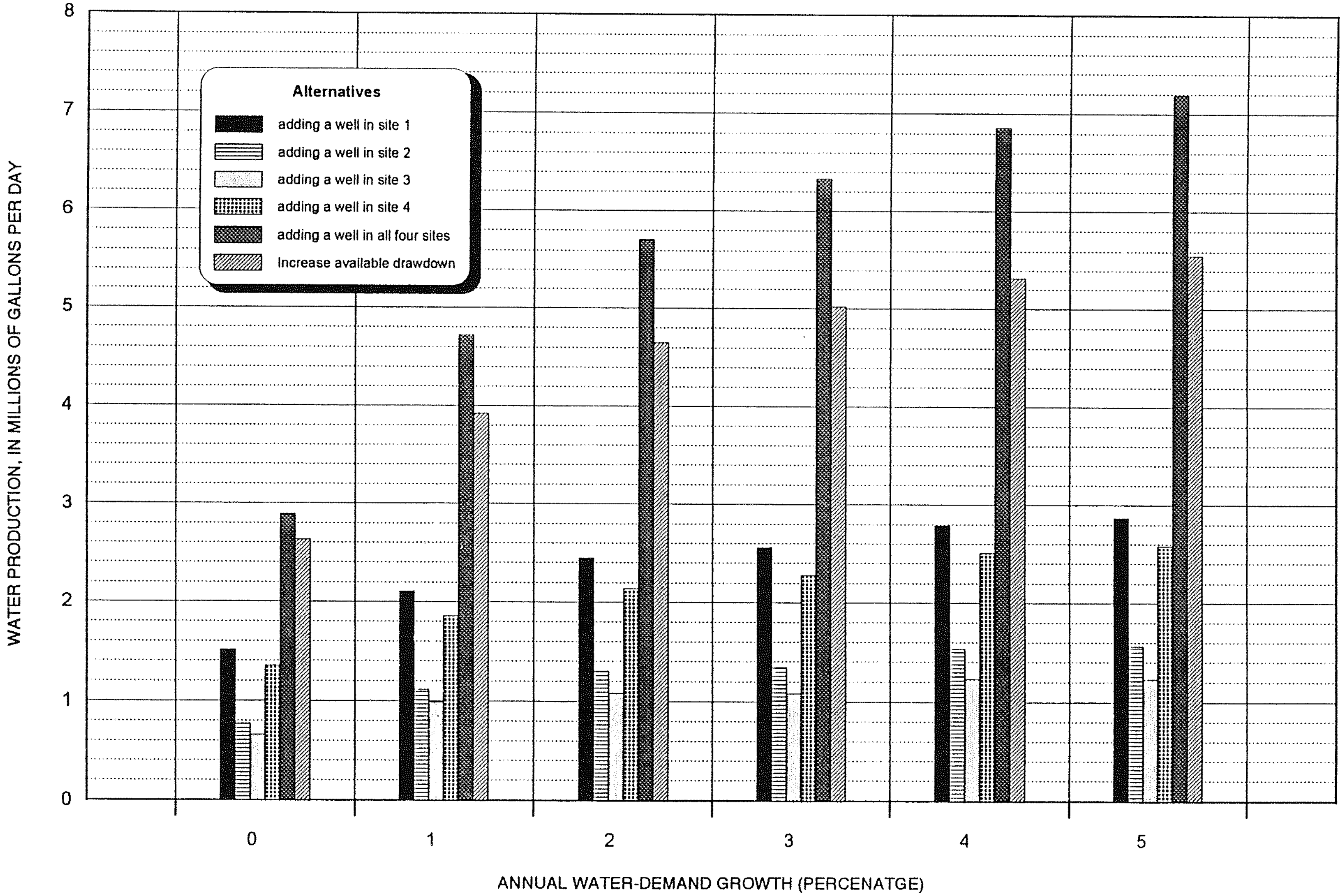

Figure 38. Increase in total water production for various alternatives and water-demand growth rates.

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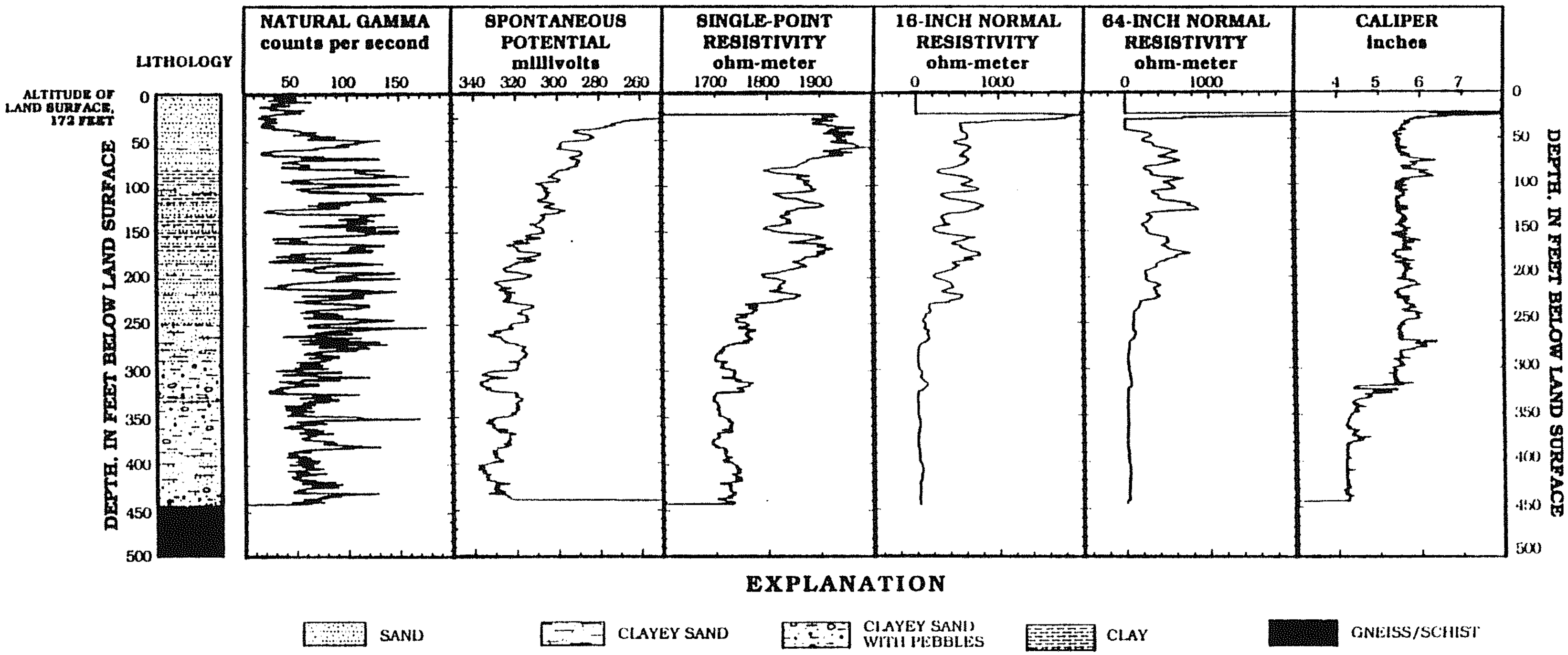
APPENDICES

APPENDIX 1 -- LITHOLOGIC DESCRIPTIONS OF CORED BOREHOLES AT LAKE DARPO (TABLE 1) AND LAKE CITY (TABLE 2)

Note: The following data were taken directly from U.S. Geological Survey Open-File Report 94-58 entitled "Lithologic Descriptions of Two Cores and Ground-Water-Quality Data from Five Counties in the Northeastern Part of the Coastal Plain of South Carolina, 1988 and 1991" by W. Fred Falls.



Lithologic columnar section based on descriptions of cored sediments and geophysical logs of the Lake Darpo borehole, ro thern Darlington County

Table 1.--Lithologic description of sediment recovered from a continuously cored borehole at Lake Darpo in northern Darlington County

[Note: the borehole is located at lat 34°27'31"N. and long 79°52'48"W. with a land surface altitude of 172 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than; mm, millimeter]

Depths (feet)	Lithologic description
0 - 7	No recovery.
7 -10	Sand, dark yellowish orange (10YR6/6), fine- to medium-grained, moderately sorted, subangular, mica (1-2%), dark heavy minerals (<1%).
10 - 13	No recovery.
13 - 16	Sand, dark yellowish orange (10YR6/6) with moderate red (5R5/4) staining, fine- to medium-grained grading down to fine- to coarse- grained, poorly sorted, subangular to angular, mica (1-2%).
16 - 18	No recovery.
18 - 25	Sand, grayish orange (10YR7/4) with moderate red (5R5/4) staining, medium- to coarse-grained, moderately sorted, subangular to angular,lignite (<1%), dark heavy minerals (<1%).
25 - 30	No recovery.
30 - 33	Sand, grayish orange (10YR7/4), fine- to very coarse-grained, poorly sorted, subangular to angular, clayey sand at 33 feet.
33 - 40	No recovery.
40 - 41	Sand, pale yellowish orange (10YR8/6), medium- to coarse-grained, poorly sorted, subangular to angular, clay matrix (10%), sandy clay at 41 feet.
41 - 50	No recovery.
50 - 51	Sand, pale yellowish orange (10YR8/6), fine- to very coarse-grained, poorly sorted, subangular to angular, sharp lower contact.
51 - 56	Clay, light gray (N7) with moderate red (5R5/4) staining, massive with sand-filled burrows or fractures at top, mica (1%),silt (<10%), dark heavy minerals (1%).
56 - 60	No recovery.
60 - 62	Sand, light gray (N7), fine- to medium-grained, moderately sorted, subangular, mica (1%), heavy minerals (1-2%) including garnet, monazite, and dark grains, a thin lamina of limonite-cemented sand at 62 feet.
62 - 70	No recovery.
70 - 81	Sand, light gray (N7) to yellowish gray (5Y8/1), fine- to very coarse- grained with granules (5%), pebbles (5-10%, 4-6 mm) above sharp lower contact at 81 feet, poorly to very poorly sorted, subangular, massive, clay matrix (5-10%), pyrite-cemented at 81 feet, heavy minerals (1-2%) including garnet and monazite, mica (1-2%), lignite (1%), sharp lower contact.
81 - 91	Clay, light gray (N7) to white (N9), massive, laminated from 83 to 84 feet, mottled below 86 feet, sharp lower contact.
91 - 96	Sand, light gray (N7), fine- to very coarse-grained, poorly sorted, subangular, massive, garnets (1%), mica (1%), sharp lower contact.

Table 1.--Lithologic description of sediment recovered from a continuously cored borehole at Lake Darpo in northern Darlington County--Continued

[Note: the borehole is located at lat 34°27'31"N. and long 79°52'48"W. with a land surface altitude of 172 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than; mm, millimeter]

Depths (feet)	Lithologic description
96 - 98	Clay, light gray (N7), massive, gradational lower contact.
98 - 99	Sand, very light gray (N8), fine-grained, well-sorted, subangular, clay matrix (25%), massive, gradational lower contact.
99 -108	Sand, very light gray (N8) with moderate yellow (5Y7/6) staining, fine- to very coarse-grained, poorly sorted, subangular to angular, clay matrix (5-15%), massive, mica (1-2%), dark heavy minerals (1%), including garnet, thin (0.5 feet) bed of clay at 106 feet, sharp lower contact.
108 -117	Clay, very light gray (N8) with moderate yellow (5Y7/6) staining, massive with rooted to wavy-laminated texture at 114 feet, gradational lower contact.
117 -118	Sand, very light gray (N8) with moderate yellow (5Y7/6) staining, fine grained, well-sorted, subangular, massive, clay matrix (25%), gradational lower contact.
118 -125	Sand, very light gray (N8), fine-grained, well-sorted, subangular, clay matrix (5-10%), gradational lower contact.
125 -130	Sand, very light gray (N8) with light red (5R6/6) and moderate yellow (5Y7/6) staining, medium- to very coarse-grained, poorly sorted, subangular, massive to cross-bedded, dark heavy minerals (1%) including garnet, mica (1%), small iron concretions above sharp lower contact at 130 feet.
130 -141	Clay, very light gray (N8) to yellowish gray (5Y8/1) with moderate red (5R5/4) staining of fractures at top of clay, rooted pattern from 135 to 141 feet, silt (10%), sand (10%), gradational lower contact.
141 -142	Sand, very light gray (N8) to grayish yellow (5Y8/4), fine- to medium- grained, moderately sorted, clay matrix (25%), massive, gradational lower contact.
142 -145	Sand, very light gray (N8) to grayish yellow (5Y8/4), fine- to very coarse-grained, poorly sorted, subangular, massive, sharp lower contact.
145 -155	Clay, medium gray (N5) with moderate red (5R5/4) staining at 145 feet, massive, silt (<10%), fine-grained sand (25%) at 153 feet, gradational lower contact.
155 -158	Sand, pinkish gray (5YR8/1), fine- to medium-grained, moderately sorted, subangular, clay matrix (5-10%), massive, mica (2%), sharp lower contact.
158 -164	Sand, medium gray (N5) to light gray (N7), fine- to medium-grained, moderately sorted, subangular, massive with thin laminae of olive gray (5Y4/1) clay at 162 feet, lignite (5%) and pyritized lignite fragments (2%), mica (1-2%, 1-2 mm), sharp lower contact.
164 -172	Clay, very light gray (N8) to light gray (N7) with moderate red (5R5/4) staining of rooted pattern at 167 feet, massive, sand (10%), silt (10%), lignite (1-2%), sharp lower contact.
172 -177	Sand, light gray (N7) to light olive gray (5Y6/1) with moderate yellow (5Y7/6) staining at 177 feet, fine- to medium-grained, moderately sorted, grades down to fine- to very coarse-grained, poorly sorted, subangular to angular, clay matrix (5-10%), massive, mica (1-2%), sharp lower contact.
177 -180	Clay, medium gray (N5), massive, silt (10%), sharp lower contact.

Table 1.--Lithologic description of sediment recovered from a continuously cored borehole at Lake Darpo in northern Darlington County--Continued

[Note: the borehole is located at lat 34°27'31"N. and long 79°52'48"W. with a land surface altitude of 172 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than; mm, millimeter]

Depths (feet)	Lithologic description
180 -182	Sand, light gray (N7), fine- to medium-grained, moderately sorted, subangular, mica (1-2%), massive with clay laminae at 181 feet, sharp lower contact.
182 -185	Clay, medium gray (N5) to light gray (N7) with moderate red (5R5/4) and moderate yellow (5Y7/6) staining, massive, fine- to medium- grained sand (25%) below 184 feet, small circular iron concretion at 185 feet, gradational lower contact.
185 -193	Sand, yellowish gray (5Y7/2) to light gray (N7), fine- to very coarse- grained, granules at 190 and 191 feet, poorly to very poorly sorted, subangular, massive, mica (1-2%, 1-2 mm), heavy minerals (1%) including garnet and monazite, clay matrix (5-10%).
193 -195	No recovery.
195 -200	Clay, medium gray (N5) mottled with moderate yellow (5Y7/6) staining, massive, silt (10%), very fine-grained sand (20%), gradational lower contact.
200 -212	Sand, yellowish gray (5Y8/1) to very light gray (N8), fine- to medium- grained grading downward to fine- to very coarse-grained, poorly sorted, subangular, massive, mica (1-2%), heavy minerals (1%) including garnet and monazite, sharp lower contact.
212 -215	Clay, light bluish gray (5B7/1), massive with thin beds and laminae of very fine-grained sand, well-sorted, massive, mica (1-2%), sharp lower contact.
215 -217	Sand, very light gray (N8) to yellowish gray (5Y8/1), very fine-grained, well-sorted, subangular, clay matrix (5-10%), massive, mica (1-2%).
217 -220	No recovery.
220 -224	Sand, very light gray (N8) to yellowish gray (5Y8/1), fine-grained, well- sorted, and fine- to coarse-grained sand, poorly sorted, subangular, massive with thin clay beds and lignite at 221 and 222 feet, large piece of lignite and pyrite at 223 feet, mica (1-2%).
224 -228	No recovery.
228 -230	Clay, dark gray (N3), massive, fine-grained sand (10-25%), gradational lower contact.
230 -239	Sand, medium gray (N5) to light gray (N7), fine- to medium-grained grading downward to fine- to very coarse-grained, moderately to poorly sorted, subangular, clay matrix (5-10%), massive with discontinuous clay laminae at 235 feet, mica (1-2%).
239 -240	No recovery.
240 -241	Clay, greenish gray (5GY6/1) to light olive gray (5Y6/1), mottled with dusky yellow (5Y6/4) and moderate red (5R4/6) staining, dense, waxy texture, sharp lower contact.
241 -245	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine- to very coarse-grained, poorly sorted, angular to subangular, clay laminae at 243 feet, clay matrix (10-20%), massive, feldspar (5%), dark heavy minerals (1%), sharp lower contact.
245 -249	Clay, medium gray (N5) to light brownish gray (5YR6/1), mottled with dusky yellow (5Y6/4) staining, dense, waxy, fine- to medium-grained sand at 247 feet, sharp lower contact.

Table 1.--Lithologic description of sediment recovered from a continuously cored borehole at Lake Darpo in northern Darlington County--Continued

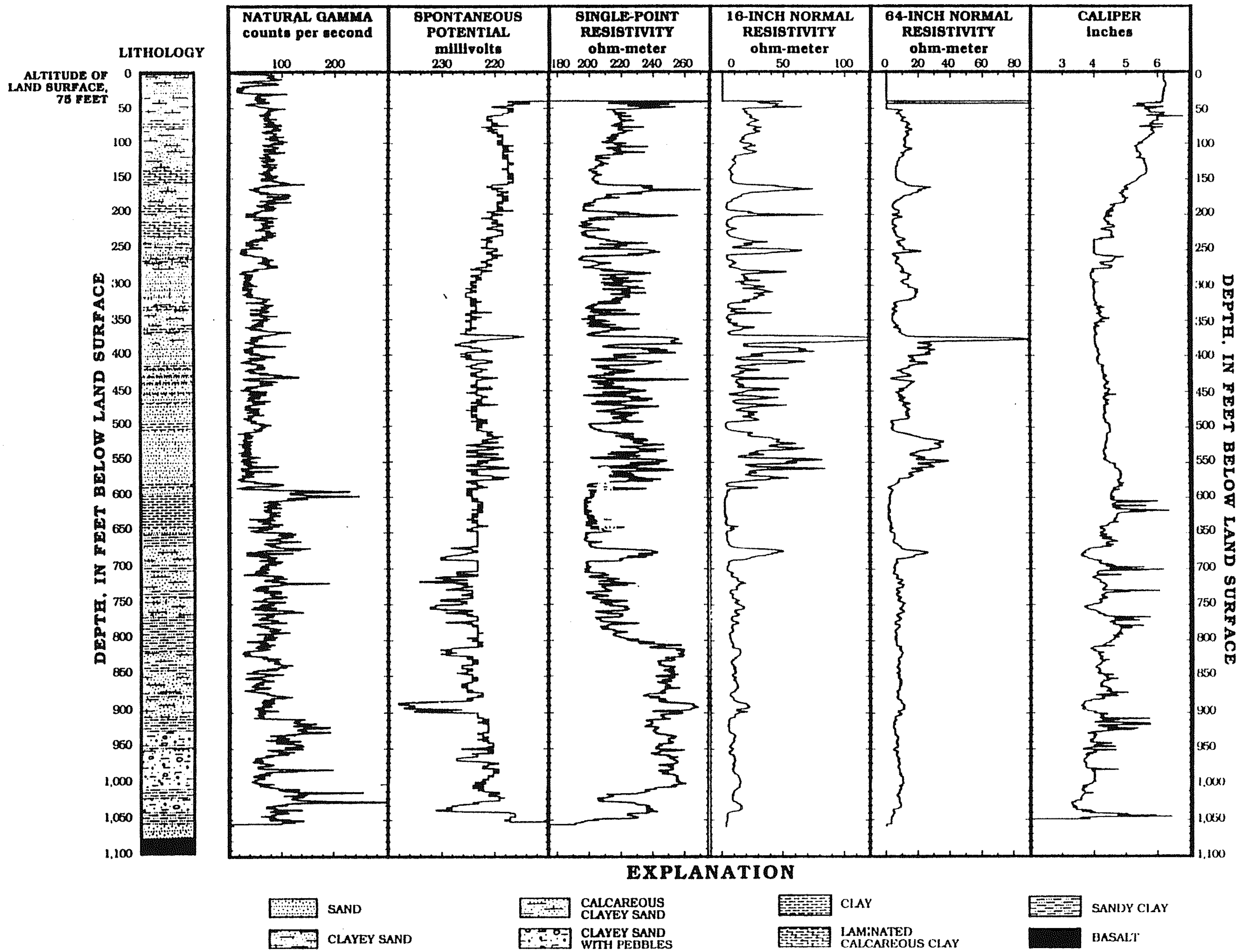
[Note: the borehole is located at lat 34°27'31"N. and long 79°52'48"W. with a land surface altitude of 172 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than; mm, millimeter]

Depths (feet)	Lithologic description
249 -253	Sand, light gray (N7) to greenish gray (5GY6/1), fine- to coarse- grained, poorly sorted, subangular to angular, clay matrix (10-20%), massive, mica (1%), feldspar (5%), sharp lower contact.
253 -255	Clay, olive gray (5Y4/1) to greenish gray (5GY6/1) streaked and mottled with dusky red (5R3/4) staining, wavy-laminated, dense, waxy, fine- to coarse-grained sand (10-20%), sharp lower contact.
255 -274	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine- to coarse-grained, poorly sorted, angular to subangular, beds of medium gray (N5) clay at 256, 260, 261, 264, 265, and 271 feet, pyrite and lignite at 273 feet, sharp lower contact.
274 -278	Clay, greenish gray (5GY6/1) to medium light gray (N6), very fine- grained sand (10-25%), wavy-laminated, mica (1%), feldspars (5%), gradational lower contact.
278 -285	Sand, medium light gray (N6) to light olive gray (5Y6/1) mottled with moderate red (5R4/6) staining, fine- to medium-grained, moderately sorted, subangular to angular, clay matrix (10-20%), mica (1%), feldspar (5%), sharp lower contact.
285 -289	Clay, greenish gray (5GY6/1) to light olive gray (5Y6/1) mottled with dusky yellow (5Y6/4) and moderate red (5R5/4) staining, dense, waxy, fine- to medium-grained sand, mica (1-2%), gradational lower contact.
289 -301	Sand, greenish gray (5GY6/1) mottled with dusky yellow (5Y6/4) and moderate red (5R5/4), fine- to very coarse-grained, granules and pebbles (5-10%, 2-6 mm) at 299 feet, poorly to very poorly sorted, subangular to angular, clay matrix (10-20%), massive, indurated at 294 and 300 feet, olive black (5Y2/1) clay at 291 and 292 feet.
301 -314	No recovery.
314 -324	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine- to very coarse-grained with granules and pebbles (10-40%, 2-20 mm), very poorly sorted, subangular to angular, pebbles of clear, smoky, red, and rutilated quartz, clay matrix (5-10%), massive with lignitic clay laminae at 322 and 323 feet, feldspar (5%),
324 -330	No recovery.
330 -332	Clay, yellowish gray (5Y7/2) to pale olive (10Y6/2) mottled in part with moderate reddish brown (10R4/6) staining, massive, silt (10%), very fine- to fine-grained sand (20-25%).
332 -335	No recovery.
335 -344	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), very fine- to fine-grained grading down to fine- to very coarse-grained with granules and pebbles (5-20%, 2-15 mm), moderately to very poorly sorted, subangular to angular, clay matrix (10-20%), massive to laminated, silty clay clasts at 343 feet, pyrite-cemented sandstone clasts at 335 feet, feldspar (5%), thin clay bed at 344 feet.
344 -347	No recovery.
347 -360	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1) mottled with moderate reddish brown (10R4/6) staining, fine- to very coarse- grained, granules and pebbles (5-10%, 2-10 mm), poorly to very poorly sorted, subangular to angular, clay matrix (5-20%), cross-bedded, mica (2%), silty clay at 353 feet, lignite at 355 feet.

Table 1.--Lithologic description of sediment recovered from a continuously cored borehole at Lake Darpo in northern Darlington County--Continued

[Note: the borehole is located at lat 34°27'31"N. and long 79°52'48"W. with a land surface altitude of 172 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than; mm, millimeter]

Depths (feet)	Lithologic description
360 -370	No recovery.
370 -374	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine- to very coarse-grained, granules and pebbles (5-20%, 2-10 mm), moderately to very poorly sorted, subangular to angular, clay matrix (5-20%), massive with silty gray clay at 370 feet, sharp lower contact.
374 -381	Clay, grayish yellow (5Y8/4) to light olive brown (5Y5/6) mottled with dark reddish brown (10R3/4) staining, fine- to coarse-grained sand (10-15%).
381 -389	No recovery.
389 -393	Sand, light olive gray (5Y6/1), fine- to very coarse-grained, granules and pebbles (5%, 2-15 mm), moderately to very poorly sorted, subangular to angular, mica (2%), clay matrix (5-15%), olive gray (5Y3/2) clay at 392 feet.
393 -400	No recovery.
400 -404	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine- to very coarse-grained, pebbles (5%, 4-10 mm) at 402 feet, subangular to angular, moderately to poorly sorted, clay matrix (5-10%), massive, mica (1-2%), heavy minerals (1-2%) including monazite and garnet, feldspar (5%).
404 -410	No recovery.
410 -413	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine- to very coarse-grained, granules and pebbles (5%, 2-10 mm) at 413 feet, subangular to subrounded, clay matrix (15%), massive, mica (2%), large lignite fragment at 410 feet.
413 -420	No recovery.
420 -421	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine- to very coarse-grained with granules and pebbles (5-20%, 2-20 mm), very poorly sorted, subangular to subrounded, massive with a bed of light olive gray (5Y5/2) clay, mica (2%).
421 -425	No recovery.
425 -427	Sand, light olive gray (5Y6/1), fine- to very coarse-grained with granules and pebbles (5-10%, 2-40 mm), poorly to very poorly sorted, subrounded to angular, clay matrix (10-15%), cross-bedded, mica (2%).
427 -430	No recovery.
430 -431	Recovered subrounded granules and pebbles (2-6 mm) of smoky, clear, white, and rutilated quartz.
431 -435	No recovery.
435 -437	Sand, light olive gray (5Y6/1), fine- to very coarse-grained with granules and pebbles (15-25%, 2-50 mm), very poorly sorted, angular to subrounded, clay matrix (15-25%), massive, clast of gneiss, subrounded pebbles.
437 -438	No recovery.
438 -447	Gneiss/schist with garnets, steeply inclined foliations, weathered cleavage surfaces.



Lithologic columnar section based on descriptions of cored sediments and geophysical logs of the Lake City borehole, south-central Florence County

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County

[Note: The borehole is located at lat 33° 51'20"N. and long 79° 46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than; mm, millimeters]

Depths (feet)	Lithologic description
0 - 8	No recovery.
8 - 11	Sand, white (N9), fine- to coarse-grained, poorly sorted, subangular, clay matrix (20-25%), massive, gradational lower contact.
11 - 12	Sand, grayish yellow (5Y8/4), fine- to very coarse-grained, poorly sorted, subangular, massive.
12 - 14	No recovery.
14 - 16	Clay, light olive gray (5Y6/1) to yellowish gray (5Y8/1), massive, silt and very fine-grained sand (35%), sharp lower contact.
16 - 20	Sand, yellowish gray (5Y7/2), fine- to medium-grained, moderately sorted, subangular, massive, wood fragments,mica (1%), gradational lower contact.
20 - 24	Sand, yellowish gray (5Y8/1), medium- to coarse-grained, moderately sorted, subangular, massive, mica (1%).
24 - 30	No recovery.
30 - 47	Sand, olive gray (5Y4/1), fine-grained, well-sorted, subangular, clay matrix (5-10%), wavy-laminated to burrow-mottled.
47 - 50	No recovery.
50 - 57	Sand, olive gray (5Y4/1), fine-grained, well-sorted, subangular, clay matrix (15-20%), carbonate matrix (5-10%), wavy-laminated to burrow-mottled, clay beds and laminae (10-15%), glauconite (1%), pelecypods (5%), mica (1%).
57 - 60	No recovery.
60 - 61	Sand, light bluish gray (5B7/1), very fine-grained, well-sorted, subangular, carbonate matrix (20-25%), massive to burrow-mottled, pelecypods (5-10%),glauconite (1%), lithified.
61 - 70	No recovery.
70 - 74	Clay, olive gray (5Y4/1), massive, fine-grained sand (25-35%), carbonate matrix (10-20%), pelecypods (5%), mica (1%), lignite (1%), sharp lower contact.
74 - 79	Sand, light olive gray (5Y6/1) to light bluish gray (5B7/1), very fine- to fine-grained, moderately sorted, subangular, clay matrix (25%), carbonate matrix (15%), massive to burrow-mottled, pelecypods (5%), lithified interval from 74 to 75 feet.
79 - 80	No recovery.
80 - 96	Sand, olive gray (5Y4/1) to light olive gray (5Y6/1) to light bluish gray (5B7/1), fine-grained, well-sorted, subangular to subrounded, carbonate matrix (10-15%), clay matrix (15-25%), whole and fragmented pelecypods (5%), lithified intervals from 89 to 90 feet and 95 to 96 feet.
96 - 100	No recovery.
100 - 106	Sand, light olive gray (5Y6/1) to light bluish gray (5B7/1), fine-grained, well-sorted, subangular to subrounded, clay matrix (15-20%), carbonate matrix (15%), massive, pelecypods (<5%), glauconite (1%), lithified interval from 102 to 103 feet.

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County--Continued

[Note: The borehole is located at lat 33° 51'20"N. and long 79°46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than]

Depths (feet)	Lithologic description
106 - 110	No recovery.
110 - 112	Sand, light bluish gray (5B7/1), fine-grained, well-sorted, subangular to subrounded, carbonate matrix (35%), burrow-mottled, pelecypod (5-10%), glauconite (1%), lithified.
112 - 120	No recovery.
120 - 123	Sand, light olive gray (5Y6/1), fine-grained, well-sorted, subangular to subrounded, carbonate matrix (20%), clay matrix (15%), pelecypods (5-10%), glauconite (1%).
123 - 135	No recovery.
135 - 156	Clay, olive gray (5Y4/1), burrow-mottled to wavy-laminated, carbonate matrix (10-25%), fine-grained sand (10-15%), large fragment (50 mm) of pyritized lignite at 148 feet, irregularly shaped pyrite nodules from 145 to 148 feet, fossils include small pelecypods (5-10%) and benthic foraminifera (1%), sharp lower contact.
156 - 158	Sand, olive gray (5Y4/1), fine- to very coarse-grained with rounded granules and pebbles (1-2%, 2-8 mm) of phosphate, very poorly sorted, subangular to subrounded, clay matrix (10-15%), massive, fragmented pelecypods (5-10%), glauconite (1%), sharp lower contact.
158 - 183	Sand, light olive gray (5Y6/1) to light bluish gray (5B7/1), fine- to medium-grained, moderately sorted, carbonate matrix (10-15%), clay matrix (5%), burrow-mottled to massive, glauconite (1%), mica (1%), pelecypods (5-10%), lithified interval from 164 to 166 feet, no recovery from 166 to 170 feet, sharp lower contact.
183 - 196	Clay, olive gray (5Y4/1), well-laminated with laminae and thin beds of fine-grained sand (10%), carbonate matrix (5-10%), pelecypods (5%), glauconite (1-2%), sharp lower contact.
196 - 205	Sand, light olive gray (5Y6/1), fine- to medium-grained, moderately sorted, subangular to subrounded, clay matrix (5-10%), carbonate matrix (5-10%), massive with an olive black (5Y2/1) clay bed at 198 feet, pelecypods (5%), glauconite (2-3%), subrounded phosphate granules (2-3%) below 204 feet, a large pebble (20 mm) of phosphate at 199 feet, sharp lower contact.
205 - 219	Clay, olive gray (5Y4/1), massive to wavy-laminated with laminae and thin beds of very fine-grained sand, carbonate matrix (5-10%), glauconite (5%) in sand beds, fine-grained lignite (1%) observed on bedding surfaces, sharp lower contact.
219 - 222	Sand, light olive gray (5Y6/1), very fine-grained, well-sorted, subangular, clay matrix (5-10%), massive, carbonate matrix (10-15%), glauconite (2-3%), mica (1%), sharp lower contact.
222 - 229	Clay, olive gray (5Y4/1), wavy-laminated to burrow-mottled with laminae of very fine-grained sand (5-10%), pelecypods (5-10%), mica (2%), fine-grained lignite (1%), gradational lower contact.
229 - 239	Sand, light olive gray (5Y6/1), very fine-grained grading down to fine- to medium-grained, well-sorted to moderately sorted, subangular, clay matrix (5-10%), carbonate matrix (10-25%), burrow-mottled to massive, glauconite (1-2%), a large piece (30 mm) of lignite and an olive gray (5Y4/1) clay laminae at 237 feet, shark teeth and small phosphate granules (3-5%), pelecypods (5%).

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County--Continued

[Note: The borehole is located at lat 33° 51'20"N. and long 79° 46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than]

Depths (feet)	Lithologic description
239 - 242	No recovery.
242 - 244	Sand, light olive gray (5Y6/1), fine-grained, well-sorted, subangular, massive with a thin bed (0.3 feet) of olive gray (5Y4/1) clay, glauconite (3%), dark heavy minerals (1%), lignite (1%), mica (1%), sharp lower contact.
244 - 249	Clay, dark gray (N3) to olive gray (5Y4/1), wavy-laminated, pelecypods (5-15%), carbonate matrix (5-10%), mica (1%),lignite (1%).
249 - 254	No recovery.
254 - 265	Clay, olive gray (5Y4/1) to dark gray (N3), well-laminated, silt and very fine-grained sand (35%) below 264 feet, carbonate matrix (10%), pelecypods (5-10%), mica (1%), lignite (1%).
265 - 270	No recovery.
270 - 273	Sand, light olive gray (5Y6/1) to medium light gray (N6), very fine-grained, well-sorted, silty clay matrix (15-20%), carbonate matrix (5-10%), laminated to cross-bedded, pelecypods (10%), dark heavy minerals (1%), glauconite (1%), mica (2%), gradational lower contact.
273 - 283	Sand, light olive gray (5Y6/1) to medium light gray (N6), fine-to medium-grained, granules (2%) and pebbles (2%, 4-6 mm) of phosphate at 276 and 280 feet, moderately to poorly sorted, subangular to subrounded, massive, clay laminae from 282 to 283 feet, carbonate matrix (5-10%), clay matrix (5%), pelecypod fragments (5%), mica (1%).
283 - 285	No recovery.
285 - 306	Sand, greenish gray (5GY6/1) to light greenish gray (5GY8/1), fine- to medium-grained grading down fine-grained, moderately to well-sorted, subangular to subrounded, carbonate matrix (5%), laminated, lignitic clay laminae at 294 and 302 feet, glauconite (5-10%), mica (1-2%), pelecypods (<5%).
306 - 310	No recovery.
310 - 316	Sand, greenish gray (5GY6/1) to dark greenish gray (5GY4/1), fine- to coarse-grained, pebbles (5%, 5-20 mm) of phosphate, poorly to very poorly sorted, subangular to subrounded, massive, a thin (0.3 feet) bed of olive black (5Y2/1) clay, glauconite (5-10%), lignite (10%).
316 - 320	No recovery.
320 - 327	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine-grained, well-sorted, subangular to subrounded, clay matrix (5-10%), massive, glauconite (10%), dark heavy minerals (1-2%), sharp lower contact.
327 - 375	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine-grained and fine- to medium-grained, moderately and well-sorted, subangular to subrounded, massive, interlaminated and interbedded with olive gray (5Y4/1) clay (20-50%), glauconite (5%), lignite (2%), dark heavy minerals (1%), mica (1%), no recovery from 359 to 360 feet and 369 to 370 feet.
375 - 380	No recovery.

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County--Continued

[Note: The borehole is located at lat 33°51'20"N. and long 79°46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than]

Depths (feet)	Lithologic description
380 - 395	Sand, greenish gray (5GY6/1) to light olive gray (5Y6/1), fine- to medium-grained, granules of phosphate (<1%), moderately sorted, subangular to subrounded, clay matrix (5-10%), glauconite (5-10%), mica (1%), no recovery from 384 to 390 feet, gradational lower contact.
395 - 397	Sand, greenish gray (5GY6/1), fine- to very coarse-grained, pebbles of phosphate (2-3%, 4-8 mm), very poorly sorted, massive, subangular, clay matrix (5-10%), lignite (2-3%), mica (1%), shark teeth.
397 - 400	No recovery.
400 - 406	Sand, light greenish gray (5GY8/1) to light olive gray (5Y6/1), fine- grained with pebbles of phosphate (2%, 4-10 mm), well-sorted to poorly sorted, subangular to subrounded, massive with thin laminae of dark greenish gray (5GY4/1) clay (5-10%), glauconite (5%), mica (1-2%), lignite (2-3%), sharp lower contact.
406 - 414	Sand, light greenish gray (5GY8/1), fine- to very coarse-grained, poorly sorted, subangular, massive, lignitic (5-10%) clay laminae from 411 to 412 feet, glauconite (2-3%), mica (1%), no recovery from 408 to 410 feet.
414 - 420	No recovery.
420 - 424	Sand, light olive gray (5Y6/1), well-sorted, subangular, massive to laminated, a clay lamina at 423 feet, glauconite (1%), mica (1%).
424 - 430	No recovery.
430 - 452	Sand, light olive gray (5Y6/1), fine- to medium-grained and fine- to very coarse-grained, moderately to poorly sorted, subangular to subrounded, clay matrix (5-10%), massive, laminae and thin beds of clay at 434 and 446 feet, glauconite (0-1%), mica (1%), dark heavy minerals (1%), lignite and clay clasts at 443 feet, no recovery from 447 to 450 feet, sharp lower contact.
452 - 462	Sand, yellowish gray (5Y8/1), fine- to medium-grained, moderately sorted, subangular, laminated to massive, laminae of olive gray (5Y4/1) lignitic clay (10%), beds of olive gray (5Y4/1) clay from 453 to 455 feet and 461 to 462 feet, glauconite (0-1%), mica (1%), dark heavy minerals (1%), other heavy minerals (1%) include garnet and monazite, lignite (5%) in sand, sharp lower contact.
462 - 464	Sand, greenish gray (5GY6/1), fine- to very coarse-grained with granules (5%), very poorly sorted, subangular, massive with clay laminae, clay clasts (2-3%, 1-4 mm), dark heavy minerals (1%), sharp lower contact.
464 - 466	Clay, olive black (5Y2/1), well-laminated, laminae of fine- to medium- grained sand (10%), sharp lower contact.
466 - 476	Sand, light olive gray (5Y5/2), fine- to very coarse-grained, poorly sorted, subangular to subrounded, laminated to massive, clay laminae (5%), lignite (10-20%), dark heavy minerals (1%), mica (1%).
476 - 480	No recovery.
480 - 492	Sand, light olive gray (5Y6/1) to yellowish gray (5Y8/1), fine- to medium-grained, moderately sorted, subangular to subrounded, laminated to massive, a lamina of olive gray (5Y4/1) clay at 485 feet, lignite (1-5%), glauconite (<1%), dark heavy minerals (1%), mica (1%), sharp lower contact.

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County--Continued

[Note: The borehole is located at lat 33°51'20"N. and long 79°46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than]

Depths (feet)	Lithologic description
492 - 503	Clay, olive black (5Y2/1), laminated, laminae of fine- to medium- grained sand (5-10%), lignite (2-3%), mica (1-2%), dark heavy minerals (1-2%), sharp lower contact.
503 - 538	Sand, yellowish gray (5Y8/1), fine- to medium-grained, moderately sorted, subangular to subrounded, massive to cross-bedded, laminae of olive gray (5Y4/1) clay (10%) from 503 to 514 feet, lignite (2-5%), glauconite (1%), dark heavy minerals (1%), pyrite (1-2%), garnet (<1%), gradational lower contact.
538 - 543	Sand, light olive gray (5Y6/1), fine- to very coarse-grained, pebbles of chert (1-2%), very poorly sorted, subangular to subrounded, massive with laminae (5%) of olive gray (5Y4/1) to greenish gray (5GY6/1) clay, lignite fragments (2-5%, 1-20 mm), glauconite (<1%), dark heavy minerals (1%), sharp lower contact.
543 - 578	Sand, yellowish gray (5Y8/1) to light olive gray (5Y5/2), fine-grained and fine- to coarse-grained, well-sorted to poorly sorted, subangular to subrounded, massive, laminae and thin beds of olive black (5Y2/1) clay (10%), mica (2-3%), a large fragment of lignite (20 mm) at 547 feet, fine-grained lignite (1-2%).
578 - 580	No recovery.
580 - 584	Clay, olive black (5Y2/1), well-laminated, laminae of fine- to medium- grained sand (5%), sharp lower contact.
584 - 587	Sand, yellowish gray (5Y8/1), fine- to coarse-grained, poorly sorted, subangular to subrounded, massive, olive black (5Y2/1) clay laminae (20%), mica (1-2%), sharp lower contact.
587 - 590	Clay, olive black (5Y2/1), well-laminated, laminae of fine- to medium- grained sand (30%), sharp lower contact.
590 - 599	Sand, yellowish gray (5Y8/1), fine-grained, well-sorted, subangular to subrounded, laminated to burrow-mottled, laminae of olive black (5Y2/1) clay (30%), brown and black heavy minerals (1%), other heavy minerals include monazite (<1%) and garnet (<1%), mica (1-2%, 1 mm), glauconite (<1%), pyrite (1%), sharp lower contact.
599 - 641	Clay, light olive gray (5Y5/2) to olive gray (5Y4/1), well-laminated, very fine- to fine-grained sand (10-20%) in laminae and lenses, ripple- laminated and burrow-mottled textures observed in sand laminae, fine- grained lignite (1-2%), mica (1%, <1 mm), a bed of silica-cemented sand at 615 feet, nodules of pyrite at 631 feet, no recovery from 636 to 638 feet, sharp lower contact.
641 - 642	Sand, yellowish gray (5Y8/1), fine- to coarse-grained, poorly sorted, subangular to subrounded, massive, laminae of olive gray (5Y4/1) clay (5%), mica (1-2%, 1-2 mm), fragments of lignite and pyrite (5%, 5-20 mm), dark heavy minerals (1%).
642 - 650	No recovery.
650 - 671	Clay, pale olive (10Y6/2) to light olive gray (5Y6/1) to medium gray (N5), mottled (5%) with dusky yellow (5Y6/4) staining and silty (10-20%) from 662 to 671 feet, massive, dense, waxy, lignite fragments (10%) below 670 feet, mica (1%).
671 - 680	No recovery.

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County--Continued

[Note: The borehole is located at lat 33°51'20"N. and long 79°46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than]

Depths (feet)	Lithologic description
680 - 682	Sand, light gray (N7), fine- to coarse-grained, poorly sorted, subangular to angular, dense clay matrix (5-10%), massive, pyritized lignite (10%) at 682 feet, mica (1%), dark heavy minerals (1%).
682 - 691	No recovery.
691 - 704	Clay, light olive gray (5Y6/1) to pale olive (10Y6/2), root-like pattern (5%) of dusky yellow (5Y6/4) and moderate reddish brown (10R4/6) staining, massive, waxy, dense, sand (5-20%) below 702 feet, gradational lower contact.
704 - 707	Sand, yellowish gray (5Y8/1), fine- to very coarse-grained, poorly sorted, subangular to angular, dense clay matrix (15-25%), massive, mica (1%), dark heavy minerals (1%), feldspar (5%), sharp lower contact.
707 - 710	Clay, yellowish gray (5Y8/1) to light olive gray (5Y6/1), massive, fine- to medium-grained sand (10-15%), gradational lower contact.
710 - 729	Sand, yellowish gray (5Y8/1) to pale olive (10Y6/2), fine- to medium- grained grading down to fine- to very coarse-grained, moderately to poorly sorted, subangular to angular, dense clay matrix (10-25%), massive, feldspar (5%), mica (1-2%, 1-2 mm), monazite (<1%), dark heavy minerals (1%) including garnet, sharp lower contact.
729 - 741	Clay, light gray (N7) with patchy staining of dusky yellow (5Y6/4) and moderate reddish orange (10R6/6), massive, dense, waxy, fine- to coarse-grained sand (10-20%), gradational lower contact.
741 - 750	Sand, light olive gray (5Y6/1) to very light gray (N8) with patchy staining of dusky yellow (5Y6/4) and moderate red (5R4/6), fine- to very coarse-grained, poorly sorted, subangular to angular, dense clay matrix (15-25%), massive with wispy clay laminae at 742 feet, mica (1%), feldspar (5%), sharp lower contact.
750 - 753	Clay, light gray (N7) with root-like pattern of dusky yellow (5Y6/4) and moderate red (5R4/6) staining, dense, waxy, gradational lower contact.
753 - 765	Sand, very light gray (N8) to light gray (N7) with moderate reddish brown (10R4/6) staining (5%), fine- to medium-grained grading down to fine- to very coarse-grained, moderately to poorly sorted, subangular to angular, dense clay matrix (10-25%), massive, feldspar (5-10%), mica (1%), heavy minerals (1%) including garnet, sharp lower contact.
765 - 786	Clay, light olive gray (5Y6/1) to pale olive (10Y6/2) mottled with dusky yellow (5Y6/4) and pale reddish brown (10R5/4) staining (5-10%), massive, dense, waxy, beds of fine- to very coarse-grained sand with granules and pebbles from 768 to 770 feet, 775 to 776 feet, 779 to 780 feet, and 784 to 786 feet, sharp lower contact.
786 - 799	Clay, yellowish gray (5Y7/2) mottled (10-20%) with dusky red (5R3/4) and dusky yellow (5Y6/4) staining, massive, dense, waxy, fine- to coarse-grained sand (25-35%), gradational lower contact.
799 - 800	Sand, yellowish gray (5Y7/2), fine to very coarse-grained with granules, very poorly sorted, subangular to angular, dense clay matrix, massive, mica (1%), dark heavy minerals (1%), sharp lower contact.
800 - 812	Clay, yellowish gray (5Y8/1) to light olive gray (5Y6/1), mottled with dusky yellow (5Y6/4) staining (5%), massive, dense, waxy, very fine- to fine-grained sand (20-30%), beds of fine- to very coarse-grained sand with granules from 802 to 805 feet and 807 to 812 feet, clay beds grade down into sand beds.

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County--Continued

[Note: The borehole is located at lat 33°51'20"N. and long 79°46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than]

Depths (feet)	Lithologic description
812 - 820	No recovery.
820 - 825	Sand, pale greenish yellow (10Y8/2) to yellowish gray (5Y8/1), mottled with moderate reddish orange (10R6/6), fine- to very coarse-grained with granules (5-10%), very poorly sorted, subangular to angular, dense clay matrix (15-25%), mica (1%, 1-2 mm), feldspar (5-10%).
825 - 830	No recovery.
830 - 844	Clay, light olive gray (5Y6/1) with patchy staining (5-10%) of moderate reddish brown (10R4/6) and dusky yellow (5Y6/4), massive to burrow- mottled, dense, waxy, very fine-grained sand (35%), gradational lower contact.
844 - 850	No recovery.
850 - 871	Sand, pale olive (10Y6/2) to yellowish gray (5Y7/2), fine- to very coarse-grained with granules (5%), very poorly sorted, angular to subangular, dense clay matrix (10-15%), laminated to cross-bedded, irregularly laminated bed of medium gray (N5) clay 851 to 853 feet, feldspar (5-10%), mica (1-2%, 1-2 mm), monazite (<1%), laminae of dark heavy minerals (1%), sharp lower contact.
871 - 874	Clay, light olive gray (5Y6/1) to yellowish gray (5Y8/1) mottled (25%) with pale reddish brown (10R5/4) to dusky yellow (5Y6/4) staining, massive to burrow-mottled, fine- to medium-grained sand (10-15%) below 873 feet, gradational lower contact.
874 - 884	Sand, pale olive (10Y6/2) to yellowish gray (5Y7/2), fine- to medium- grained, moderately sorted, subangular, dense clay matrix (5-10%), laminated to cross-bedded, mica (1-2%, 1-2 mm), feldspar (5-10%), dark heavy minerals (1%), monazite (<1%).
884 - 890	No recovery.
890 - 891	Clay, medium light gray (N6), well-laminated, silt (10-20%), mica (2-3%, 1-2 mm), fine-grained lignite (1%), laminae of very fine-grained sand (20%).
891 - 899	No recovery.
899 - 906	Sand, pale greenish yellow (10Y8/2), fine- to very coarse-grained with granules (10%) below 904 feet, poorly to very poorly sorted, subangular, dense clay matrix (10-15%), feldspar (5-10%), sharp lower contact.
906 - 926	Clay, very light gray (N8) to light olive gray (5Y6/1) with patchy moderate reddish brown (10R4/6) and dusky yellow (5Y6/4) staining, massive, dense, waxy, silica-cemented fractures, fine- to coarse- grained sand (25-35%) below 924 feet, gradational lower contact.
926 - 941	Sand, pale olive (10Y6/2) to yellowish gray (5Y7/2) with patchy staining (5%) of dusky yellow (5Y6/4), fine- to very coarse-grained with granules (5%) and pebbles (10-25%, 4-8 mm), very poorly sorted, angular to subangular, dense clay matrix (10-15%), laminated to cross-bedded, mica (1-2%, 1-2 mm), sharp lower contact.
941 - 950	Clay, light olive gray (5Y6/1) to light brownish gray (5YR6/1) with patchy staining (10%) of pale red (5R6/2) and pale reddish purple (5RP6/2), massive, dense, waxy, silt and very fine-grained sand (20-30%), mica (1-2%, 1-2 mm), gradational lower contact.

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County--Continued

[Note: The borehole is located at lat 33°51'20"N. and long 79°46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than]

Depths (feet)	Lithologic description
950 - 953	Sand, yellowish gray (5Y7/2) to pale olive (10Y6/2), fine- to very coarse-grained with pebbles (5%, 4-8 mm), very poorly sorted, subangular to angular, dense clay matrix (10-15%), massive, mica (1-2%, <1 mm), feldspar (5-10%), sharp lower contact.
953 - 957	Clay, light olive gray (5Y6/1) mottled with moderate reddish brown (10R4/6) and pale greenish yellow (10Y8/2) staining, massive, dense, waxy, very fine-grained sand (20-35%), gradational lower contact.
957 - 977	Sand, yellowish gray (5Y7/2) to pale greenish yellow (10Y8/2), fine- to very coarse-grained with angular quartz and feldspar pebbles (5-10%, 4-15 mm) below 968 feet, very poorly sorted, angular to subangular, dense clay matrix (10-15%), massive to cross-bedded, mica (1-2%, 1-2 mm), feldspar (5-10%), sharp lower contact.
977 - 980	Clay, light olive gray (5Y6/1) to yellow gray (5Y8/1) with patchy and root-like pattern of light olive brown (5Y5/6) and dusky red (5R3/4) staining (5-10%), massive, dense, waxy, silt and very fine-grained sand (20-35%), gradational lower contact.
980 -1,005	Sand, white (N9) to light gray (N7) with patches of dusky red (5R3/4) and dusky yellow (5Y6/4) staining (5%), fine- to very coarse-grained, granules (5%) and angular pebbles (10-15%, 4-10 mm) below 1,000 feet, poorly to very poorly sorted, subangular to angular, dense, clay matrix (15-35%), massive, dark heavy minerals (1%), mica (1-2%, 1 mm), sharp lower contact.
1,005-1,022	Clay, white (N9) with root-like and patchy patterns of dusky yellow (5Y6/4) and grayish orange (10YR7/4) staining, pale greenish yellow (10Y8/2) with pale reddish brown (10R514) staining (20%) below 1,012 feet, massive, dense, fine- to coarse-grained sand (20-30%), gradational lower contact.
1,022-1,030	Sand, pale olive (10Y6/2) to yellowish gray (5Y7/2) with dusky yellow (5Y6/4) staining (5%), fine- to medium-grained grading down to fine- to very coarse-grained with granules (5%) and pebbles (5%, 5-10 mm), moderately to very poorly sorted, subangular to angular, dense clay matrix (5-20%), massive, mica (1-2%, 1-2 mm), dark heavy minerals (1%), feldspar (5-10%), monazite (1%).
1,030-1,038	No recovery.
1,038-1,048	Clay, pale olive (10Y6/2) to light olive gray (5Y6/1) with pale reddish brown (10R5/4) staining above 1,046 feet, very fine- to fine-grained sand (20-35%), gradational lower contact.
1,048-1,050	Sand, pale olive (10Y6/2), fine- to very coarse-grained, poorly sorted, angular to subangular, dense clay matrix (10-20%), massive, feldspar (5%), mica (1-2%, 1-2 mm), sharp lower contact.
1,050-1,060	Clay, pale olive (10Y6/2) with patchy dusky yellow (5Y6/4) and moderate red (5R5/4) staining, massive, dense, waxy, fine- to coarse-grained sand (10-25%), gradational lower contact.
1,060-1,062	Sand, pale olive (10Y6/2) with dusky yellow (5Y6/4) and moderate red (5R5/4) staining, medium- to coarse-grained, poorly sorted, subangular to angular, dense clay matrix (20-35%), massive, feldspar (5%), mica (1%).
1,062-1,075	No recovery.

Table 2.--Lithologic description of sediment recovered from a continuously cored borehole in Lake City in south-central Florence County--Continued

[Note: The borehole is located at lat 33°51'20"N. and long 79°46'02"W. with a land surface altitude of 75 feet above sea level. All depths are reported in feet below land surface. %, percent; <, less than]

Depths (feet)	Lithologic description
1,075-1,076	Sand, yellowish gray (5Y7/2) with dusky red (5R3/4) and dusky yellow (5Y6/4), fine- to very coarse-grained with feldspar and quartz pebbles (10-15%), clasts of weathered basalt (5%, 5-20 mm), very poorly sorted, angular to subangular, mica (1-2%, 1-2 mm), feldspar (5-10%), sharp lower contact.
1,076-1,090	Basalt, weathered pale olive (10Y6/2), dark gray (N3) to black (N1) below 1,085 feet, poikilotopic with mineralized vesicles (3 mm in diameter), finely crystalline, massive.

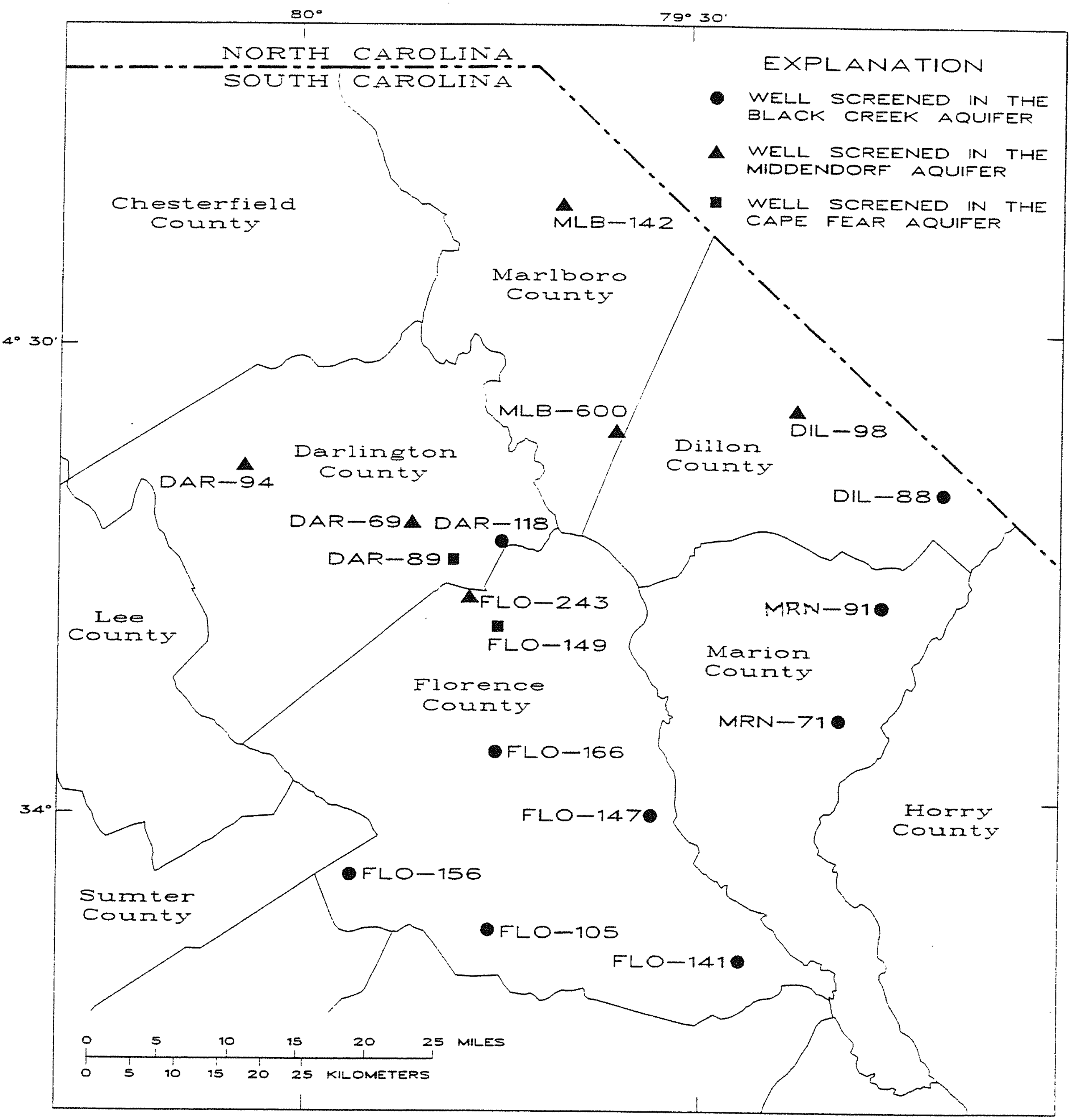
APPENDIX 2 -- DESCRIPTIONS AND WATER-QUALITY ANALYSES OF SELECTED WELLS IN THE PEE DEE REGION

Table 1. Identification, location, and screened intervals of wells

Table 2. Field water-quality analyses

Table 3. Laboratory water-quality analyses

Note: The following data were taken directly from U.S. Geological Survey Open-File Report 94-58 entitled "Lithologic Descriptions of Two Cores and Ground-Water-Quality Data from Five Counties in the Northeastern Part of the Coastal Plain of South Carolina, 1988 and 1991" by W. Fred Falls.



Location of wells sampled for water-quality constituents

Table 1--Identification, location, and screened intervals of 17 wells in the study area selected for collection of water-quality samples, November 1988 and April and May 1991

[USGS, U.S. Geological Survey; DAR, Darlington; DIL, Dillon; FLO, Florence; MRN, Marion; MLB, Marlboro; USDA, U.S. Department of Agriculture]

USGS county-well identification (fig. 3)	USGS site identification number	Description of locality	Altitude of land surface, in feet above sea level	Tops and bottoms of screened intervals, in feet below land surface
		Black Creek Aquifer		
DAR-118	341716079444800	Darlington, USDA Peedee Station	126	100-110
DIL-88	341958079110000	Lake View, Old Kemper Road	100	230-240, 265-275
FLO-105	335220079455700	Lake City, Morris Street	78	152-157, 232-242, 271-276, 314-319, 349-354, 372-377, 397-402, 418-428
FLO-141	335010079264900	Johnsonville, Wellman Industries	55	240-275, 311-321, 370-400
FLO-147	335934079332800	Pamplico, 1st and Old River Road	85	210-230, 250-260, 270-300
FLO-156	335559079562300	Olanta, Avondale Street	100	175-185, 200-220
FLO-166	340345079452000	Effingham, McCall Farms	92	106-126
MRN-71	340534079190400	Raines, U.S. Highway 501	88	230-270, 280-290
MRN-91	341248079154400	Mullins, Dogwood Street	100	326-346

Table 1--Identification, location, and screened intervals of 17 wells in the study area selected for collection of water-quality samples, November 1988 and April and May 1991 (Continued)

[USGS, U.S. Geological Survey; DAR, Darlington; DIL, Dillon; FLO, Florence; MRN, Marion; MLB, Marlboro; USDA, U.S. Department of Agriculture]

USGS county-well identification (fig. 3)	USGS site identification number	Description of locality	Altitude of land surface, in feet above sea level	Tops and bottoms of screened intervals, in feet below land surface
		Middendorf aquifer		
DAR-69	341835079513600	Darlington, Hampton Street	105	180-195, 218-223, 228-238, 248-273, 290-305
DAR-94	342219080042400	Hartsville, 5th Street	216	214-224, 234-244, 248-268, 276-286, 296-306
DIL-98	342528079220308	Dillon, 1st and Jackson Avenue	120	200-210, 225-250, 275-285, 318-353
FLO-243	341345079471500	Florence, Lucas Street	131	325-425
MLB-142	343848079400200	Bennettsville, Beauty Spot Road	185	60-70, 81-116, 125-160
MLB-600	342416079355801	Brownsville, International Paper	125	150-164, 170-180, 189-216, 220-240
		Cape Fear aquifer		
DAR-89	341608079482700	Darlington, Fiber Industries, Inc.	133	530-550, 576-586, 604-624
[1]FLO-149	341148079450803	Florence, Ballard Street	140	450-465, 555-570, 640-650, 710-760

[1]Screens in the Middendorf and Cape Fear aquifers from Aucott and others (1987).

Table 2.--Water-quality results determined in the field for water samples collected from 17 wells in the study area, November 1988 and April and May 1991

[USGS, U.S. Geological Survey; DAR, Darlington; DIL, Dillon; FLO, Florence; MRN, Marion; MLB, Marlboro; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter;°C, degrees Celsius; $CaCO_3$, calcium carbonate; <, less than (the minimal detection limit of the analytical procedure in the field)]

USGS county-well identification (fig. 3)	Specific conductance (µS/cm at 25 °C)	Dissolved oxygen (mg/L)	Temperature (°C)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)
Black Creek aquifer					
DAR-118	46	7.8	19.4	5.95	15.3
DIL-88	162	<.2	20.5	7.15	75
FLO-105	140	<.2	20.3	8.88	72
FLO-141	393	<.2	20.2	9.20	192
FLO-147	141	<.2	20.1	8.71	66
FLO-156	142	<.2	19.5	7.61	58
FLO-166	131	<.2	20.4	6.68	53.5
MRN-71	990	<.2	21.2	7.90	440
MRN-91	172	<.2	21.8	7.35	87

Table 2.--Water-quality results determined in the field for water samples collected from 17 wells in the study area, November 1988 and April and May 1991 (Continued)

[USGS, U.S. Geological Survey; DAR, Darlington; DIL, Dillon; FLO, Florence; MRN, Marion; MLB, Marlboro; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius, mg/L, milligrams per liter °C, degrees Celsius; $CaCO_3$, calcium carbonate; <, less than (the minimal detection limit of the analytical procedure in the field)]

USGS county-well identification (fig. 3)	Specific conductance (µS/cm at 25 °C)	Dissolved oxygen (mg/L)	Temperature (°C)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)
		Middendorf aquifer			
DAR-69	38	4.9	18.7	5.88	11
DAR-94	12	8.1	19.2	4.98	.7
DIL-98	135	.3	19.7	6.73	68
FLO-243	43	<.2	21.2	6.01	10.3
MLB-142	50	7.8	18.5	4.73	2
MLB-600	67	<.2	19	6.26	32
		Cape Fear aquifer			
DAR-89	257	<.2	22.6	6.86	61.5
[1]FLO-149	260	<.2	23	6.92	61

[1]Screens in the Middendorf and Cape Fear aquifers from Aucott and others (1987).

Table 3.--Water-quality results determined in the laboratory for water samples collected from 17 wells in the study area, November 1988 and April and May 1991

[USGS, U.S. Geological Survey; DAR, Darlington; DIL, Dillon; FLO, Florence; MRN, Marion; MLB, Marlboro; mg/L, milligrams per liter; µg/L, micrograms per liter;--, no data; <, less than (the minimal detection limit of the analytical procedure in the laboratory)]

USGS county-well identification (fig. 3)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Aluminum, dissolved (µg/L as Al)	Manganese, dissolved (µg/L as Mn)	Iron, dissolved (µg/L as Fe)
Black Creek aquifer							
DAR-118	5.7	1.7	2.2	2.3	<10	20	1,100
DIL-88	7.9	1.4	27	4.9	<10	30	200
FLO-105	2.3	.5	33	3.8	<10	10	10
FLO-141	1.2	.2	92	4.8	10	---	<10
FLO-147	.6	.1	34	2.9	<10	10	10
FLO-156	11	3.2	3.1	15	<10	---	220
FLO-166	8.9	4.2	4.5	7	<10	50	2,400
MRN-71	5.1	2.8	250	11	<10	30	30
MRN-91	1.6	.5	41	3.6	40	20	150

Table 3.--Water-quality results determined in the laboratory for water samples collected from 17 wells in the study area, November 1988 and April and May 1991--Continued

[USGS, U.S. Geological Survey; DAR, Darlington; DIL, Dillon; FLO, Florence; MRN, Marion; MLB, Marlboro; mg/L, milligrams per liter; µg/L, micrograms per liter;--, no data; <, less than (the minimal detection limit of the analytical procedure in the laboratory)]

USGS county-well identification (fig. 3)	Silica, dissolved (mg/L as SiO_2)	Fluoride, dissolved (mg/L as F)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Hydrogen sulfide, total (mg/L as sulfide)	Nitrate plus nitrite, dissolved (mg/L as N)
			Middendorf aquifer			
DAR-69	12	0.3	2.5	8.9	---	<0.02
DAR-94	9	<.1	1.4	1.4	---	<.02
DIL-98	27	.3	3.4	2.6	---	<.02
FLO-243	15	<.1	1.5	8.1	<1	<.02
MLB-142	7.1	<.1	5.5	.1	---	3.8
MLB-600	13	.1	3.7	4	<1	<.02
			Cape Fear aquifer			
DAR-89	25	.4	30	20	1.3	<.02
[1]FLO-149	18	.3	39	13	<1	<.02

[1]Screens in the Middendorf and Cape Fear aquifers from Aucott and others (1987).

Table 3.--Water-quality results determined in the laboratory for water samples collected from 17 wells in the study area, November 1988 and April and May 1991--Continued

[USGS, U.S. Geological Survey; DAR, Darlington; DIL, Dillon; FLO, Florence; MRN, Marion; MLB, Marlboro; mg/L, milligrams per liter; µg/L, micrograms per liter;--, no data; <, less than (the minimal detection limit of the analytical procedure in the laboratory)]

USGS county-well identification (fig. 3)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Aluminum, dissolved (µg/L as Al)	Manganese, dissolved (µg/L as Mn)	Iron, dissolved (µg/L as Fe)
			Middendorf aquifer				
DAR-69	1.4	0.4	7	1.7	10	10	300
DAR-94	.5	.2	1.1	.6	10	10	10
DIL-98	1.6	1.5	27	4.9	10	20	700
FLO-243	.8	.8	3.9	4.3	10	10	640
MLB-142	1.1	.9	6.9	.9	30	30	20
MLB-600	2.2	1.3	10	3.9	10	70	2,200
			Cape Fear aquifer				
DAR-89	8.3	4.8	32	9.5	10	150	1,800
[1]FLO-149	3.1	1.3	49	7	10	20	200

Table 3.--Water-quality results determined in the laboratory for water samples collected from 17 wells in the study area, November 1988 and April and May 1991--Continued

[USGS, U.S. Geological Survey; DAR, Darlington; DIL, Dillon; FLO, Florence; MRN, Marion; MLB, Marlboro; mg/L, milligrams per liter; µg/L, micrograms per liter;--, no data; <, less than (the minimal detection limit of the analytical procedure in the laboratory)]

USGS county-well identification (fig. 3)	Silica, dissolved (mg/L as SiO_2)	Fluoride, dissolved (mg/L as F)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Hydrogen sulfide, total (mg/L as sulfide)	Nitrate plus nitrite, dissolved (mg/L as N)
			Black Creek aquifer			
DAR-118	33	0.3	4.1	8.4	---	<0.02
DIL-88	38	.4	3.4	3.3	---	<.02
FLO-105	28	.4	2.4	8	<1	.04
FLO-141	24	1.7	4.1	6.4	<1	---
FLO-147	30	.5	2.6	8.4	<1	<.02
FLO-156	39	.1	1.9	7.7	<1	---
FLO-166	39	.2	2.5	6.2	<1	<.02
MRN-71	30	1.6	82	14	.5	<.02
MRN-91	37	.8	5.7	2.5	1.1	<.02

Development of the Ground-Water Modeling Program

A finite-difference computer model was developed to simulate 15 years of pumping from the surficial, Black Creek, and Middendorf aquifers in Darlington, Dillon, Florence, Marion, and Marlboro Counties in order to study the effect of this pumping on the potentiometric surfaces.

The model used in this study is ultimately derived from the South Carolina Regional Aquifer Systems Analysis (SC RASA) model developed by the U. S. Geological Survey (Aucott, 1988) to simulate deep regional ground water flow in the aquifers of South Carolina's Coastal Plain. The RASA model's finite-difference discretization scheme divided the Coastal Plain with a grid of 48 rows and 63 columns, forming square cells 4 miles on a side. Each aquifer in the model was treated as a layer, and each cell within each layer was treated as a homogeneous, isotropic unit, having explicitly defined hydrologic properties. The computer program MODFLOW, developed by the U. S. Geological Survey (McDonald and Harbough, 1984), was used to solve the finite-difference ground-water flow equations and determine the head in each cell of each Coastal Plain aquifer for predevelopment conditions.

The SC RASA model was considerably refined by Campbell and van Heeswijk, who improved the model's resolution by reducing the cell widths from 4 miles to 1 mile in some areas, creating a grid of 115 rows and 127 columns, some of which is shown on the map. In addition to refining the grid, Campbell and van Heeswijk calibrated the model to 1989 observed water levels, meaning that the model could simulate the historical pumping in South Carolina from the mid-1800s through 1989, and its output would closely match the observed 1989 potentiometric surfaces of the Black Creek, Middendorf, and Cape Fear aquifers.

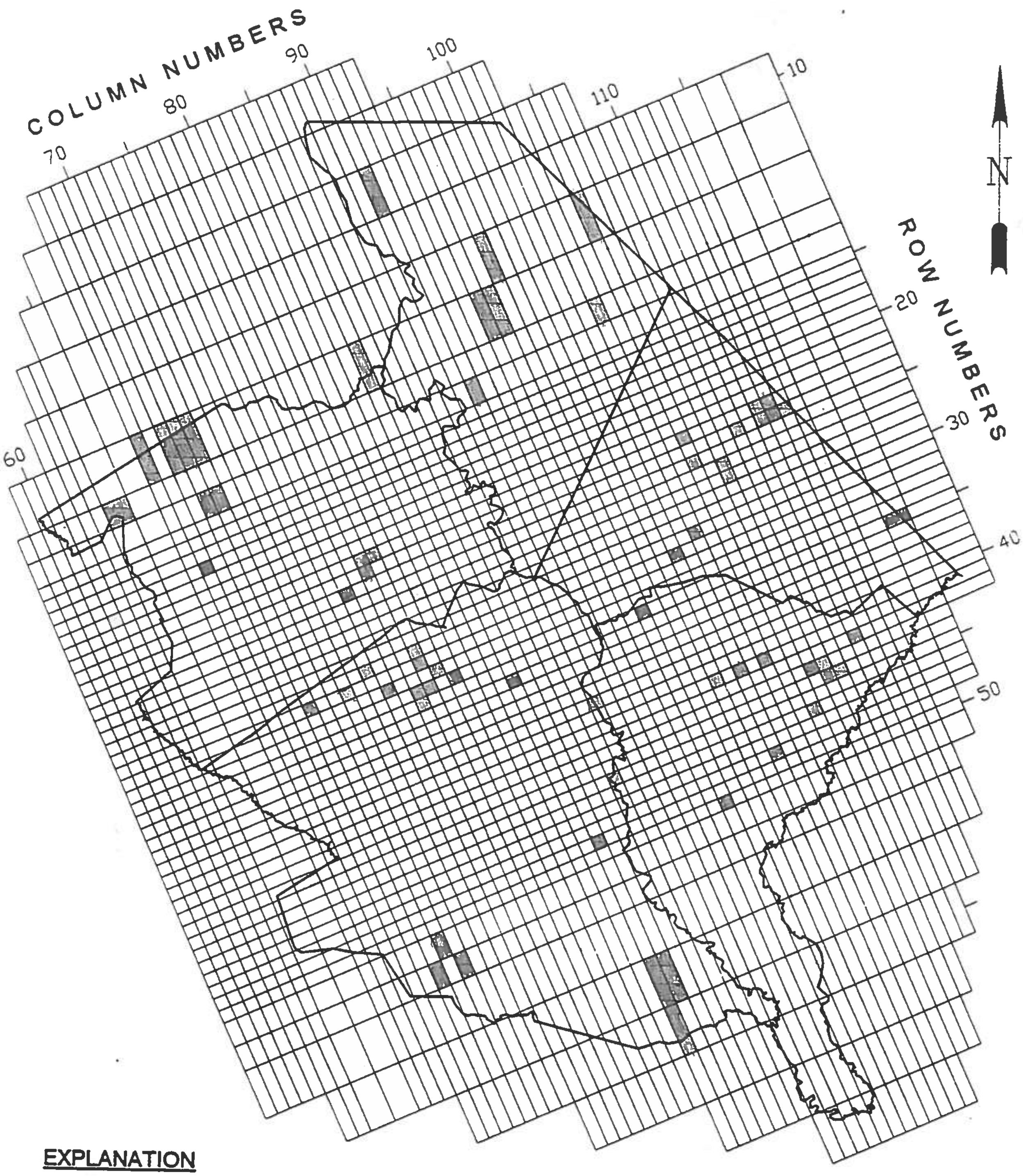
The model used for the simulations in this report is essentially that developed by Campbell and van Heeswijk. The grid geometry is the same, as is the aquifer layering scheme: Layer 1 in the model represents the surficial, Floridan, and Peedee aquifers; Layer 2 represents the aquifers of the Black Creek formation; Layer 3 represents the aquifers of the Middendorf formation; and Layer 4 represents the aquifers of the Cape Fear formation. Pre-Cretaceous rock underlying the Coastal Plain sediment is assumed to have no hydraulic connection to the overlying Cretaceous aquifers, so this basement rock is not incorporated into the model.

Except for the well pumping, only minor modifications were made to Campbell and van Heeswijk's model. In order to better match observed Middendorf water levels in the city of Florence area, transmissivity values of some of the Layer 3 cells in northern Florence County and southern Darlington County were reduced by 20 percent. Also, for the same reason, the hydraulic connection between the Middendorf and Black Creek aquifers in the Florence County area was reduced.

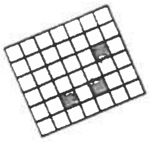
Pumping Rates of the Modeled Wells

Table 1 lists information for the all the modeled wells in each of the five counties of the study area: the county identification number of the well, if known; the well's location (row, and column) in the model grid; the aquifer from which the well pumps (the model layer), the name of the well owner, and the pumping rate of the well for each year of the simulations. In addition, Table 1 lists each county's total modeled pumping for each year of the simulations. The pumping rates listed for 1993-2003 are the predicted pumping rates for those wells; these values were used only in simulations in which that county's pumping was not held at its 1992 rates. On the map, the shaded model grid cells indicate the location of wells pumping more than 100,000 gallons per day at any time during the simulations.

Two scenarios were modeled in which Florence County pumping increased yearly after 1992 but the city of Florence pumping was held constant. Table 2 lists the pumping rates of the 11 city of Florence wells used for the years 1993-2003 during those two simulations. The 1993-2003 pumping rate for each of these wells is approximately the average of that well's 1989-92 pumping rates.



EXPLANATION



Shaded cells indicate location of modeled wells pumping more than 100,000 gallons per day.

Map of the five-county study area showing the finite-difference grid and the locations of the major pumping sites.

Table 1. Modeled well information

PEE DEE MODEL WELL INVENTORY - DARLINGTON COUNTY																			
	WELL LOCATION				MODELED WELL PUMPING RATES (million gallons per day)														
COUNTY NO.	LAYER	ROW	COLUMN	WELL OWNER	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DAR-89	3	26	82	Fiber Industries	1.163	1.200	1.104	1.164	1.167	1.174	1.182	1.189	1.197	1.204	1.212	1.219	1.227	1.234	1.242
DAR-86	3	23	79	Dixie Cup Corp.	0.091	0.105	0.056	0.056	0.056	0.056	0.057	0.057	0.058	0.058	0.058	0.059	0.059	0.059	0.060
DAR-80	3	14	71	Sonoco Products	2.000	1.995	2.006	2.006	2.006	2.006	1.939	1.959	1.979	2.000	2.021	2.042	2.063	2.084	2.106
DAR-216	2	18	82	Kirven well	0.000	0.000	0.000	0.055	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
DAR-214	1	14	83	Ross Farms, #1	0.000	0.000	0.027	0.047	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
	1	14	85	Ross Farms, #4 pond	0.000	0.000	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
DAR-215	1	14	83	Ross Farms, #2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	1	26	83	B. F. Williamson, #1	0.000	0.012	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
	1	12	77	Chapman Home pond #1	0.000	0.015	0.000	0.030	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
	1	12	77	Byrd pond #2	0.000	0.021	0.000	0.009	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
DAR-61	3	12	67	Carolina Power Light, #1	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194
DAR-62	3	12	67	CP&L, #2	0.214	0.214	0.214	0.214	0.214	0.214	0.214	0.214	0.214	0.214	0.214	0.214	0.214	0.214	0.214
DAR-99	3	12	67	CP&L, #3	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191	0.191
DAR-100	3	12	67	CP&L, #4	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283
DAR-101	3	12	67	CP&L, #5	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283	0.283
DAR-103	3	12	71	Dar. Co. Wat. & Sew. #1	0.000	0.455	0.406	0.432	0.449	0.486	0.509	0.494	0.509	0.524	0.551	0.586	0.615	0.662	0.691
DAR-210	3	12	71	Dar. Co. Wat. & Sew. #4	0.425	0.461	0.560	0.572	0.598	0.613	0.636	0.561	0.576	0.591	0.613	0.636	0.660	0.682	0.709
DAR-120	3	12	70	Dar. Co. Wat. & Sew. #3	0.430	0.486	0.557	0.557	0.561	0.576	0.598	0.561	0.576	0.576	0.598	0.621	0.643	0.666	0.693
DAR-102	3	12	69	Dar. Co. Wat. & Sew. #2	0.355	0.424	0.479	0.491	0.524	0.551	0.576	0.561	0.561	0.576	0.598	0.621	0.643	0.666	0.693
DAR-219	3	13	65	Dar. Co. Wat. & Sew. #5	0.000	0.542	0.583	0.513	0.567	0.598	0.621	0.561	0.576	0.591	0.613	0.636	0.660	0.682	0.709
DAR-226	3	13	65	Dar. Co. Wat. & Sew. #6	0.000	0.368	0.413	0.634	0.628	0.636	0.658	0.561	0.576	0.591	0.613	0.636	0.660	0.682	0.709
	3	18	68	Dar. Co. Wat. & Sew. #7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.444	0.519	0.600	0.622	0.643	0.673	0.696	0.722
DAR-208	3	22	79	Darlington (N. Main St.)	0.529	0.141	0.252	0.376	0.380	0.384	0.387	0.391	0.395	0.399	0.403	0.407	0.411	0.415	0.420
DAR-69	3	22	80	Darlington (#1 Hampton)	0.180	0.049	0.001	0.019	0.019	0.019	0.019	0.019	0.020	0.020	0.020	0.020	0.020	0.021	0.021
DAR-113	3	22	79	Darlington (Edwards Ave.)	0.541	0.513	0.479	0.479	0.484	0.489	0.494	0.499	0.503	0.509	0.514	0.519	0.524	0.529	0.534
DAR-229	3	24	77	Darlington (By-Pass)	0.000	0.000	0.000	0.444	0.449	0.453	0.458	0.462	0.467	0.471	0.476	0.481	0.486	0.491	0.495
DAR-24	3	14	70	City of Hartsville	0.599	1.105	0.690	1.075	1.086	1.097	1.108	1.119	1.130	1.141	1.153	1.164	1.176	1.188	1.199
DAR-1	3	12	85	Town of Society Hill	0.760	0.000	0.135	0.135	0.136	0.138	0.139	0.141	0.142	0.144	0.145	0.147	0.148	0.150	0.151
				Total pumping	2.609	2.176	1.970	3.162	3.182	3.215	3.263	3.636	3.752	3.875	3.947	4.017	4.099	4.171	4.252

Table 1. Modeled well information (cont.)

PEE DEE MODEL WELL INVENTORY - DILLON COUNTY																			
	WELL LOCATION				MODELED WELL PUMPING RATES (million gallons per day)														
COUNTY NO.	LAYER	ROW	COLUMN	WELL OWNER	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DIL-84	3	23	111	Dixiana Mill #9	0.525	0.529	0.466	0.392	0.389	0.398	0.407	0.416	0.426	0.426	0.426	0.426	0.426	0.426	0.426
DIL-86	3	23	111	Dixiana Mill #10	0.221	0.149	0.094	0.171	0.172	0.172	0.172	0.172	0.172	0.181	0.191	0.200	0.209	0.209	0.209
DIL-80	3	23	111	Dixiana Mill #5	0.249	0.199	0.300	0.282	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299
DIL-81	3	24	111	Dixiana Mill #6	0.061	0.042	0.078	0.094	0.095	0.096	0.097	0.097	0.098	0.099	0.100	0.101	0.102	0.104	0.105
DIL-82	3	23	111	Dixiana Mill #8	0.000	0.000	0.000	0.041	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.047	0.058
DIL-104	3	31	99	Huggins Farm	0.022	0.000	0.099	0.058	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
DIL-87	3	24	109	Dillon, Hwy 9	0.392	0.436	0.399	0.344	0.349	0.354	0.359	0.364	0.369	0.374	0.379	0.384	0.386	0.387	0.389
DIL-98	3	26	108	Dillon, 1st & Jackson	0.529	0.483	0.459	0.415	0.421	0.427	0.433	0.439	0.445	0.451	0.457	0.463	0.465	0.467	0.469
DIL-55	3	27	108	Dillon, 20th & Hudson	0.229	0.292	0.231	0.336	0.341	0.346	0.351	0.356	0.361	0.365	0.370	0.375	0.377	0.378	0.380
DIL-83	3	35	116	Town of Lake View	0.123	0.174	0.255	0.071	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DIL-73	3	30	103	Town of Latta	0.000	0.083	0.000	0.272	0.277	0.281	0.284	0.288	0.292	0.295	0.299	0.303	0.307	0.310	0.314
DIL-91	3	23	112	TRICO, #3	0.000	0.254	0.024	0.135	0.132	0.137	0.143	0.148	0.154	0.160	0.167	0.174	0.181	0.189	0.196
DIL-92	3	24	113	TRICO, #4	0.000	0.254	0.024	0.269	0.265	0.275	0.285	0.297	0.308	0.321	0.334	0.348	0.362	0.377	0.393
DIL-102	3	31	101	TRICO, #6	0.000	0.000	0.000	0.194	0.192	0.198	0.206	0.215	0.224	0.232	0.242	0.251	0.262	0.273	0.284
DIL-110	3	31	101	TRICO, #7	0.000	0.000	0.000	0.194	0.192	0.198	0.206	0.215	0.224	0.232	0.242	0.251	0.262	0.273	0.284
DIL-112	3	25	106	TRICO, #8	0.000	0.000	0.000	0.177	0.599	0.598	0.925	1.020	1.030	1.077	1.107	1.182	1.189	1.263	1.272
	3	24	112	TRICO, #9	0.000	0.000	0.000	0.135	0.132	0.137	0.143	0.148	0.154	0.160	0.167	0.174	0.181	0.189	0.196
DIL-113	3	23	106	TRICO, #10	0.000	0.000	0.000	0.000	0.000	0.282	0.598	0.673	0.748	0.785	0.823	0.823	0.898	0.898	0.984
				Total pumping	2.351	2.896	2.429	3.580	3.953	4.296	5.007	5.245	5.401	5.557	5.700	5.852	6.003	6.149	6.317

Table 1. Modeled well information (cont.)

PEE DEE MODEL WELL INVENTORY - FLORENCE COUNTY																			
	WELL LOCATION				MODELED WELL PUMPING RATES (million gallons per day)														
COUNTY NO.	LAYER	ROW	COLUMN	WELL OWNER	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
FLO-145	2	39	91	Stone Container Co. (all)	0.209	0.215	0.218	0.112	0.217	0.219	0.221	0.224	0.226	0.228	0.230	0.233	0.235	0.237	0.239
FLO-141	3	54	88	Wellman Industries, #3	0.427	0.339	0.454	0.511	0.524	0.524	0.524	0.524	0.524	0.524	0.524	0.524	0.524	0.524	0.524
FLO-155	3	54	88	Wellman Industries, #5	0.532	0.385	0.538	0.620	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.636	0.636
FLO-148	3	54	88	Wellman Industries, #4	0.450	0.312	0.494	0.265	0.247	0.269	0.292	0.314	0.337	0.359	0.389	0.411	0.434	0.456	0.486
FLO-246	3	54	88	Wellman Industries, #6	0.793	0.579	0.471	0.857	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860
FLO-151	2	45	90	Delta Mills (Stevens)	0.134	0.142	0.161	0.156	0.158	0.159	0.161	0.162	0.164	0.166	0.168	0.169	0.171	0.173	0.174
FLO-260	2	40	80	Joseph C. Jones #2	0.006	0.016	0.008	0.001	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
FLO-261	2	40	79	Joseph C. Jones #1	0.007	0.034	0.033	0.023	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
	1	37	79	Joseph C. Jones, pond 3	0.007	0.033	0.031	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
	1	43	81	Joseph C. Jones, pond 4	0.011	0.039	0.030	0.023	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
FLO-184	2	55	87	Johnsonville, #1 Uptown	0.034	0.239	0.277	0.363	0.377	0.393	0.408	0.424	0.441	0.459	0.477	0.497	0.498	0.500	0.501
FLO-185	2	54	88	Johnsonville, #2 Oak St.	0.176	0.109	0.077	0.064	0.067	0.067	0.069	0.072	0.075	0.077	0.081	0.082	0.105	0.127	0.150
FLO-178	2	54	87	Johnsonville, #3 W. side	0.214	0.089	0.057	0.002	0.002	0.002	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.007	0.007
FLO-208	3	33	82	Florence, #16 Pine St.	1.058	0.813	0.304	0.591	0.608	0.627	0.646	0.665	0.684	0.705	0.726	0.748	0.770	0.794	0.818
FLO-243	3	30	80	Florence, #24 Lucas St.	0.816	1.329	1.184	0.959	0.988	1.017	1.048	1.079	1.112	1.145	1.180	1.216	1.251	1.289	1.328
FLO-154	3	31	80	Florence, #21 W. Darl. St	1.253	1.498	1.963	1.473	1.517	1.563	1.610	1.658	1.708	1.759	1.812	1.866	1.922	1.980	2.039
FLO-149	3	32	81	Florence, #20 S. Ballard	0.541	0.039	0.425	0.512	0.527	0.543	0.560	0.576	0.593	0.611	0.630	0.649	0.668	0.688	0.708
FLO-140	3	33	80	Florence, #18, Gully Br.	1.200	0.804	1.069	1.194	1.230	1.266	1.305	1.343	1.384	1.426	1.468	1.513	1.557	1.605	1.652
FLO-146	3	33	79	Florence, #19 S. Edisto	0.000	0.056	0.775	0.453	0.467	0.481	0.495	0.510	0.525	0.542	0.557	0.575	0.592	0.609	0.628
FLO-161	3	32	77	Florence, #22 McGowen	1.195	1.368	1.014	0.822	0.847	0.872	0.898	0.925	0.953	0.982	1.011	1.041	1.073	1.105	1.139
FLO-187	3	34	79	Florence, #17 Dexter Dr.	0.608	0.788	0.731	0.745	0.767	0.791	0.814	0.839	0.864	0.889	0.916	0.944	0.972	1.001	1.032
FLO-179	3	30	76	Florence, #23	1.153	0.431	0.485	0.286	0.295	0.304	0.313	0.322	0.331	0.341	0.352	0.362	0.373	0.384	0.396
FLO-196	3	31	74	Florence, Oakdale	1.214	1.261	0.518	0.653	0.672	0.693	0.714	0.735	0.757	0.779	0.803	0.827	0.852	0.877	0.904
FLO-263	3	35	86	Florence, #26	0.248	1.007	0.744	0.746	0.769	0.791	0.815	0.840	0.865	0.891	0.918	0.946	0.974	1.003	1.033
FLO-204	3	31	71	Town of Timmonsville	0.374	0.393	0.070	0.420	0.438	0.455	0.474	0.492	0.512	0.533	0.554	0.576	0.598	0.623	0.648
FLO-247	3	52	74	Lake City, A.B. Dick	0.361	0.403	0.413	0.472	0.491	0.511	0.531	0.551	0.573	0.598	0.621	0.643	0.670	0.696	0.724
FLO-250	3	51	73	Lake City, Davis St.	0.000	0.063	0.152	0.208	0.216	0.225	0.234	0.243	0.254	0.265	0.275	0.287	0.298	0.310	0.323
FLO-105	3	51	73	Lake City, #3	0.383	0.235	0.337	0.227	0.236	0.246	0.256	0.266	0.278	0.289	0.300	0.312	0.325	0.337	0.350
FLO-162	3	52	72	Lake City, #2	0.335	0.436	0.257	0.309	0.321	0.334	0.348	0.361	0.376	0.389	0.405	0.419	0.436	0.453	0.473
FLO-147	3	49	87	Town of Pamplico	0.115	0.123	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FLO-156	2	43	66	Town of Olanta	0.000	0.103	0.091	0.096	0.099	0.103	0.108	0.112	0.117	0.121	0.126	0.131	0.136	0.141	0.147
				Total pumping	13.85	13.68	13.40	13.19	13.66	14.03	14.42	14.82	15.23	15.66	16.10	16.55	17.02	17.50	18.00

Table 1. Modeled well information (cont.)

PEE DEE MODEL WELL INVENTORY - MARION COUNTY																			
COUNTY NO.	WELL LOCATION			WELL OWNER	MODELED WELL PUMPING RATES (million gallons per day)														
	LAYER	ROW	COLUMN		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	3	50	97	B&M Aquaculture, #1	0.180	0.200	0.163	0.063	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
	3	50	97	B&M Aquaculture, #2	0.000	0.386	0.386	0.047	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
MRN-97	2	45	99	Mace Farms, McMillan	0.001	0.010	0.009	0.001	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
MRN-98	2	49	94	Mace Farms, Island #1	0.000	0.008	0.001	0.001	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
MRN-99	2	49	94	Mace Farms, Island #2	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MRN-100	2	50	93	Mace Farms, Half Moon	0.002	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MRN-101	2	51	94	Mace Farms, Vickers	0.000	0.007	0.000	0.001	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
MRN-62	2	41	100	City of Marion (all wells)	1.312	1.311	1.876	2.240	2.349	2.461	2.581	2.693	2.805	2.917	3.030	3.164	3.291	3.426	3.591
MRN-71	2	48	102	MARCO #4	0.029	0.016	0.169	0.208	0.187	0.209	0.224	0.224	0.224	0.224	0.262	0.284	0.284	0.284	0.292
MRN-95	3	41	102	MARCO #3	0.179	0.178	0.234	0.205	0.187	0.209	0.224	0.239	0.254	0.254	0.269	0.337	0.337	0.337	0.337
MRN-68	3	34	97	MARCO #1,2	0.484	0.422	0.468	0.445	0.434	0.449	0.374	0.449	0.449	0.449	0.449	0.449	0.449	0.449	0.449
MRN-110	3	42	111	MARCO #5	0.000	0.390	0.385	0.362	0.337	0.374	0.299	0.337	0.337	0.411	0.486	0.486	0.486	0.486	0.486
MRN-115	3	41	104	MARCO #6	0.000	0.000	0.000	0.000	0.000	0.000	0.224	0.224	0.337	0.411	0.449	0.539	0.524	0.524	0.561
	3	46	106	MARCO #7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.209	0.434	0.636
MRN-67	2	44	109	Town of Mullins, Springs	0.000	0.000	0.041	0.226	0.235	0.244	0.254	0.264	0.275	0.286	0.297	0.309	0.322	0.334	0.348
MRN-89	2	44	108	Town of Mullins Cleveland	0.000	0.000	0.056	0.131	0.136	0.141	0.147	0.153	0.159	0.165	0.172	0.179	0.186	0.194	0.201
MRN-60	2	43	107	Town of Mullins, Gapway	0.000	0.000	0.046	0.156	0.162	0.169	0.176	0.183	0.190	0.197	0.206	0.214	0.222	0.231	0.240
MRN-43	2	43	108	Town of Mullins, Front	0.000	0.000	0.026	0.125	0.130	0.135	0.141	0.146	0.152	0.158	0.165	0.171	0.178	0.185	0.192
MRN-59	2	43	107	Town of Mullins, Prevatte	0.000	0.000	0.034	0.154	0.160	0.166	0.173	0.180	0.187	0.194	0.202	0.210	0.218	0.227	0.236
				Total pumping	2.187	2.933	3.896	4.364	4.627	4.869	5.127	5.402	5.679	5.979	6.296	6.652	7.017	7.421	7.879

Table 1. Modeled well information (cont.)

PEE DEE MODEL WELL INVENTORY - MARLBORO COUNTY																			
	WELL LOCATION				MODELED WELL PUMPING RATES (million gallons per day)														
COUNTY NO.	LAYER	ROW	COLUMN	WELL OWNER	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	3	14	92	Oak River Mill, #4	0.221	0.211	0.220	0.153	0.153	0.153	0.153	0.157	0.165	0.172	0.180	0.187	0.187	0.187	0.187
MLB-117	3	14	92	Oak River Mill, #3	0.029	0.192	0.192	0.318	0.319	0.319	0.322	0.322	0.322	0.322	0.322	0.322	0.329	0.337	0.337
	3	14	92	Oak River Mill, #5	0.389	0.422	0.324	0.258	0.265	0.273	0.276	0.280	0.280	0.281	0.281	0.281	0.281	0.282	0.290
MLB-145	3	22	96	International Paper	0.000	0.000	0.093	0.085	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090
	1	22	96	International Paper, pond	0.000	0.000	0.023	0.023	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
MLB-172	3	12	101	Hinson Farm, #4, #5	0.000	0.000	0.015	0.021	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
MLB-167	3	12	102	Hinson Farm, #1	0.000	0.000	0.013	0.015	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
MLB-179	3	12	102	Hinson Farm, #2	0.000	0.000	0.009	0.004	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
MLB-147	3	13	101	Hinson Farm, #3	0.000	0.000	0.013	0.022	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
MLB-168	3	15	97	Rogers Farm, Blenheim	0.037	0.082	0.071	0.082	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
MLB-174	3	11	103	Tatum Farm	0.000	0.014	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
MLB-176	3	12	96	Hodges Farm	0.035	0.000	0.145	0.210	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180	0.180
MLB-177	1	13	104	Calhoun Farm, water hole	0.000	0.003	0.006	0.014	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
	1	12	103	Calhoun Farm, pond #3	0.003	0.031	0.002	0.035	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
MLB-150	3	11	97	Bennettsville (all wells)	1.736	1.909	1.304	0.937	0.895	0.898	0.898	0.898	0.898	0.898	0.898	0.898	0.898	0.898	0.898
MLB-139	3	12	95	Marlb. Co. W. & S. #1	0.000	0.075	0.253	0.024	0.024	0.024	0.025	0.025	0.025	0.026	0.026	0.027	0.027	0.027	0.028
MLB-140	3	12	95	Marlb. Co. W. & S, #2	0.000	0.000	0.104	0.016	0.016	0.017	0.017	0.018	0.018	0.018	0.019	0.019	0.019	0.020	0.020
MLB-31	3	11	105	Town of McColl	0.423	0.421	0.000	0.025	0.344	0.348	0.352	0.355	0.359	0.363	0.367	0.370	0.374	0.378	0.382
MLB-171	3	13	103	Town of Clio	0.124	0.124	0.124	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112
	1	9	91	Wallace Water Co.	0.280	0.280	0.280	0.200	0.202	0.204	0.206	0.208	0.210	0.212	0.214	0.216	0.218	0.221	0.223
				Total pumping	3.278	3.765	3.194	2.555	2.777	2.794	2.808	2.822	2.836	2.850	2.865	2.879	2.894	2.908	2.923

Table 2. Constant-rate pumping values for city of Florence wells

PEE DEE MODEL - CITY OF FLORENCE WELLS									
	WELL LOCATION				MODELED WELL PUMPING RATES (Mgd)				
COUNTY NO.	LAYER	ROW	COLUMN	WELL OWNER	1989	1990	1991	1992	1993-2003
FLO-208	3	33	82	Florence, #16 Pine St.	1.058	0.813	0.304	0.591	0.691
FLO-243	3	30	80	Florence, #24 Lucas St.	0.816	1.329	1.184	0.959	1.070
FLO-154	3	31	80	Florence, #21 W. Darl. St	1.253	1.498	1.963	1.473	1.548
FLO-149	3	32	81	Florence, #20 S. Ballard	0.541	0.039	0.425	0.512	0.379
FLO-140	3	33	80	Florence, #18, Gully Br.	1.200	0.804	1.069	1.194	1.070
FLO-146	3	33	79	Florence, #19 S. Edisto	0.000	0.056	0.775	0.453	0.322
FLO-161	3	32	77	Florence, #22 McGowen	1.195	1.368	1.014	0.822	1.100
FLO-187	3	34	79	Florence, #17 Dexter Dr.	0.608	0.788	0.731	0.745	0.718
FLO-179	3	30	76	Florence, #23	1.153	0.431	0.485	0.286	0.589
FLO-196	3	31	74	Florence, Oakdale	1.214	1.261	0.518	0.653	0.913
FLO-263	3	35	86	Florence, #26	0.248	1.007	0.744	0.746	0.686
				Total pumping	9.29	9.39	9.21	8.43	9.09

APPENDIX 4 -- PUMPAGE SIMULATIONS FOR THE GROUND-WATER MANAGEMENT ALTERNATIVES AT FLORENCE

Alternative 1. Existing well configuration

Alternative 2. Total available drawdown increased

Alternative 3. Well placement--includes one well at either Site 1, Site 2, or Site 3 or wells at all three sites

ALTERNATIVE 1
Existing well configuration

Well pumpage, in millions of gallons per day, for 0% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.45	0.72	0.72	0.57	0.33	0.09
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.02	0.11	0.00	0.00	0.00
21	0.62	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.15	0.33	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.69	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.22	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.50	0.05	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.10	0.64	0.72	0.72	0.70	0.52	0.50	0.48	0.46	0.44
33	0.00	0.00	0.00	0.31	0.00	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.56	0.54	0.41	0.37	0.36	0.34	0.33
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.77	0.76	0.68	0.64	0.56	0.52	0.50	0.47	0.45
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.66	9.66	9.65	9.67	9.65	9.67	9.33	9.02	8.71	8.42

Well pumpage, in millions of gallons per day, for 1% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.64	0.72	0.72	0.72	0.52	0.28	0.05
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.31	0.06	0.00	0.00	0.00
21	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	0.10	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.88	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.09	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.23	0.72	0.72	0.69	0.54	0.52	0.50	0.48	0.46	0.44
33	0.00	0.10	0.45	0.00	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.57	0.56	0.41	0.39	0.37	0.36	0.34	0.33
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.77	0.70	0.66	0.57	0.54	0.52	0.49	0.47	0.45
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.76	9.85	9.94	10.06	9.93	9.59	9.28	8.96	8.66	8.38

Existing well configuration (continued)

Well pumpage, in millions of gallons per day, for 2% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.49	0.25	0.02
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.28	0.03	0.00	0.00	0.00
21	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.34	0.06	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.72	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.62	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.34	0.72	0.72	0.56	0.54	0.52	0.50	0.48	0.46	0.44
33	0.00	0.01	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.44	0.41	0.39	0.37	0.36	0.34	0.33
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.77	0.71	0.60	0.57	0.54	0.51	0.49	0.47	0.45
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.85	10.05	10.25	10.25	9.89	9.56	9.24	8.93	8.63	8.35

Well pumpage, in millions of gallons per day, for 3% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.29	0.72	0.72	0.72	0.72	0.47	0.23	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.26	0.00	0.00	0.00	0.00
21	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.97	0.31	0.04	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.47	0.72	0.57	0.55	0.54	0.52	0.50	0.48	0.46	0.44
33	0.00	0.55	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.49	0.43	0.41	0.39	0.37	0.36	0.34	0.33
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.74	0.65	0.60	0.57	0.54	0.51	0.49	0.47	0.45
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.95	10.25	10.56	10.20	9.87	9.54	9.21	8.91	8.61	8.33

Existing well configuration (continued)

Well pumpage, in millions of gallons per day, for 4% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.71	0.46	0.22	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.47
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.24	0.00	0.00	0.00	0.00
21	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.58	0.29	0.03	0.00	0.00	0.00	0.00	0.00
25	0.00	0.61	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.61	0.72	0.58	0.56	0.54	0.52	0.50	0.48	0.46	0.44
33	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.47	0.43	0.40	0.39	0.37	0.36	0.34	0.33
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.76	0.64	0.60	0.56	0.54	0.51	0.49	0.47	0.45
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.05	10.44	10.58	10.19	9.84	9.52	9.20	8.90	8.60	8.32

Well pumpage, in millions of gallons per day, for 5% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.70	0.45	0.21	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.46
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.23	0.00	0.00	0.00	0.00
21	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.57	0.28	0.02	0.00	0.00	0.00	0.00	0.00
25	0.00	0.93	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.72	0.72	0.57	0.56	0.54	0.52	0.50	0.48	0.46	0.44
33	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.47	0.43	0.40	0.39	0.37	0.36	0.34	0.33
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.75	0.63	0.60	0.56	0.54	0.51	0.49	0.47	0.45
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.14	10.65	10.55	10.18	9.83	9.51	9.19	8.89	8.59	8.31

ALTERNATIVE 2

Total available drawdown increased

Well pumpage, in millions of gallons per day, for 0% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.55	0.00	0.72	0.47
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.48	0.48
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.04	0.00
21	0.97	0.43	0.25	0.09	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.47	1.15	1.15	1.15
26	0.00	0.00	0.00	0.00	0.17	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.72	0.72	0.55	0.19	0.00	0.15	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.69	0.67
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.29	0.47	0.63	0.72	0.72	0.66	0.42	0.42	0.40
33	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.92	0.96	0.96
34	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.52	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.56	9.23

Well pumpage, in millions of gallons per day, for 1% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.16	0.72	0.72	0.64	0.38
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.47	0.18	0.00	0.00
21	0.94	0.37	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.15	1.15	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.12	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.13	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.72	0.63	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.73	0.70	0.68	0.66
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.54	0.72	0.72	0.72	0.50	0.45	0.43	0.41	0.39
33	0.00	0.00	0.00	0.00	0.61	0.46	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.65	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.76	9.85	9.95	10.05	10.15	10.25	10.06	9.72	9.42	9.12

Total available drawdown increased (continued)

Well pumpage, in millions of gallons per day, for 2% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.58	0.32
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.40	0.13	0.00	0.00
21	0.91	0.30	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	0.52	0.20	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.65	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.09	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.72	0.40	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.75	0.72	0.70	0.68	0.66
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.72	0.71	0.48	0.47	0.45	0.43	0.41	0.39
33	0.00	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.85	10.05	10.25	10.46	10.66	10.31	9.98	9.67	9.36	9.06

Well pumpage, in millions of gallons per day, for 3% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.55	0.30
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.37	0.10	0.00	0.00
21	0.89	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	0.46	0.16	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.35	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.75	0.72	0.70	0.68	0.66
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.12	0.72	0.72	0.55	0.48	0.46	0.45	0.43	0.41	0.39
33	0.00	0.00	0.75	0.47	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.95	10.25	10.56	10.87	10.60	10.26	9.95	9.64	9.33	9.04

Total available drawdown increased (continued)

Well pumpage, in millions of gallons per day, for 4% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.53	0.27
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.34	0.07	0.00	0.00
21	0.86	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.77	0.43	0.14	0.00	0.00	0.00	0.00
25	0.00	0.00	0.97	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.74	0.72	0.70	0.68	0.66
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.25	0.72	0.67	0.50	0.48	0.47	0.45	0.43	0.41	0.39
33	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.05	10.45	10.87	10.93	10.57	10.24	9.92	9.61	9.31	9.01

Well pumpage, in millions of gallons per day, for 5% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.51	0.26
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
18	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.32	0.06	0.00	0.00
21	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.73	0.41	0.12	0.00	0.00	0.00	0.00
25	0.00	0.00	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.74	0.72	0.70	0.68	0.66
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.37	0.72	0.56	0.49	0.48	0.46	0.45	0.42	0.41	0.39
33	0.00	0.09	0.66	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.14	10.65	11.19	10.88	10.55	10.21	9.90	9.59	9.29	9.00

ALTERNATIVE 3
One well at Site 1

Well pumpage, in millions of gallons per day, for 0% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.00	0.00	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.21	0.00	0.13	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00
21	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.10	0.79	0.89	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.44	1.15	1.15	1.15	1.15
26	0.00	0.00	0.00	0.00	0.25	0.48	0.48	0.48	0.48	0.48
27	0.72	0.70	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.00	0.16	0.72	0.66	0.48	0.40	0.41	0.42
33	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.96	0.74	0.41
34	0.58	0.58	0.58	0.58	0.58	0.58	0.57	0.43	0.45	0.46
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.18	0.53	0.72	0.68	0.64	0.61	0.52	0.51	0.50
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.66	9.66	9.66	9.66	9.66	9.65	9.66	9.44	9.11	8.79

Well pumpage, in millions of gallons per day, for 1% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.08	0.00	0.19	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.48	0.00	0.48	0.35	0.01	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.43	0.00	0.00	0.00	0.00	0.00
21	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.15	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.01	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.59	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.26	0.72	0.54	0.43	0.41	0.41	0.42	0.43
33	0.00	0.00	0.00	0.00	0.00	0.96	0.96	0.96	0.64	0.32
34	0.58	0.58	0.58	0.58	0.25	0.42	0.41	0.44	0.45	0.46
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.48	0.77	0.70	0.77	0.56	0.53	0.52	0.51	0.50
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.76	9.85	9.95	10.05	10.14	10.04	9.66	9.34	9.02	8.71

One well at Site 1 (continued)

Well pumpage, in millions of gallons per day, for 2% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.53	0.00	0.43	0.13	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.12	0.48	0.48	0.29	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00
21	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.99	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.20	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.03	0.72	0.59	0.45	0.43	0.42	0.41	0.42	0.43
33	0.00	0.00	0.00	0.00	0.96	0.96	0.96	0.91	0.58	0.27
34	0.58	0.58	0.58	0.58	0.43	0.41	0.42	0.45	0.46	0.47
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.77	0.74	0.70	0.58	0.55	0.53	0.52	0.51	0.50
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.85	10.05	10.25	10.46	10.33	9.96	9.62	9.29	8.97	8.67

Well pumpage, in millions of gallons per day, for 3% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.18	0.69	0.38	0.10	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.25	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.40	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.38	0.72	0.48	0.45	0.43	0.41	0.41	0.42	0.43
33	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.87	0.54	0.23
34	0.58	0.58	0.58	0.45	0.42	0.41	0.42	0.45	0.46	0.47
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.02	0.77	0.72	0.60	0.57	0.55	0.53	0.52	0.51	0.50
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.95	10.25	10.56	10.66	10.26	9.93	9.57	9.25	8.93	8.63

One well at Site 1 (continued)

Well pumpage, in millions of gallons per day, for 4% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.00	0.67	0.36	0.07	0.00	0.00	0.00	0.00
17	0.48	0.48	0.38	0.48	0.48	0.48	0.22	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.01	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.57	0.47	0.45	0.43	0.42	0.41	0.42	0.43
33	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.85	0.52	0.21
34	0.58	0.58	0.58	0.44	0.42	0.41	0.43	0.45	0.46	0.47
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.14	0.77	0.71	0.60	0.57	0.55	0.53	0.52	0.51	0.50
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.05	10.45	10.86	10.62	10.24	9.90	9.56	9.23	8.91	8.61

Well pumpage, in millions of gallons per day, for 5% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.64	0.34	0.06	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.20	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.51	0.47	0.45	0.43	0.41	0.41	0.42	0.43
33	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.83	0.50	0.19
34	0.58	0.58	0.47	0.44	0.42	0.41	0.43	0.45	0.46	0.47
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.25	0.64	0.63	0.60	0.57	0.55	0.53	0.52	0.51	0.50
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.14	10.65	11.00	10.59	10.22	9.89	9.53	9.21	8.89	8.59

One well at Site 2

Well pumpage, in millions of gallons per day, for 0% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.00	0.37	0.72	0.72	0.21	0.00	0.72	0.72	0.72	0.72
17	0.48	0.48	0.48	0.48	0.48	0.04	0.48	0.00	0.00	0.05
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00
21	0.73	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.15	1.15	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.01	1.15	1.01	0.97	0.99	1.01
26	0.00	0.00	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.42	0.08	0.00	0.12	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.72	0.72	0.72	0.72	0.65	0.42	0.37	0.36	0.37	0.38
33	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.72	0.38	0.00
34	0.58	0.58	0.58	0.58	0.53	0.00	0.37	0.41	0.42	0.43
35	0.53	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.00	0.07	0.41	0.64	0.77	0.51	0.50	0.49	0.48
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.66	9.66	9.66	9.66	9.67	9.65	9.57	9.20	8.89	8.59

Well pumpage, in millions of gallons per day, for 1% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.00	0.71	0.72	0.40	0.43	0.72	0.72	0.72	0.72	0.71
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.00	0.08	0.00	0.00	0.00	0.00
21	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	0.92	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.20	1.15	1.01	1.02	0.98	1.00	1.01
26	0.00	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.69	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.72	0.72	0.72	0.63	0.40	0.37	0.38	0.36	0.37	0.38
33	0.00	0.00	0.00	0.00	0.19	0.74	0.47	0.64	0.30	0.00
34	0.58	0.58	0.58	0.54	0.47	0.37	0.37	0.41	0.42	0.43
35	0.66	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.00	0.54	0.65	0.59	0.52	0.51	0.50	0.49	0.48
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.76	9.85	9.95	10.05	10.15	9.81	9.47	9.13	8.82	8.53

One well at Site 2 (continued)

Well pumpage, in millions of gallons per day, for 2% annual water demand growth.

Well No.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.01	0.72	0.72	0.00	0.72	0.72	0.72	0.72	0.72	0.68
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.04	0.00	0.00	0.00	0.00
21	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.97	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	1.15	1.09	1.01	1.02	0.98	1.00	1.00
26	0.00	0.00	0.44	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.57	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.72	0.72	0.72	0.40	0.40	0.37	0.38	0.36	0.37	0.38
33	0.00	0.00	0.00	0.36	0.47	0.73	0.42	0.59	0.26	0.00
34	0.58	0.58	0.58	0.48	0.41	0.37	0.38	0.42	0.43	0.43
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.31	0.60	0.62	0.56	0.52	0.51	0.50	0.49	0.48
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.85	10.05	10.25	10.46	10.13	9.76	9.43	9.09	8.79	8.49

Well pumpage, in millions of gallons per day, for 3% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.17	0.72	0.52	0.72	0.72	0.72	0.72	0.72	0.72	0.66
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.02	0.00	0.00	0.00	0.00
21	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.63	1.09	1.10	1.01	1.02	0.98	1.00	1.00
26	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.72	0.72	0.57	0.39	0.40	0.37	0.38	0.36	0.37	0.38
33	0.00	0.00	0.00	0.84	0.42	0.73	0.39	0.57	0.23	0.00
34	0.58	0.58	0.54	0.40	0.41	0.37	0.38	0.42	0.43	0.43
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.63	0.67	0.57	0.55	0.52	0.51	0.50	0.49	0.48
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.95	10.25	10.56	10.49	10.08	9.74	9.40	9.07	8.76	8.47

One well at Site 2 (continued)

Well pumpage, in millions of gallons per day, for 4% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.33	0.72	0.59	0.72	0.72	0.72	0.72	0.72	0.72	0.64
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00
21	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	1.15	1.08	1.11	1.01	1.03	0.98	1.01	1.00
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.72	0.72	0.40	0.39	0.41	0.37	0.38	0.37	0.37	0.37
33	0.00	0.00	0.83	0.80	0.38	0.72	0.36	0.54	0.20	0.00
34	0.58	0.58	0.43	0.40	0.41	0.37	0.38	0.42	0.43	0.43
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.49	0.61	0.57	0.55	0.52	0.51	0.50	0.49	0.47
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.05	10.45	10.86	10.44	10.06	9.71	9.38	9.05	8.74	8.43

Well pumpage, in millions of gallons per day, for 5% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.48	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.64
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00
21	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.08	1.15	1.08	1.11	1.01	1.03	0.98	1.01	1.00
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.72	0.71	0.41	0.39	0.41	0.37	0.38	0.37	0.37	0.37
33	0.00	0.00	0.79	0.78	0.37	0.72	0.35	0.53	0.19	0.00
34	0.58	0.58	0.43	0.40	0.41	0.37	0.38	0.42	0.43	0.43
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.73	0.61	0.57	0.55	0.52	0.51	0.50	0.49	0.47
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.14	10.65	10.86	10.42	10.05	9.71	9.37	9.04	8.73	8.43

One well at Site 3

Well pumpage, in millions of gallons per day, for 0% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.37	0.00	0.72	0.72	0.51	0.29
17	0.48	0.48	0.48	0.48	0.48	0.43	0.39	0.04	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00
21	0.49	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.15	1.15	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.25	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.00	0.11	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.47	0.15	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.43	0.72	0.72	0.72	0.58	0.49	0.49	0.47	0.45
33	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.49	0.45	0.58	0.32	0.35	0.34	0.34
35	0.77	0.77	0.77	0.77	0.77	0.07	0.70	0.71	0.70	0.69
36	0.00	0.00	0.13	0.58	0.54	0.61	0.44	0.42	0.41	0.39
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	1.00	1.00	0.89	0.74	0.70	0.86	0.61	0.59	0.57	0.55
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.66	9.66	9.66	9.66	9.66	9.66	9.53	9.18	8.86	8.57

Well pumpage, in millions of gallons per day, for 1% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.69	0.72	0.72	0.72	0.68	0.45	0.22
17	0.48	0.48	0.48	0.48	0.48	0.48	0.28	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00
21	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	0.35	0.10	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.77	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.16	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.71	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.72	0.72	0.53	0.51	0.50	0.48	0.46	0.45
33	0.00	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.52	0.58	0.34	0.31	0.33	0.35	0.34	0.34
35	0.77	0.77	0.77	0.00	0.74	0.71	0.71	0.71	0.70	0.69
36	0.01	0.00	0.61	0.46	0.48	0.45	0.43	0.43	0.41	0.39
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	1.00	0.98	0.78	0.98	0.67	0.63	0.60	0.59	0.57	0.55
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.76	9.86	9.96	10.06	10.17	9.77	9.43	9.10	8.79	8.50

One well at Site 3 (continued)

Well pumpage, in millions of gallons per day, for 2% annual water demand growth.

Well No.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.65	0.42	0.19
17	0.48	0.48	0.48	0.48	0.48	0.48	0.24	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.56	0.31	0.07	0.00	0.00	0.00	0.00
25	0.00	0.00	0.26	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.60	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.72	0.54	0.52	0.51	0.49	0.48	0.46	0.44
33	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.51	0.35	0.33	0.31	0.33	0.35	0.34	0.34
35	0.77	0.77	0.77	0.75	0.73	0.71	0.71	0.71	0.70	0.69
36	0.12	0.41	0.52	0.50	0.47	0.45	0.43	0.42	0.41	0.39
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	1.00	0.87	0.77	0.70	0.66	0.62	0.60	0.59	0.57	0.55
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.85	10.05	10.25	10.46	10.08	9.73	9.38	9.06	8.76	8.46

Well pumpage, in millions of gallons per day, for 3% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.63	0.40	0.18
17	0.48	0.48	0.48	0.48	0.48	0.48	0.21	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.54	0.29	0.05	0.00	0.00	0.00	0.00
25	0.00	0.00	0.91	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.19	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.70	0.54	0.52	0.51	0.50	0.48	0.46	0.44
33	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.54	0.57	0.35	0.33	0.31	0.33	0.35	0.34	0.33
35	0.77	0.77	0.30	0.75	0.73	0.71	0.71	0.71	0.70	0.69
36	0.25	0.63	0.64	0.49	0.47	0.44	0.43	0.42	0.41	0.39
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	1.00	0.82	0.87	0.69	0.65	0.62	0.60	0.58	0.57	0.55
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	9.95	10.25	10.57	10.42	10.05	9.70	9.36	9.03	8.74	8.44

One well at Site 3 (continued)

Well pumpage, in millions of gallons per day, for 4% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.61	0.38	0.16
17	0.48	0.48	0.48	0.48	0.48	0.48	0.18	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.34	0.51	0.27	0.03	0.00	0.00	0.00	0.00
25	0.00	0.07	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.58	0.54	0.52	0.51	0.49	0.48	0.46	0.44
33	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.52	0.36	0.35	0.33	0.31	0.34	0.35	0.34	0.33
35	0.77	0.77	0.76	0.75	0.73	0.71	0.71	0.71	0.70	0.69
36	0.37	0.62	0.51	0.49	0.47	0.44	0.43	0.42	0.41	0.39
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	1.00	0.81	0.71	0.69	0.65	0.62	0.60	0.58	0.56	0.55
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.05	10.45	10.80	10.39	10.03	9.68	9.33	9.01	8.71	8.42

Well pumpage, in millions of gallons per day, for 5% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.60	0.37	0.15
17	0.48	0.48	0.48	0.48	0.48	0.48	0.17	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.32	0.50	0.26	0.02	0.00	0.00	0.00	0.00
25	0.00	0.41	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.57	0.54	0.52	0.51	0.49	0.48	0.46	0.44
33	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.51	0.36	0.35	0.33	0.31	0.34	0.35	0.34	0.33
35	0.77	0.77	0.76	0.75	0.73	0.71	0.71	0.71	0.70	0.69
36	0.48	0.61	0.51	0.49	0.47	0.44	0.43	0.42	0.41	0.39
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	1.00	0.80	0.71	0.69	0.65	0.62	0.60	0.58	0.56	0.55
Site 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	10.14	10.66	10.77	10.38	10.02	9.67	9.32	9.00	8.70	8.41

One well at Site 4

Well pumpage, in millions of gallons per day, for 0% annual water demand growth.

Well No.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.36	0.00	0.00	0.21	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.21	0.00	0.48	0.43	0.14
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00
21	0.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.15	1.15	0.95	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.54	1.15	1.15	1.15	1.15
26	0.00	0.00	0.00	0.00	0.34	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.56	0.18	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.00	0.39	0.72	0.71	0.51	0.47	0.45	0.44
33	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.96	0.96	0.96
34	0.58	0.58	0.58	0.58	0.54	0.55	0.49	0.34	0.33	0.36
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.00	0.40	0.65	0.68	0.63	0.61	0.55	0.47	0.45	0.44
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	1.00	1.00	1.00	0.96	0.92	0.90	0.87	0.79	0.76	0.72
Total	9.66	9.66	9.66	9.66	9.66	9.67	9.65	9.39	9.05	8.73

Well pumpage, in millions of gallons per day, for 1% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.50	0.00	0.64	0.37	0.12	0.00	0.00
17	0.48	0.48	0.48	0.48	0.41	0.48	0.48	0.48	0.34	0.06
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00
21	0.58	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	1.15	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.03	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.72	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.45	0.72	0.60	0.51	0.49	0.46	0.45	0.44
33	0.00	0.00	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.55	0.58	0.37	0.35	0.34	0.34	0.37
35	0.77	0.77	0.77	0.77	0.38	0.77	0.77	0.77	0.77	0.77
36	0.01	0.64	0.72	0.65	0.70	0.52	0.49	0.46	0.45	0.44
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	1.00	1.00	1.00	0.96	0.96	0.85	0.82	0.78	0.75	0.71
Total	9.76	9.85	9.95	10.04	10.16	10.00	9.63	9.27	8.96	8.65

One well at Site 4 (continued)

Well pumpage, in millions of gallons per day, for 2% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.00	0.72	0.58	0.33	0.08	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.29	0.01
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00
21	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	1.15	0.12	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.96	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.28	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.67	0.11	0.06	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.16	0.72	0.66	0.52	0.51	0.48	0.46	0.45	0.44
33	0.00	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96
34	0.58	0.58	0.58	0.54	0.39	0.36	0.35	0.34	0.35	0.38
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.12	0.77	0.69	0.63	0.54	0.51	0.48	0.46	0.45	0.44
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	1.00	1.00	1.00	0.99	0.90	0.85	0.81	0.78	0.74	0.70
Total	9.85	10.05	10.25	10.47	10.30	9.92	9.56	9.23	8.91	8.60

Well pumpage, in millions of gallons per day, for 3% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.58	0.72	0.72	0.55	0.30	0.05	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.26	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.33	0.09	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.39	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.52	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.51	0.72	0.55	0.52	0.50	0.48	0.46	0.45	0.44
33	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.94
34	0.58	0.58	0.56	0.42	0.38	0.36	0.35	0.34	0.35	0.38
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.24	0.77	0.67	0.57	0.53	0.51	0.48	0.46	0.45	0.44
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	1.00	1.00	1.00	0.95	0.89	0.85	0.81	0.78	0.74	0.70
Total	9.95	10.25	10.56	10.65	10.24	9.88	9.53	9.20	8.88	8.57

One well at Site 4 (continued)

Well pumpage, in millions of gallons per day, for 4% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.31	0.72	0.72	0.53	0.28	0.03	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.23	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	1.15	0.31	0.07	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	1.07	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.16	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.66	0.54	0.53	0.50	0.48	0.46	0.45	0.44
33	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.92
34	0.58	0.58	0.55	0.41	0.38	0.36	0.35	0.34	0.36	0.38
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.37	0.75	0.65	0.57	0.53	0.51	0.48	0.46	0.45	0.44
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	1.00	1.00	1.00	0.95	0.88	0.84	0.81	0.78	0.74	0.70
Total	10.05	10.45	10.87	10.61	10.22	9.85	9.51	9.18	8.86	8.55

Well pumpage, in millions of gallons per day, for 5% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.72	0.72	0.72	0.72	0.72	0.51	0.26	0.02	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.22	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
24	1.15	1.15	0.47	0.29	0.05	0.00	0.00	0.00	0.00	0.00
25	0.00	0.03	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
26	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.72	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.72	0.57	0.54	0.52	0.50	0.48	0.46	0.45	0.44
33	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.90
34	0.58	0.58	0.44	0.41	0.38	0.36	0.35	0.34	0.36	0.38
35	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
36	0.48	0.73	0.60	0.56	0.53	0.51	0.48	0.46	0.45	0.44
Site 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Site 4	1.00	1.00	1.00	0.94	0.88	0.84	0.81	0.78	0.74	0.70
Total	10.14	10.65	11.00	10.57	10.19	9.83	9.49	9.17	8.85	8.53

One well at all four sites

Well pumpage, in millions of gallons per day, for 0% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.48	0.48	0.48	0.43	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.00	0.00
24	1.15	1.15	1.15	1.15	1.15	0.59	0.00	0.43	0.33	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	1.15	1.11
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.48	0.48
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.50	0.33
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.00	0.00	0.00	0.12	0.72	0.38	0.40	0.41
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.58	0.58	0.07	0.00	0.41
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.71
36	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.62	0.41
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	0.95	0.95	0.95	0.95	1.00	0.95	0.85	1.00	0.72	0.52
Site 4	1.00	1.00	1.00	1.00	0.95	0.86	0.80	0.81	0.72	0.65
Total	9.66	9.66	9.66	9.66	9.66	9.66	9.66	9.67	9.66	9.38

Well pumpage, in millions of gallons per day, for 1% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.48	0.26	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.12	0.00	0.00
24	1.15	1.15	1.15	1.15	0.63	0.56	0.02	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	1.02	1.04	1.09	1.15
26	0.00	0.00	0.00	0.00	0.00	0.48	0.48	0.48	0.48	0.48
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.52	0.15
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.00	0.00	0.69	0.55	0.33	0.36	0.39	0.43
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.05	0.14	0.24	0.35	0.58	0.55	0.30	0.41	0.41	0.41
35	0.00	0.00	0.00	0.00	0.00	0.37	0.76	0.72	0.71	0.70
36	0.00	0.00	0.00	0.00	0.00	0.56	0.46	0.42	0.41	0.40
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	1.00	1.00	1.00	1.00	1.00	0.74	0.60	0.56	0.53	0.51
Site 4	1.00	1.00	1.00	0.99	0.91	0.85	0.79	0.73	0.68	0.64
Total	9.76	9.85	9.95	10.05	10.15	10.26	10.36	9.96	9.57	9.22

One well at all four sites (continued)

Well pumpage, in millions of gallons per day, for 2% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.29	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.36	0.01	0.00	0.00
24	1.15	1.15	1.15	0.83	0.95	0.16	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	1.15	1.05	1.02	1.06	1.12	1.15
26	0.00	0.00	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.40	0.06
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.00	0.72	0.37	0.33	0.34	0.37	0.41	0.45
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.14	0.34	0.54	0.58	0.00	0.42	0.41	0.41	0.41	0.41
35	0.00	0.00	0.00	0.00	0.00	0.76	0.73	0.72	0.71	0.70
36	0.00	0.00	0.00	0.00	0.17	0.46	0.43	0.42	0.41	0.40
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	1.00	1.00	1.00	1.00	1.00	0.62	0.58	0.55	0.53	0.50
Site 4	1.00	1.00	1.00	0.96	0.95	0.83	0.77	0.72	0.67	0.63
Total	9.85	10.05	10.25	10.46	10.67	10.71	10.24	9.86	9.49	9.13

Well pumpage, in millions of gallons per day, for 3% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.14	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.29	0.00	0.00	0.00
24	1.15	1.15	1.15	1.15	0.33	0.10	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	1.08	1.09	1.03	1.03	1.08	1.14	1.15
26	0.00	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.71	0.33	0.00
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.12	0.42	0.34	0.33	0.35	0.38	0.41	0.45
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.24	0.54	0.58	0.00	0.44	0.41	0.41	0.41	0.41	0.41
35	0.00	0.00	0.00	0.00	0.77	0.75	0.73	0.72	0.71	0.70
36	0.00	0.00	0.00	0.00	0.49	0.45	0.43	0.42	0.41	0.40
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	1.00	1.00	1.00	1.00	0.65	0.61	0.58	0.55	0.53	0.50
Site 4	1.00	1.00	1.00	1.00	0.87	0.82	0.76	0.71	0.67	0.62
Total	9.95	10.25	10.56	10.87	11.06	10.58	10.18	9.81	9.44	9.06

One well at all four sites (continued)

Well pumpage, in millions of gallons per day, for 4% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.25	0.00	0.00	0.00
24	1.15	1.15	0.83	0.78	0.30	0.08	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	1.15	1.07	1.03	1.04	1.08	1.14	1.15
26	0.00	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.67	0.30	0.00
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.72	0.36	0.34	0.33	0.35	0.38	0.42	0.45
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.34	0.58	0.58	0.32	0.43	0.41	0.41	0.41	0.41	0.35
35	0.00	0.00	0.17	0.00	0.77	0.75	0.73	0.72	0.71	0.71
36	0.00	0.00	0.02	0.72	0.47	0.45	0.43	0.42	0.41	0.41
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	1.00	1.00	1.00	0.93	0.64	0.60	0.57	0.55	0.52	0.50
Site 4	1.00	1.00	0.99	0.95	0.87	0.81	0.76	0.71	0.66	0.62
Total	10.05	10.45	10.87	11.29	10.97	10.54	10.14	9.77	9.40	9.02

Well pumpage, in millions of gallons per day, for 5% annual water demand growth.

City well no.	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.48	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.48	0.48	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.48	0.48	0.48	0.48	0.48	0.48	0.23	0.00	0.00	0.00
24	1.15	1.15	1.15	0.50	0.28	0.06	0.00	0.00	0.00	0.00
25	0.00	0.00	0.03	1.14	1.07	1.03	1.04	1.09	1.15	1.15
26	0.00	0.00	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
27	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.64	0.27	0.00
30	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
31	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
32	0.00	0.00	0.62	0.35	0.34	0.33	0.35	0.38	0.42	0.45
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.43	0.51	0.29	0.45	0.43	0.41	0.41	0.41	0.41	0.30
35	0.00	0.00	0.00	0.77	0.76	0.74	0.73	0.72	0.71	0.72
36	0.00	0.00	0.77	0.50	0.47	0.45	0.43	0.42	0.41	0.42
Site 1	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Site 2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Site 3	1.00	1.00	1.00	0.68	0.63	0.60	0.57	0.55	0.52	0.51
Site 4	1.00	1.00	1.00	0.92	0.86	0.81	0.76	0.71	0.66	0.61
Total	10.14	10.65	11.18	11.39	10.92	10.51	10.12	9.75	9.38	8.99

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