Effect of the Cedar River on the Quality of the Ground-Water Supply for Cedar Rapids, Iowa

By PETER M. SCHULMEYER

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 94-4211

Prepared in cooperation with the
CITY OF CEDAR RAPIDS, IOWA

Iowa City, Iowa
1995

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter
million gallons per day (Mgal/d)	3,785	cubic meter per day
gallon per minute (gal/min)	0.00006309	cubic meter per second
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.09290	meter squared per day
cubic foot per second (ft^3/d)	0.02832	cubic meter per second
gallon per day per foot [(gal/d)/ft]	0.01242	cubic meter per day per meter
gallon per minute per foot [(gal/min)/ft)	0.2070	liter per second per meter

Temperature in degrees Fahrenheint (^oF) may be converted to degrees Celsius (^oC) as follows:

degree Fahrenheit (^oF) $^oC = (^oF-32)/1.8$ degree Celsius (^oC)

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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Abstract

The Surface Water Treatment Rule under the 1986 Amendment to the Safe Drinking Water Act requires that public-water supplies be evaluated for susceptibility to surface-water effects. The alluvial aquifer adjacent to the Cedar River is evaluated for biogenic material and monitored for selected water-quality properties and constituents to determine the effect of surface water on the water supply for the City of Cedar Rapids, Iowa. Results from monitoring of selected water-quality properties and constituents showed an inverse relation to river stage or discharge. Water-quality properties and constituents of the alluvial aquifer changed as water flowed from the river to the municipal well as a result of drawdown. The values of specific conductance, pH, temperature, and dissolved oxygen at observation well CRM-4 and municipal well Seminole 10 generally follow the trends of values for the Cedar River. Values at observation well CRM-3 and the municipal water-treatment plant showed very little correlation with values from the river. The traveltime of water through the aquifer could be an indication of the susceptibility of the alluvial aquifer to surface-water effects..Estimated traveltimes from the Cedar River to municipal well Seminole 10 ranged from 7 to 17 days.

Above-normal streamflow and precipitation during the study could have increased the effect the river had on the alluvial aquifer and on the possibility of contamination by a pathogen. Microscopic particulate analysis of 29 samples found no *Giardia* cysts or *Crytosporidium* oocysts in water collected from municipal wells. Data also indicate that the aquifer is filtering out large numbers of algae, diatoms, rotifers, and nematodes as well as filtering out *Cryptosporidium, Giardia,* and other protozoa. The number of algae, diatoms, rotifers, protozoa, and vegetative debris for selected municipal wells tested showed at least a reduction to 1 per 1,000 of the number found in the river. A relative risk factor and a log-reduction rate were determined for the aquifer in the vicinity of selected wells. One municipal well had a high-risk factor, three other wells had a moderate-risk factor, and four wells had a low-risk factor. The filtering efficiency of the aquifer is equivalent to a 3 log-reduction rate or 99.99-percent reduction in particulates.

INTRODUCTION

Enactment of the 1986 Amendment to the Safe Drinking Water Act prompted a new regulation for public-water systems that use surface water or ground water that is directly affected by surface water and is referred to as "ground water under the direct influence of surface water (GWUDI)." This regulation, called the Surface Water Treatment Rule (SWTR) (U.S. Environmental Protection Agency, 1989), declares that States have primary responsibility for identifying GWUDI's and their risk pertaining to waterborne diseases such as giardiasis (Vasconcelos and Harris, 1992) or cryptosporidiosis. From January 1991 to December 1992 seven outbreaks of such diseases were caused by protozoan origin, as reported by Morbidity and Mortality Weekly Report (Last, 1994). Four outbreaks were caused by *Giardia* with 123 cases reported, and three outbreaks were caused by *Cryptosporidium* with 3,551 cases reported (Last, 1994). Both *Giardia* and *Cryptosporidium* are protozoan parasites that can reside in the digestive tracks of vertebrates. These parasites may pass into surface water from the fecal material of animals or by surface-water runoff washing this material into streams or pools. Ground water can become contaminated if these parasites move with the surface water into a ground-water flow system.

Alluvial aquifers adjacent to large streams are an important source of ground water for many municipalities as a source of drinking water. The alluvial aquifer adjacent to the Cedar River, used by Cedar Rapids, Iowa, as a source of water supply, has tentatively been evaluated as GWUDI. GWUDI is defined as any water beneath the surface of the ground with either a significant occurrence of insects, other microorganisms, algae, organic debris, or large-diameter pathogens such as *Giardia lamblia*, or significant and relatively rapid changes in water-quality properties such as specific conductance, pH, temperature, or turbidity that closely correlate to climatological or surface-water conditions (U.S. Environmental Protection Agency, 1989). A cooperative study between the City of Cedar Rapids, Iowa, and the U.S. Geological Survey (USGS) was undertaken to quantify the effect of the Cedar River on water quality of the adjacent alluvial aquifer. Results of this study will aid in an improved understanding of surface-water effects on ground water in alluvial systems.

Determining the effect that the Cedar River has on the alluvial aquifer required a review of departmental and public-water-system records; inspection of wells and their construction records; and an evaluation of the water source, which involved microscopic particulate analysis (MPA) and monitoring of selected water-quality properties and constituents. The MPA evaluates ground-water samples for surface-water indicators such as *Giardia*, coccidia, diatoms, algae, insects, rotifers, vegetative debris, amorphous debris, pollen, spores, nematodes, crustaceans, amoeba, and protozoa. Evaluation of selected water-quality properties and constituents involves measuring the specific conductance, pH, temperature, and dissolved oxygen in the alluvial aquifer and the Cedar River. If similar changes occur in the alluvial aquifer adjacent to the Cedar River, this could indicate that the ground water is directly affected by surface water and, therefore, is GWUDI.

Purpose and Scope

This report describes the hydrologic and biogenic information collected from December 1992 through January 1994 to determine the effect of surface water from the Cedar River on water quality in the adjacent alluvial aquifer. Selected water-quality properties and constituents (specific conductance, pH, temperature, and dissolved oxygen) of the Cedar River were compared with those measured in the alluvial aquifer and the Cedar Rapids municipal water-treatment plant, and the biogenic particulates in samples collected from the Cedar River were compared with samples collected from selected municipal wells in the alluvial aquifer and the water system as a whole.

Acknowledgments

The assistance of city officials and other personnel of the City of Cedar Rapids in well drilling, sample and data collection, and providing well information is here acknowledged and appreciated.

DESCRIPTION OF STUDY AREA

Location and Physical Setting

The study area is located in northwest Cedar Rapids, along the Cedar River in Linn County, east-central Iowa (fig. 1). The study area encompasses the East, Seminole, and West Well Fields that supply water to the City. There is a well-developed stream pattern that drains into the Cedar River, the largest tributary of the Iowa River. The river flows in a northwest-to-southeast direction through the study area (fig. 1). Approximately 1 mi southeast of the East Well Field is a low-head dam (fig.1). This is used for flood control, to generate hydroelectric power, and to maintain river stage to provide a source of additional recharge to the well fields, especially during periods of below-normal streamflow.

The Cedar River drainage basin upstream of the gage at Cedar Rapids has a surface area of 6,510 mi^2. Land use in the Cedar River Basin is predominantly agricultural (81 percent), with the major crops being corn and soybeans (U.S. Department of Agriculture, 1976). Annual precipitation ranges from 30 to 36 in., and seasonal temperatures vary from summer highs of

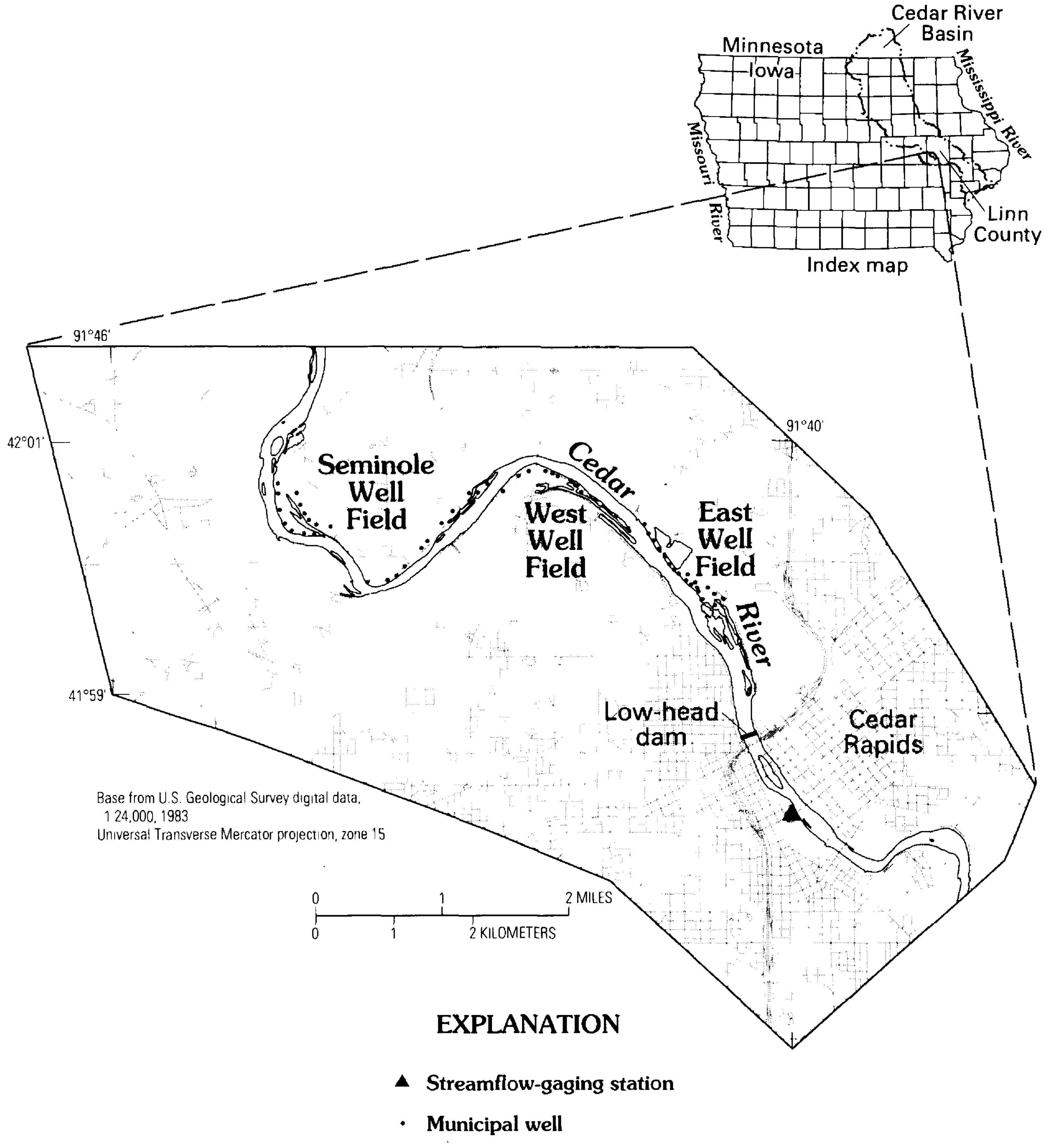


Figure 1. Location of study area, city of Cedar Rapids, Iowa.

100 °F to winter lows of -18 °F (Iowa Department of Environmental Quality, 1976).

The City of Cedar Rapids had a population of 108,751 in 1990 and has a steadily increasing demand for water (Bob Glass, City of Cedar Rapids Water Department, oral commun., 1994). There are 53 municipal wells that provide water for public and industrial needs. Pumpage from municipal wells was 8,487 Mgal in 1980, 9,118 Mgal in 1990, and 10,385 Mgal in 1992; the reporting period is from July 1 of the previous year through June 30 of the reporting year (Bob Glass, City of Cedar Rapids Water Department, oral commun., 1994).

Geology and Hydrology

Carbonate rock of Silurian and Devonian age comprise the bedrock aquifer, which is the most widely used aquifer in Linn County for industrial and domestic supply (Hansen, 1970). Overlying the bedrock is a layer of unconsolidated glacial till, loess, and alluvium. The thickness of this layer is variable, with a maximum thickness of 86 ft in the study area as interpreted from seismic refraction information. The alluvial deposits that underlie the flood plain and terraces of the Cedar River form the principal alluvial aquifer in the county. For a more detailed discussion of the geology of the area refer to Hansen (1970) and Prior (1991).

The Cedar River is a meandering stream that has cut into the bedrock surface, exposing steep valley walls in the study area. The flood plain is approximately 3,500 ft wide near the Seminole Well Field and narrows to 1,200 ft near the West Well Field. The fluvial deposits in the study area show typical point-bar sedimentation. Tabular deposits of alluvial material commonly have resulted from the lateral migration of the channel across the flood plain. Deposits of this type typically have an upward diminution of grain size (Reading, 1978). Driller's logs for most of the 53 municipal wells confirm this upward fining of material in the alluvial aquifer. Coarse-grained sand and gravel are found at the base of the alluvium. These grade into coarse- to fine-grained sand in the middle of the unit, with fine-grained sand, silt, and clay near the top. Cobbles and boulders are most prevalent at the East Well Field as noted in drillers logs.

Lithologic sections for the alluvial aquifer were developed using drillers logs (figs. 2, 3, 4, and 5) and show a typical vertical succession of grain size from coarse sand and gravel at the base of the section to fine sand, silt, and clay at the top. Coarse sand and gravel are the most permeable of the materials present in the alluvial aquifer and, where they are thick, can provide the greatest potential for large yields of water (Hansen, 1970).

The alluvial aquifer is hydraulically connected to the Cedar River, bedrock, and upland areas in the study area. Recharge to the alluvial aquifer occurs as infiltration of precipitation, seepage from adjacent aquifers, and from the river when the stage is higher than the ground-water level (Wahl and Bunker, 1986). Normally, the alluvial aquifer receives enough recharge to maintain the water table above the stage of the river (Hansen, 1970). When the river stage is lower than the water table, the aquifer discharges into the river. The Cedar River can receive as much as 80 percent of its annual discharge from ground-water contribution (Squillace, Liszewski, and Thurman, 1993).

Alluvial aquifers can have large transmissivities and hydraulic conductivities, which makes them very desirable for water supplies because large amounts of water can be withdrawn. Hansen (1970) reported a maximum transmissivity of 150,000 (gal/d)/ft for a storage coefficient of 0.1 for the alluvial aquifer of the East and West Well Fields. The hydraulic conductivity for sand and gravel generally ranges from 2.8 to 2,834 ft/d (Freeze and Cherry, 1979). Single-well hydraulic tests performed on the alluvial aquifer south of Cedar Rapids produced results ranging from 2.0 to 174.0 ft/d (Paul Squillace, USGS, written commun., 1994).

Specific capacity depends on both the hydraulic characteristics of the aquifer and construction of the well. Specific capacities for municipal wells, reported by the City of Cedar Rapids, are presented in table 1. Using a modified Theis equation, transmissivity can be calculated using the specific capacity of a well (Heath, 1987). Transmissivities for the alluvial aquifer in the vicinity of municipal well locations were calculated using this method and range from 1,543 to 19,240 ft^2/d (table 1). Hydraulic conductivities at each well location (table 1) were calculated by dividing the transmissivity by the thickness of saturated material and range from 21.3 to 315.2 ft/d.

Fifteen wells are completed in a portion of the alluvial aquifer that has a transmissivity greater than 10,000 ft^2/d. All of the wells are set close to the river. Except for municipal wells Seminole 9 and 10, West 9,

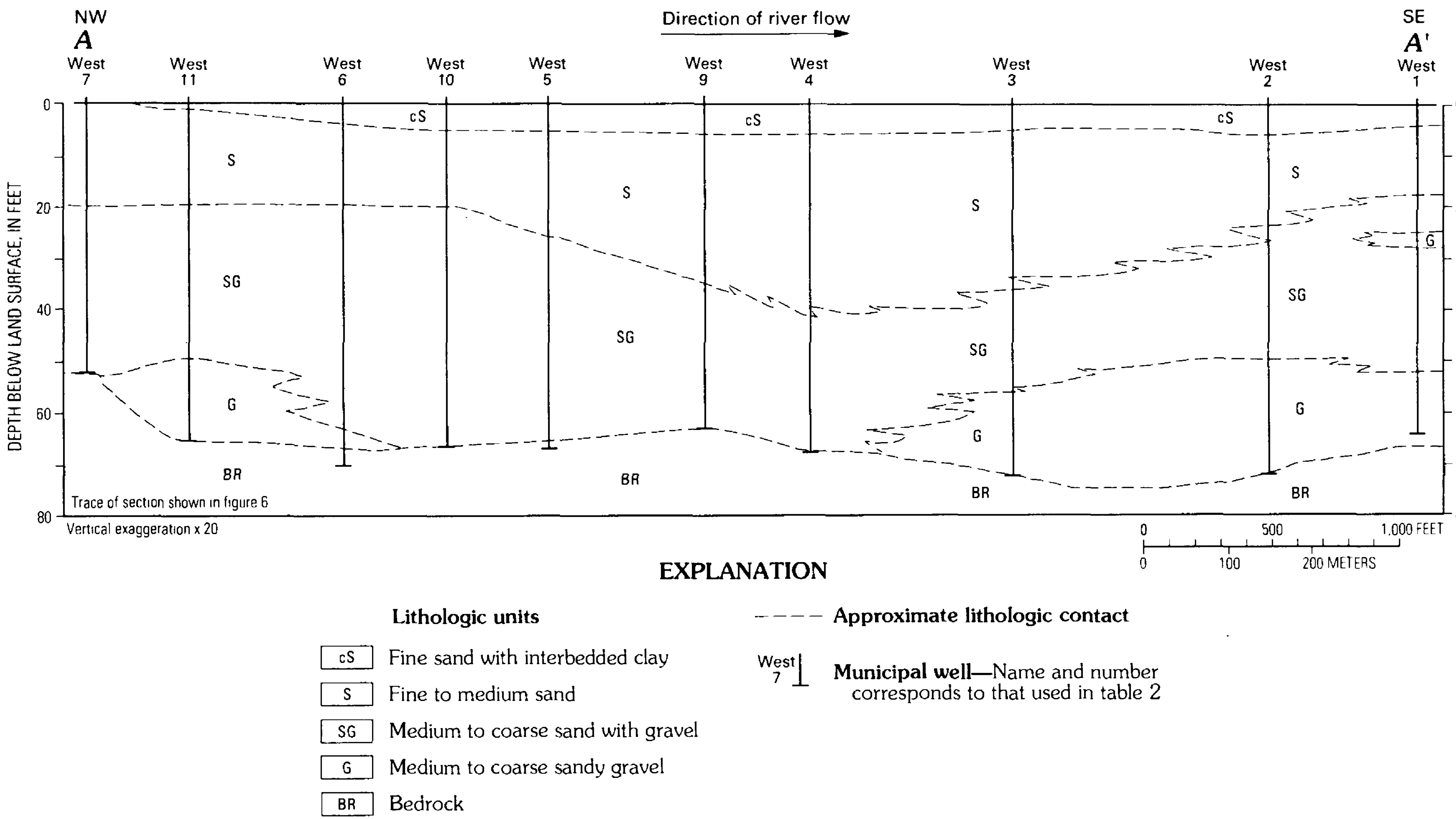


Figure 2. Lithologic section *A–A'* in the Cedar Rapids West Well Field.

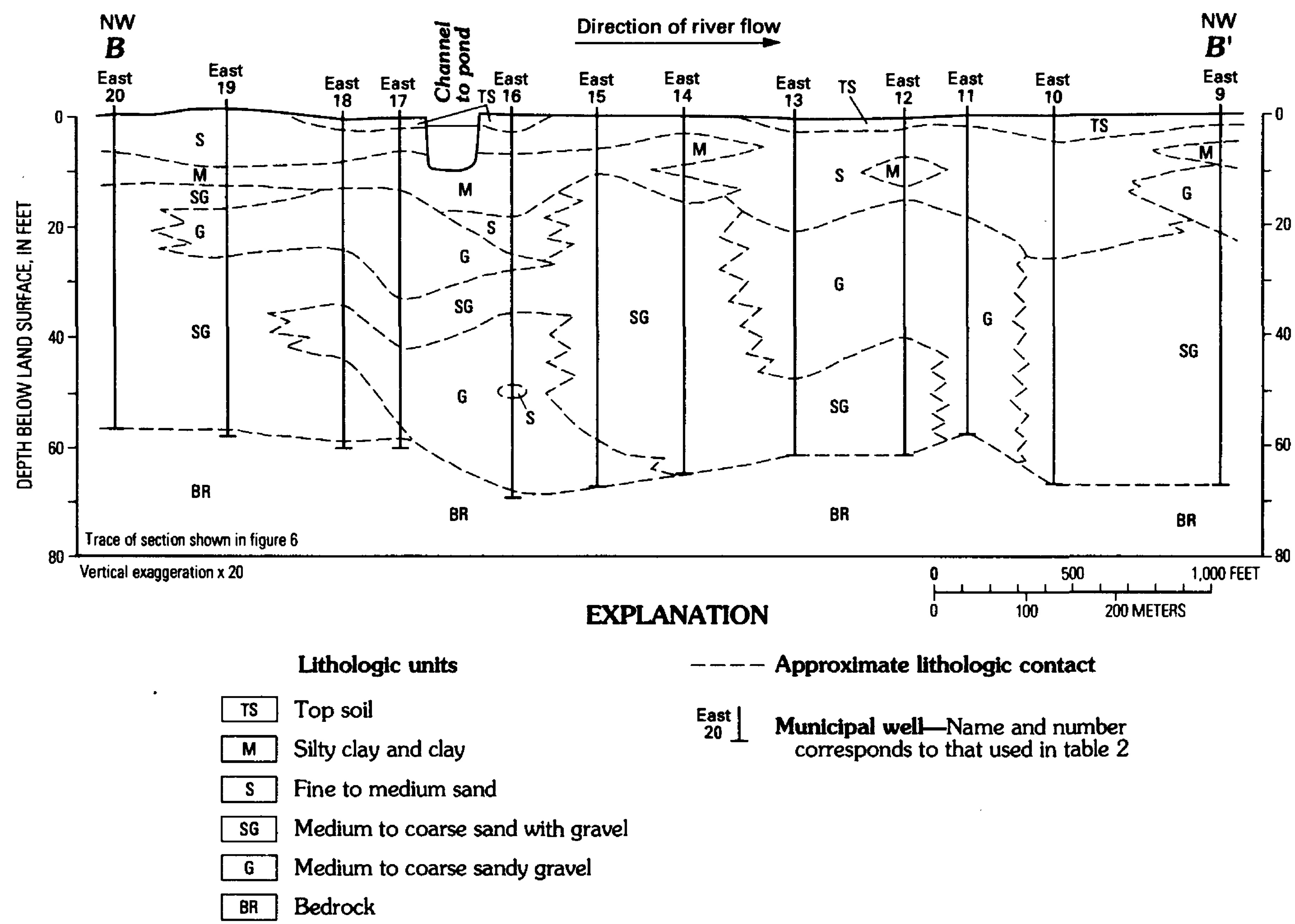
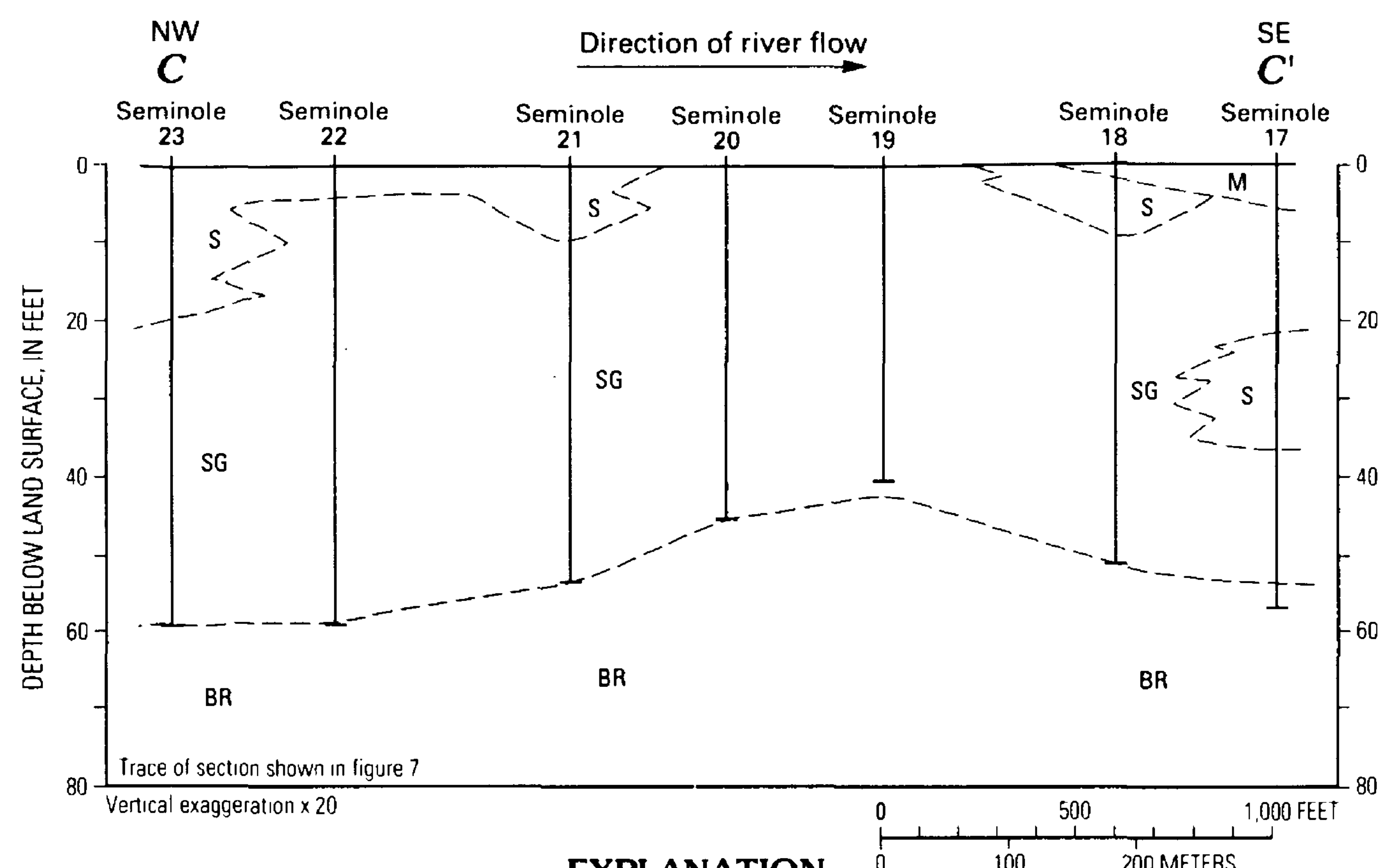


Figure 3. Lithologic section *B–B'* in the Cedar Rapids East Well Field.



EXPLANATION

Lithologic units

M	Silty clay and clay
S	Fine to medium sand
SG	Medium to coarse sand with gravel
BR	Bedrock

---- **Approximate lithologic contact**

Seminole 20 — **Municipal well**—Name and number corresponds to that used in table 2

Figure 4. Lithologic section *C–C'* in the Cedar Rapids Seminole Well Field.

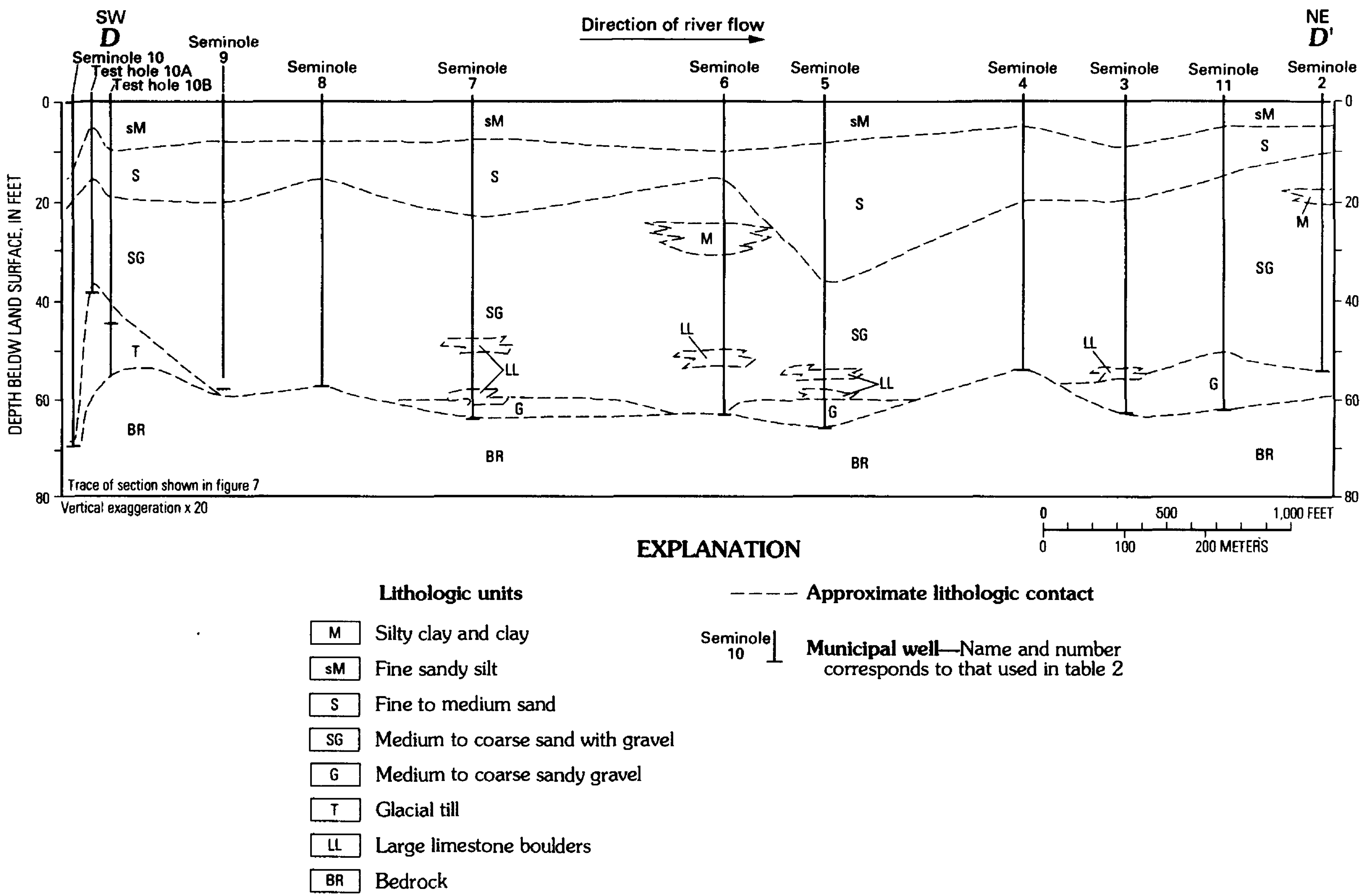


Figure 5. Lithologic section *D-D'* in Cedar Rapids Semonole Well Field.

Table 1. Hydraulic properties for alluvial aquifer in which Cedar Rapids municipal wells are completed

[(gal/min)/ft, gallons per minute per foot of drawdown; ft^2/d, foot squared per day; ft/d, foot per day; NR, no record]

Well name and number (figs. 6–7)	Specific capacity [(gal/min)/ft]	Trans-miss-ivity (ft^2/d)	Hydraulic con-ductivity (ft/d)	Well name and number (figs. 6–7)	Specific capacity [(gal/min)/ft]	Trans-miss-ivity (ft^2/d)	Hydraulic con-ductivity (ft/d)
East 1	21.1	2,706	38.7	West 9	122.0	19,240	305.4
East 2	23.7	3,153	43.8	West 10	63.6	9,354	139.6
East 3	42.9	6,156	85.5	West 11	67.0	10,244	155.2
East 4	51.3	7,362	102.3	Seminole 1	17.8	2,793	43.7
East 5	45.7	6,558	91.7	Seminole 2	60.0	10,537	195.5
East 6	29.4	4,006	57.2	Seminole 3	68.6	12,482	198.4
East 8	14.2	1,738	25.0	Seminole 4	53.1	9,325	169.9
East 9	28.5	3,884	58.0	Seminole 5	83.3	15,157	236.8
East 10	26.1	3,472	51.8	Seminole 6	62.2	10,923	178.8
East 11	29.2	3,979	70.4	Seminole 7	84.2	15,320	242.8
East 12	50.9	7,304	119.7	Seminole 8	39.9	6,877	120.0
East 13	39.1	5,439	89.2	Seminole 9	60.0	10,537	183.3
East 14	32.2	4,388	67.5	Seminole 10	61.7	10,836	158.0
East 15	75.0	11,467	171.1	Seminole 11	42.0	6,027	97.2
East 16	74.2	11,345	164.4	Seminole 12	31.2	4,251	73.3
East 17	100.0	15,770	267.3	Seminole 13	53.8	7,913	129.7
East 18	96.5	14,754	250.1	Seminole 14	25.4	3,374	57.2
East 19	62.2	9,148	160.5	Seminole 15	43.5	6,242	100.7
East 20	97.0	17,650	315.2	Seminole16	24.8	3,296	50.7
West 1	75.0	11,467	179.2	Seminole 17	73.1	11,177	192.7
West 2	25.0	3,326	46.1	Seminole 18	NR	NR	NR
West 3	12.6	1,543	21.3	Seminole 19	NR	NR	NR
West 4	17.8	2,283	33.1	Seminole 20	NR	NR	NR
West 5	NR	NR	NR	Seminole 21	NR	NR	NR
West 6	39.5	5,597	78.9	Seminole 22	NR	NR	NR
West 7	31.3	4,354	84.5	Seminole 23	NR	NR	NR
West 8	24.1	3,206	51.9				

and East 20, these well are partially completed in a gravel lens of the alluvial aquifer (figs. 2, 3, and 5).

The Cedar River is the largest source of recharge available to the alluvial aquifer, and the rate of this recharge is dependent on the hydraulic conductivity of the aquifer, the hydraulic gradient between the river and the aquifer, and the infiltration capacity of the riverbed materials (Hansen, 1970). The withdrawal of water from a well constructed in the alluvial aquifer causes a depression of the water table surrounding the well called a "cone of depression." The withdrawal establishes a hydraulic gradient between the hydraulic head in the aquifer and the hydraulic head in the well, which causes water to flow from the surrounding aquifer towards the well. With large hydraulic conductivities and transmissivities (table 1), large volumes of water can move through the aquifer to the wells; for example, 37.1 Mgal/d was obtained on May 21, 1994, from the alluvial aquifer by the Cedar Rapids municipal wells (Bob Glass, City of Cedar Rapids Water Department, oral commun., 1994).

Municipal Well Fields

The City of Cedar Rapids has three well fields in operation along the Cedar River (figs. 1, 6, and 7). There are a total of 53 municipal wells (table 2), with 19 wells in the East Well Field, 11 in the West Well Field, and 23 in Seminole Well Field. Seminole wells 17 through 23 were not in use during the study. The well fields are located in the flood plain of the Cedar River, and the ground surface at some municipal well locations is inundated during river flood stage. The wells are installed in the alluvium at varying distances from the river (table 2) and drilled to the top of the bedrock. Well depths range from 40 to about 72 ft.

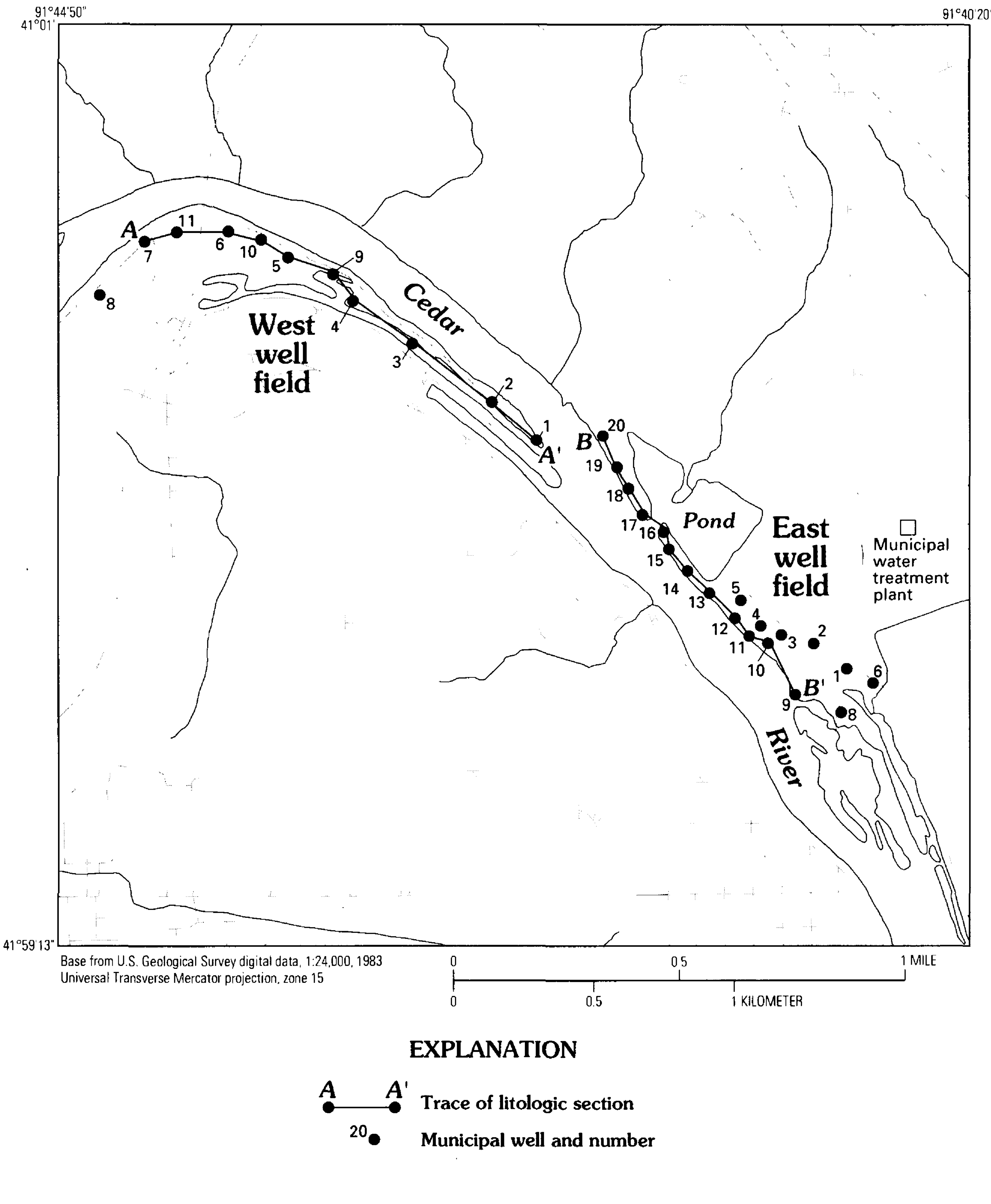
All municipal wells are of similar construction. A 42- or 52-in. diameter hole was drilled with a rotary auger. A 30-in. diameter casing was installed with a 10- to 20-ft stainless-steel screen that has 0.08- to 0.10-in. slots. Screens for all municipal wells are set close to or on top of the bedrock. Gravel was used to fill the annular space around the screen area. The remainder of the annular space was sealed with clay, such as bentonite, and cement from the top of the gravel to land surface. A berm was built-up around the well to cover the seal. Well-construction information is presented in table 2.

Intensive-Study Site

The three well fields of the City of Cedar Rapids all have a similar lithologic sequence and hydraulic properties. This similarity in material and properties throughout the study area allowed the study to focus on one municipal well, Seminole 10, and to assume that the hydrologic interpretations for this well are applicable to other municipal well locations. The intensive-study site is located northwest of Cedar Rapids at municipal well Seminole 10 and adjacent to the Cedar River (figs. 7 and 8). The aquifer in the vicinity of municipal well Seminole 10 has a transmissivity of 10,836 ft^2/d and a hydraulic conductivity of 158.0 ft/d, which is representative of the well fields. The well is 48 ft from the river, and its land-surface elevation is 725.4 ft (table 2).

Sixty feet of 6-in. diameter pipe were laid in a trench extending from the top of the riverbank down into the river, near municipal well Seminole 10, to monitor changes in water level and selected water-quality properties and constituents in the Cedar River (fig. 8). The trench was filled and covered with rip-rap for protection. The end of the pipe was perforated to allow for the free flow of water.

Two, 4-in. diameter observation wells, CRM-3 and CRM-4, were installed to monitor changes in water levels and selected water-quality properties and constituents in the alluvial aquifer. Wells CRM-4 and CRM-3 were placed between Seminole 10 and the river and beyond Seminole 10, respectively (fig. 8). The observation wells were installed in the alluvial aquifer by the USGS using a hollow-stem auger. CRM-3 is located 58 ft east, and well CRM-4 is located 22 ft west of municipal well Seminole 10 (fig. 8). Another 4-in. diameter observation well, CRM-6 (fig. 8), was installed into the bedrock. Depths for the observation wells are listed in table 2. The wells are constructed of schedule-80 polyvinyl chloride (PVC) pipe with a 2.5-ft screened interval at the bottom. The annular space was filled by allowing the sides to collapse in around the well casing after placement of the screen and pipe. A seal of bentonite clay was placed at a depth of 6 to 7 ft for wells CRM-3 and CRM-4 and at 80 ft for well CRM-6. Seal thickness varied between observation wells.



EXPLANATION

Figure 6. Location of municipal wells and traces of lithologic sections *A–A'* and *B–B'* in the Cedar Rapids East and West Well Fields.

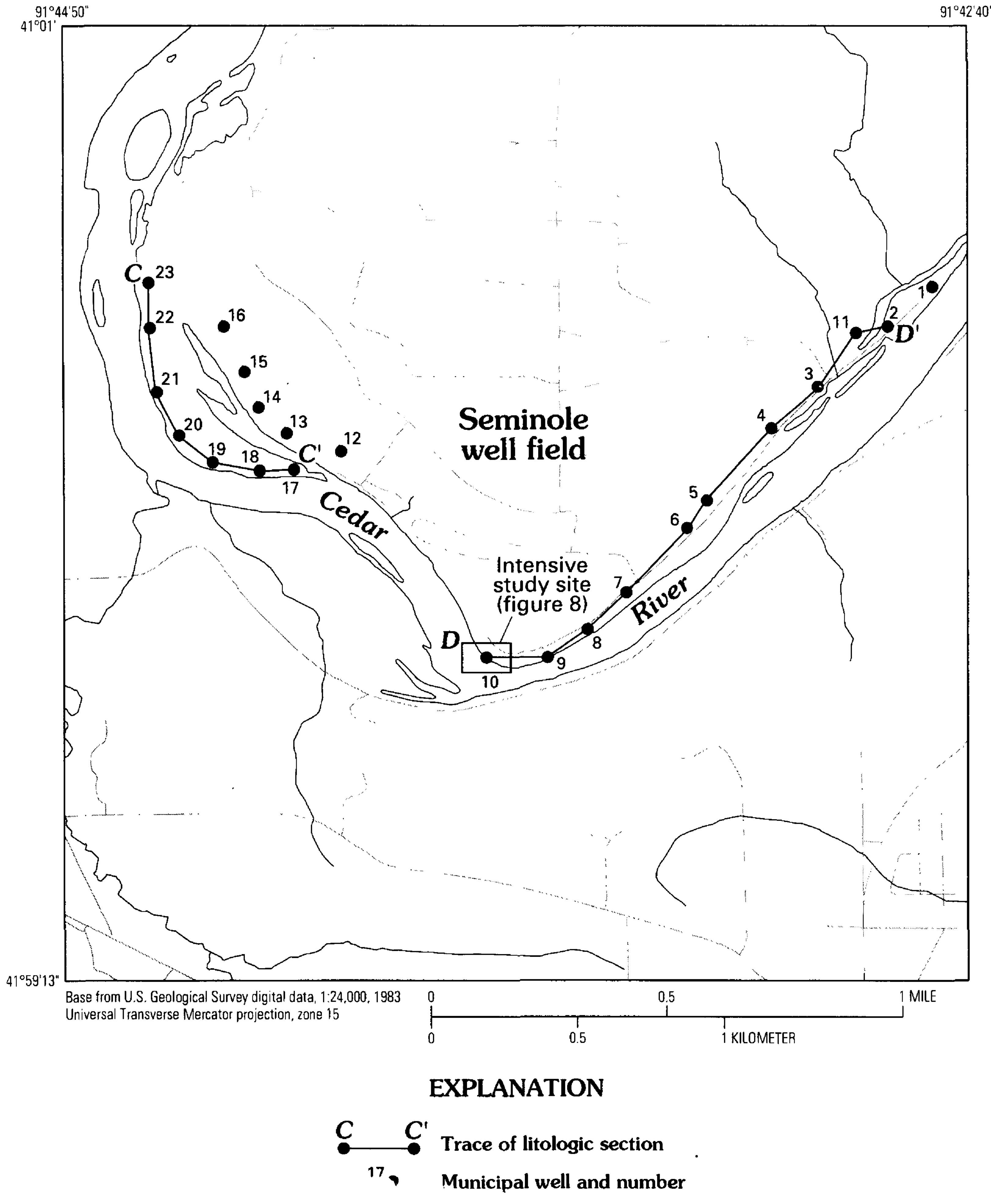


Figure 7. Location of municipal wells and traces of lithologic sections *C–C'* and *D–D'* in Cedar Rapids Seminole Well Field.

Table 2. *Construction information for municipal water wells, test holes, and observation wells in the vicinity of Cedar Rapids, Iowa*

[ft, feet; in., inches; NR, no record]

Well name and number (figs. 6,7, and 8)	Latitude/longitude (degrees, minutes, seconds)	Land-surface elevation (ft)	Well depth (ft)	Depth to bottom of sealed annular space (ft)	Diameter of hole (in.)	Diameter of casing (in.)	Depth to top of well screen (ft)	Length of well screen (ft)	Lateral distance to surface water[1] (ft)
Municipal wells									
Cedar Rapids East 1	41°59'47" 91°40'40"	728.0	70	NR	42	30	50	20	63
Cedar Rapids East 2	41°59'49" 91°40'45"	728.0	72	NR	42	30	52	20	126
Cedar Rapids East 3	41°59"50" 91°40'48"	728.0	72	NR	42	30	52	20	400
Cedar Rapids East 4	41°59'52" 91°40'48"	728.0	72	NR	42	30	52	20	400
Cedar Rapids East 5	41°59'55" 91°40'55"	728.0	71.6	NR	42	30	51.6	20	67
Cedar Rapids East 6	42°00'09" 91°40'37"	726.0	70	NR	42	30	50	20	80
Cedar Rapids East 8	41°59'41" 91°40'42"	724.0	69.6	NR	42	30	NR	20	80
Cedar Rapids East 9	41°59'44" 91°40'48"	725.0	67	NR	52	30	54	13	80
Cedar Rapids East 10	41°59'48" 91°40'52"	726.0	67	42	42	30	52	15	86
Cedar Rapids East 11	41°59'50" 91°40'56"	726.0	56.5	18	42	30	36.5	20	36
Cedar Rapids East 12	41°59'52" 91°40'58"	724.0	61	18	42	30	41	20	43
Cedar Rapids East 13	41°59'55" 91°41'01"	724.0	61	18	42	30	41	20	48
Cedar Rapids East 14	41°59'58" 91°41'05"	724.0	65	19	42	30	44.5	20	53
Cedar Rapids East 15	41°59'59" 91°41'07"	724.0	67	20	42	30	47	20	32
Cedar Rapids East 16	42°00'02" 91°41'09"	724.0	69	20	42	30	49	20	49
Cedar Rapids East 17	42°00'04" 91°41'11"	721.0	59	15	42	30	39	20	62
Cedar Rapids East 18	42°00'07" 91°41'13"	721.0	59	18	42	30	39	20	57
Cedar Rapids East 19	42°00'09" 91°41'15"	721.0	57	18	42	30	37	20	56
Cedar Rapids East 20	42°00'11" 91°41'17"	721.0	56	16	52	30	36	20	52
Cedar Rapids West 1	42°00'13" 91°41'29"	724.0	64	NR	NR	30	54	10	33

Table 2. Construction information for municipal water wells, test holes, and observation wells in the vicinity of Cedar Rapids, Iowa—Continued

Well name and number (figs. 6,7, and 8)	Latitude/longitude (degrees, minutes, seconds)	Land-surface elevation (ft)	Well depth (ft)	Depth to bottom of sealed annular space (ft)	Diameter of hole (in.)	Diameter of casing (in.)	Depth to top of well screen (ft)	Length of well screen (ft)	Lateral distance to surface water[1] (ft)
Municipal wells—Continued									
Cedar Rapids West 2	42°00'17" 91°41'34"	723.0	72.2	NR	NR	30	62.2	10	68
Cedar Rapids West 3	42°00'26" 91°41'47"	723.0	72.4	NR	NR	30	62.4	10	31
Cedar Rapids West 4	42°00'29" 91°41'53"	724.0	69	NR	NR	30	54	15	90
Cedar Rapids West 5	42°00'33" 91°42'02"	723.0	68	NR	NR	30	53	15	132
Cedar Rapids West 6	42°00'37" 91°42'14"	723.0	70.9	NR	NR	30	NR	NR	93
Cedar Rapids West 7	42°00'36" 91°42'28"	724.0	51.5	NR	NR	30	36.5	15	30
Cedar Rapids West 8	42°00'31" 91°42'36"	724.0	61.8	NR	NR	30	51.8	10	30
Cedar Rapids West 9	42°00'32" 91°41'57"	724.0	63	38	42	30	48	15	38
Cedar Rapids West 10	41°00'36" 91°42'07"	724.0	67	42	42	30	52	15	64
Cedar Rapids West 11	42°00'37" 91°42'22"	724.0	66	41	42	30	51	15	67
Cedar Rapids Seminole 1	42°00'31" 91°42'47"	720.0	64	5	52	30	53.8	10.2	62
Cedar Rapids Seminole 2	42°00'24" 91°42'58"	720.0	53.9	NR	NR	30	43.9	10	38
Cedar Rapids Seminole 3	42°00'19" 91°43'05"	720.0	62.9	20	52	30	52.6	10.2	100
Cedar Rapids Seminole 4	42°00'15" 91°43'12"	720.0	54.9	10	52	30	34.7	10.2	210
Cedar Rapids Seminole 5	42°00'09" 91°43'18"	720.0	64	15	52	30	53.7	10.2	42

Table 2. Construction information for municipal water wells, test holes, and observation wells in the vicinity of Cedar Rapids, Iowa—Continued

Well name and number (figs. 6,7, and 8)	Latitude/longitude (degrees, minutes, seconds)	Land-surface elevation (ft)	Well depth (ft)	Depth to bottom of sealed annular space (ft)	Diameter of hole (in.)	Diameter of casing (in.)	Depth to top of well screen (ft)	Length of well screen (ft)	Lateral distance to surface water[1] (ft)
Municipal wells—Continued									
Cedar Rapids Seminole 6	42°00'04" 91°43'24"	721.0	61.1	16.6	52	30	50.9	10.2	41
Cedar Rapids Seminole 7	42°00'00" 91°43'31"	721.0	63.1	5	52	30	52.9	10.2	60
Cedar Rapids Seminole 8	41°59'56" 91°43'37"	722.0	57.3	1.1	52	30	47.1	10.2	116
Cedar Rapids Seminole 9	41°59'53" 91°43'46"	724.0	57.5	12.2	52	30	47.2	10.2	115
Cedar Rapids Seminole 10	41°59'54" 91°43'53"	725.4	68.6	5	52	30	58.4	10.2	48
Cedar Rapids Seminole 11	42°00'23" 91°43'03"	722.0	62	37	42	30	47	15	235
Cedar Rapids Seminole 12	42°00'15" 91°44'13"	724.0	58	NR	42	30	43	15	500
Cedar Rapids Seminole 13	42°00'17" 91°44'20"	724.0	61	NR	42	30	46	15	500
Cedar Rapids Seminole 14	42°00'20" 91°44'25"	725.0	59	NR	42	30	44	15	800
Cedar Rapids Seminole 15	42°00'25" 91°44'27"	727.0	62	NR	42	30	47	15	800
Cedar Rapids Seminole 16	42°00'30" 91°44'30"	726.0	65	NR	42	30	50	15	900
Cedar Rapids Seminole 17	42°00'13" 91°44'19"	724.0	58	34	42	30	34	20	63
Cedar Rapids Seminole 18	42°00'13" 91°44'27"	724.0	52	20	42	30	32	20	81
Cedar Rapids Seminole 19	42°00'14" 91°44'34"	724.0	40	14	42	30	28	12	75
Cedar Rapids Seminole 20	42°00'19" 91°44'39"	719.0	43	10	42	30	28	15	52
Cedar Rapids Seminole 21	42°00'24" 91°44'40"	718.0	51.7	14	42	30	36.7	15	78
Cedar Rapids Seminole 22	42°00'30" 91°44'41"	721.0	57	14	42	30	42	15	86
Cedar Rapids Seminole 23	42°00'35" 91°44'41"	724.0	57	14	42	30	40	17	70

Table 2. Construction information for municipal water wells, test holes, and observation wells in the vicinity of Cedar Rapids, Iowa—Continued

Well name and number (figs. 6,7, and 8)	Latitude/longitude (degrees, minutes, seconds)	Land-surface elevation (ft)	Well depth (ft)	Depth to bottom of sealed annular space (ft)	Diameter of hole (in.)	Diameter of casing (in.)	Depth to top of well screen (ft)	Length of well screen (ft)	Lateral distance to surface water[1] (ft)
Test holes									
Test Hole 10-A	NR	725.0	40.0	NR	NR	NR	NR	NR	NR
Test Hole 10-B	NR	725.0	45.0	NR	NR	NR	NR	NR	NR
Observation wells									
1993 USGS CRM-3	41°59'53" 91°43'50"	725.9	39.5	6	6	4	37	2.5	106
1993 USGS CRM-4	41°59'53" 91°43'53"	725.8	42.5	7	6	4	40	2.5	26
1993 USGS CRM-6	41°59'54" 91°43'53"	725.7	95	80	6	4	92.5	2.5	30

[1]Lateral distances to surface-water source were measured on March 22, 1994. Water–surface elevation at surface-water monitoring site (fig. 8) was 717.45 feet above sea level.

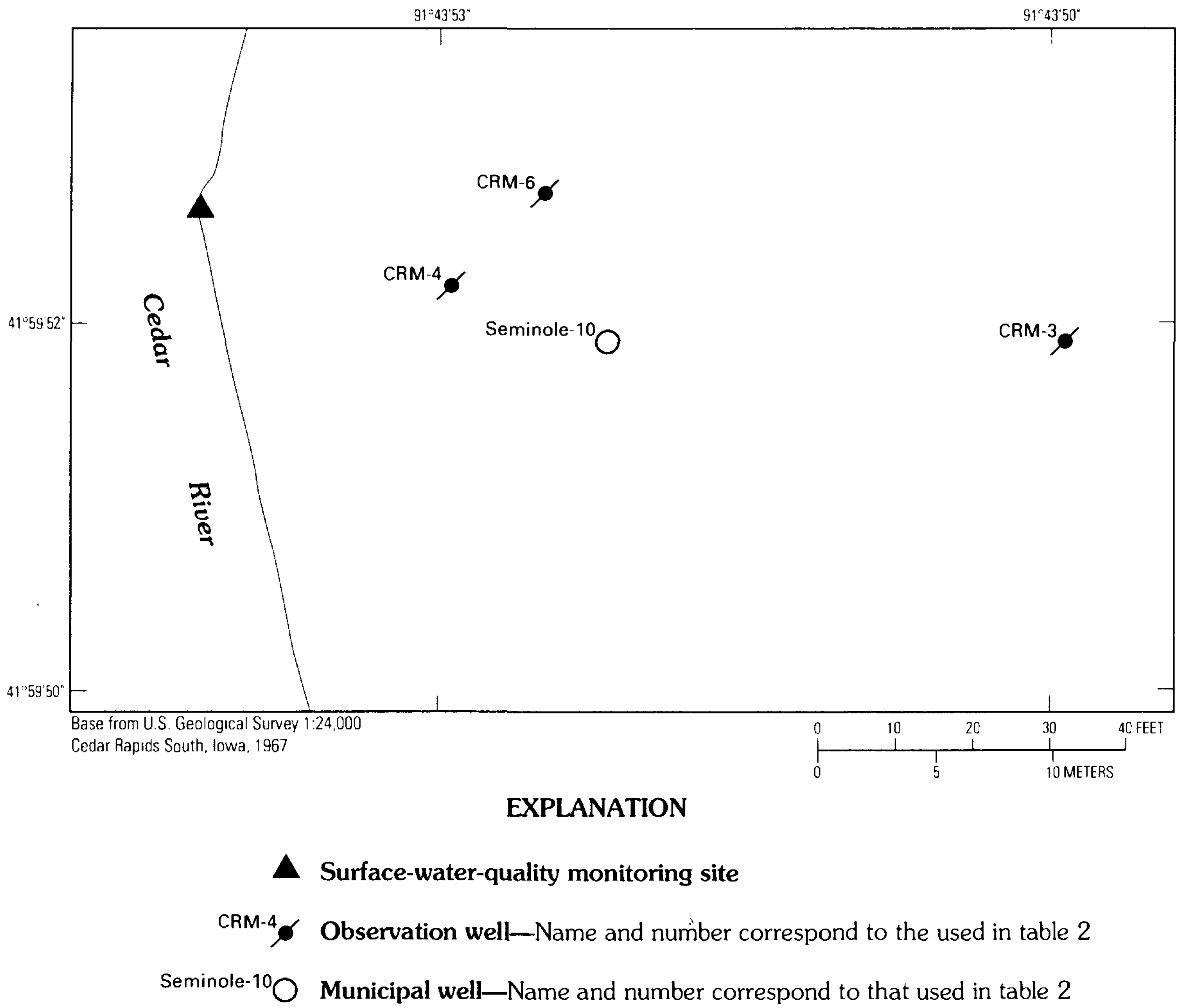


Figure 8. Intensive study site in vicinity of Cedar Rapids municipal well Seminole 10.

DATA COLLECTION AND RESULTS

A multiprobe instrument, Hydrolab DataSonde@3[1], was used to continuously monitor water level, specific conductance, pH, temperature, and dissolved oxygen in the Cedar River, observation wells CRM-3 and CRM-4, and municipal well Seminole 10 (fig. 8). The Cedar Rapids municipal water-treatment plant (fig. 6) also was monitored for the selected water-quality properties and constituents. The data were recorded at 15-, 30-, or 60-minute intervals and are stored in the National Water Information System (NWIS) data base of the USGS. Selected water-quality properties and constituents, and surface-water biogenic particulates were collected at the inten-

[1]Any use of product names is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

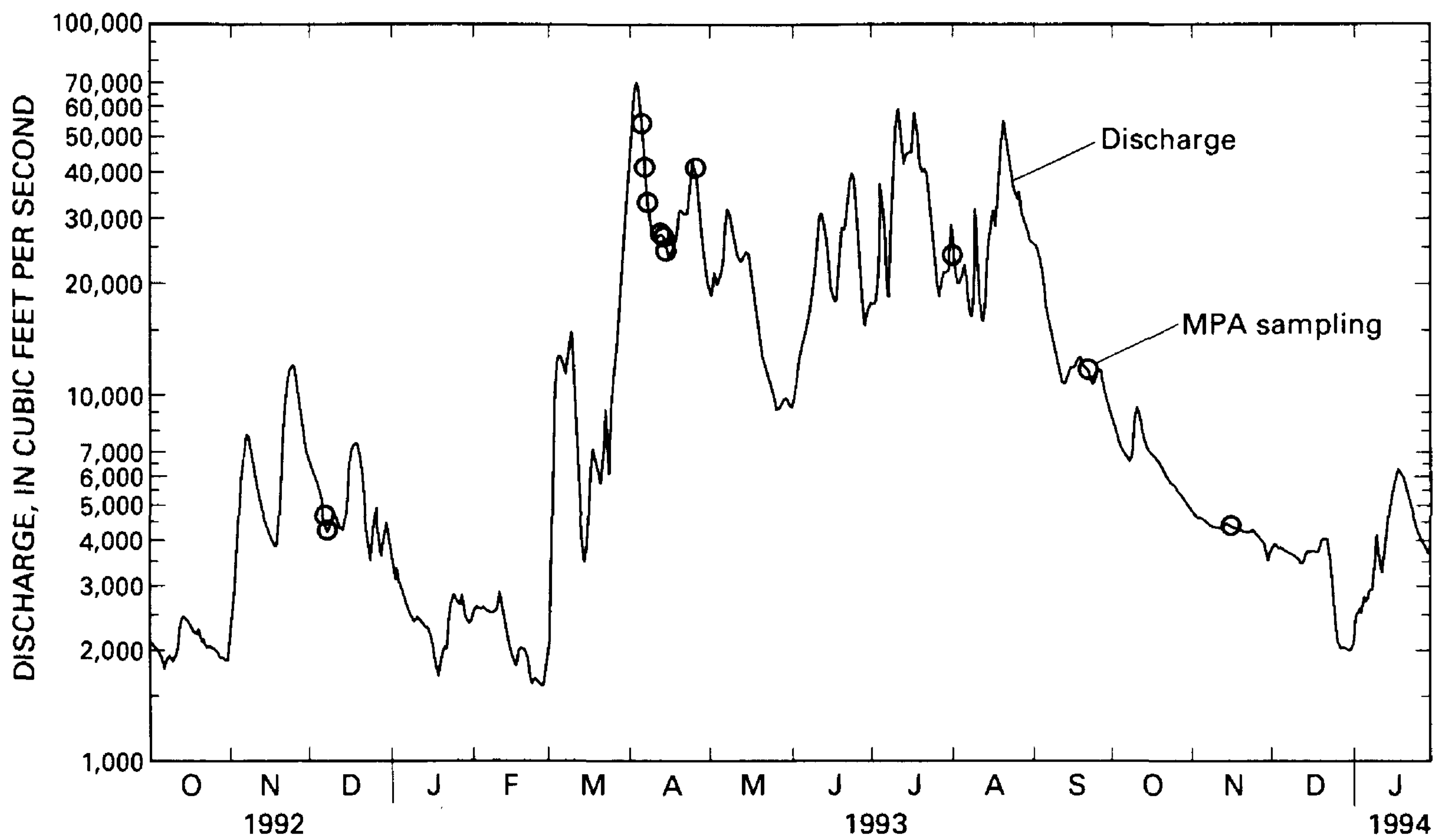


Figure 9. Daily mean discharge of the Cedar River at Cedar Rapids and collection dates of samples for microscopic particulate analysis (MPA), October 1992 through January 1994.

sive study site (figs. 7 and 8), while discharge measurements were collected about 5 mi downstream from the intensive study site below the low-head dam (fig. 1).

The multiprobes in observation wells CRM-3 and CRM-4 were attached to a packer to isolate the instrument in the screened section of the well. Multiprobes were secured in the wells on a cable attached to the well caps. The multiprobe for the Cedar Rapids municipal water-treatment plant was placed just before the first step in the treatment process. Data from the multiprobes were retrieved every 2 weeks. During the winter months, retrieval of data from the river multiprobe was less frequent due to water freezing in the pipe. After data retrieval multiprobes were recalibrated and returned to the monitoring point. Specific-conductance, pH, and dissolved-oxygen values were adjusted automatically by the multiprobe for temperature.

Cedar River Discharge and Stage

Discharge of the Cedar River is systematically measured as part of the long-term, ongoing USGS data-collection program (Southard and others, 1994). Discharge measurements used in this study were made at the USGS gaging station at Cedar Rapids located 3,000 ft downstream of the low-head dam (fig. 1). The annual mean monthly flow for 1903 to 1993 at the USGS gaging station at Cedar Rapids is 3,658 ft^3/s. The highest daily mean of 71,500 ft^3/s occurred on March 31, 1961, and the lowest daily mean of 140 ft^3/s occurred on November 18, 1989 (Southard and others, 1994).

For the period of this study, December 1992 to January 1994, the highest daily mean discharge of 70,500 ft^3/s occurred on April 4, 1993; the lowest daily mean of 1,600 ft^3/s occurred on February 23, 1993, and the annual mean monthly flow was 15,130 ft^3/s. A hydrograph (fig. 9) for the Cedar River at Cedar Rapids shows the mean daily discharge. Conditions during most of the study period were about 400 percent of normal for discharge and runoff. Annual runoff during the study was 31.55 in. compared to the mean annual runoff of 7.64 in. Due to the above-normal conditions the low-head dam had little effect on the flow of the river, which normally withholds and releases water to generate power during peak hours.

Stage of the Cedar River was measured by the multiprobe at the intensive-study site. Stage data are shown in figure 10. Records show that the ground surface at municipal well Seminole 10 was inundated four times by the Cedar River in 1993—once in April, twice in July, and once in August.

Ground-Water Levels

The multiprobes in observation wells CRM-3 and CRM-4 were fitted with strain gages to measure water levels within a range of 0–33 ft with a precision of 0.15 ft. The multiprobe used in municipal well Seminole 10 was fitted with a strain gage to measure water levels within a range of 0-328 ft with a precision of 1.48 ft (Hydrolab Corporation, 1991). The water-level sensor automatically compensated for water density. Periodically, manual water-level measurements were made with a steel tape and were recorded to within 0.01 ft to verify the multiprobe measurements.

Mean daily water levels for observation wells CRM-3 and CRM-4 and municipal well Seminole 10 are listed in tables 8 through 11 at the end of this report and are graphically compared to stage of the Cedar River in figure 10. The majority of missing water-level data for well CRM-4 resulted from water levels exceeding the tolerance of the sensor. Results of periodic manual measurements in wells CRM-3, CRM-4, and CRM-6 are listed in table 12 at the end of this report.

Water levels for wells CRM-3 and CRM-4 closely follow the stage of the river. During pumping, municipal well Seminole 10 drawdown causes the water level to range from 12 to 20 ft below river stage, which results in a steep gradient between the Cedar River and well Seminole 10. The direction of ground-water flow is toward the well. When the well was not pumping, water levels in wells CRM-3, CRM-4, and Seminole 10 were similar to the level of the river.

Generally the direction of ground-water flow was from the river to the alluvial aquifer as a result of drawdown from pumping. Water levels measured February 1 through 9, 1993, show that the direction of ground-water flow was from the alluvial aquifer to the river. During this period, municipal well Seminole 10 was not pumping.

On November 4 and December 20, 1993, comarative water levels for observation wells CRM-3, CRM-4, and CRM-6 indicate that ground-water flow from the bedrock aquifer was upward toward the alluvial aquifer. The upward gradient indicates that the bedrock is a source of recharge to the alluvial aquifer at this location.

Selected In-Situ Water-Quality Properties and Constituents

Specific Conductance

The mean daily specific-conductance values for water in the Cedar River ranged from a maximum value of 640 µS/cm (microsiemens per centimeter at 25 $^{\circ}$C) on February 1, 1993, to a minimum value of 223 µS/cm on March 5, 1993. Maximum and minimum values for mean daily specific conductance for observation well CRM-4 and municipal well Seminole 10 are similar in range and time period to those of the river. Observation well CRM-4 had a maximum value of 658 µS/cm on February 25, 1993, and the minimum value of 272 µS/cm on March 10, 1993. Municipal well Seminole 10 had a maximum values of 640 µS/cm on January 11 and 12, 1994; 635 µS/cm on February 15, 1993; and 636 µS/cm on March 3, 1993. The minimum value for well Seminole 10 was 287 µS/cm on April 10, 1993. Values of mean daily specific conductance for observation well CRM-3 and the municipal water-treatment plant were less similar to values in the river. The maximum was 655 µS/cm on February 17, 1993, and the minimum was 426 µS/cm on May 14, 1993, for observation well CRM-3. The maximum specific-conductance value for the municipal water-treatment plant was 602 µS/cm on March 2, 1993, and the minimum value was 418 µS/cm on August 20, 1993. Mean daily specific conductance values are tabulated at the end of this report in tables 13 through 17.

pH

The data show no significant or rapid changes in pH for water from wells and the municipal water-treatment plant compared to that from the Cedar River.

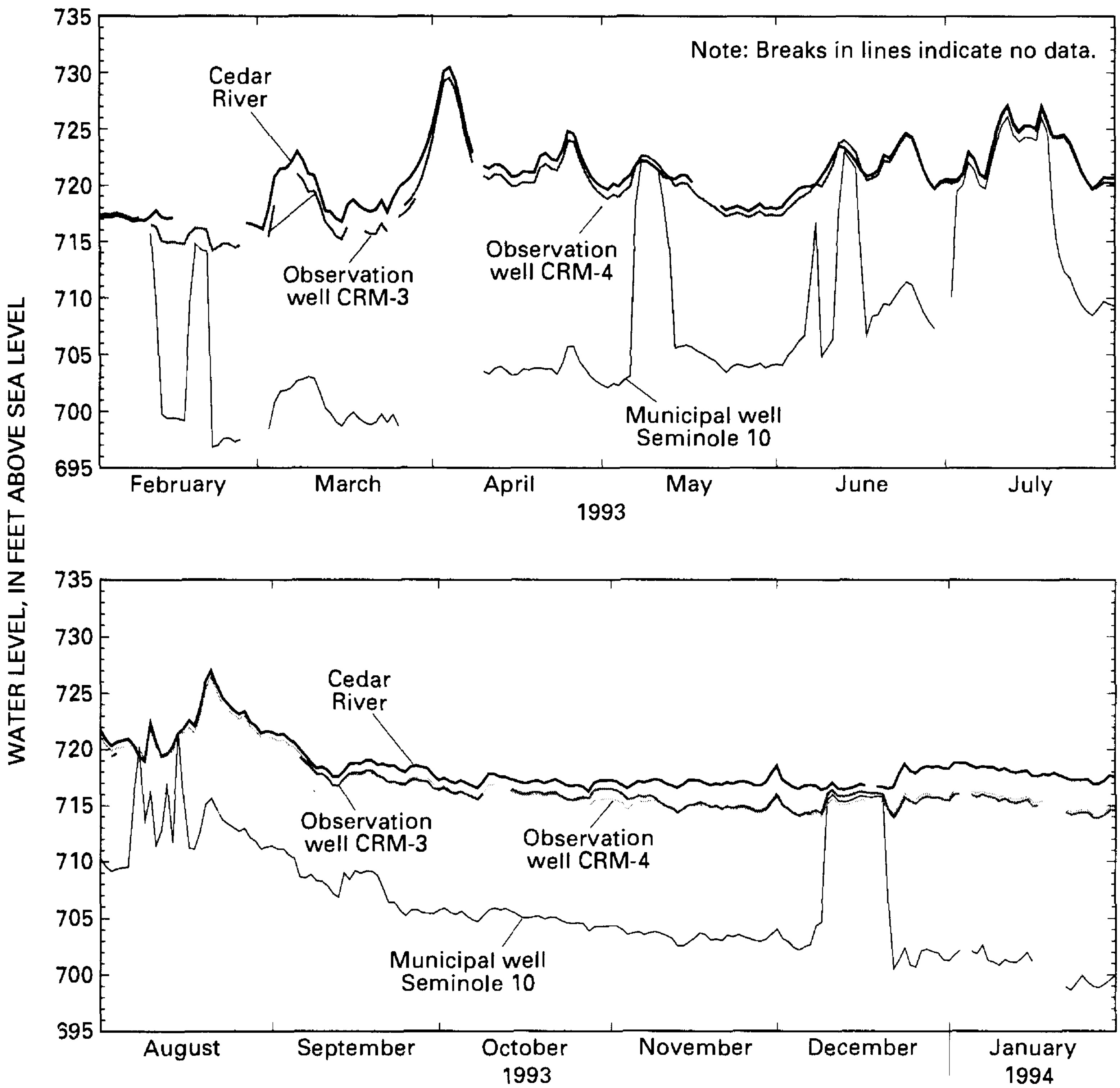


Figure 10. Water levels in the Cedar River, Cedar Rapids municipal well Seminole 10, and observation wells CRM-3 and CRM-4, February 1, 1993, through January 31, 1994.

The pH data are tabulated in tables 18 through 22 at the end of this report. The daily mean pH values for the river water ranged from a minimum of 7.3 in March 1993 to a maximum of 8.5 in May and June of 1993. Values for observation well CRM-4 were similar in range from 7.4 to 8.2 and for municipal well Seminole 10 from 7.2 to 8.0. pH. Values of pH for water from observation well CRM-3 and the municipal water-treatment plant were smaller, ranging from 6.9 to 7.5 and 6.3 to 7.5, respectively.

Temperature

Maximum mean daily river temperature was 24.6 °C on August 27, 1993, and a minimum mean daily temperature of -0.1 °C was recorded from February 1 through March 6, 1993, and from December 23, 1993, through January 25, 1994. Maximum and minimum mean daily values for observation well CRM-4 were 24.5 °C on September 3, 1993, and 0.1 °C from February 14 through March 14, 1993 and from December 31, 1993, through January 31, 1994. Maximum and minimum mean daily values for municipal well Seminole 10 were 21.4 °C on September 13, 1993, and -0.2 °C from February 5–16, 1993, and on January 23, 24, and 26–29, 1994. Maximum and minimum mean daily values for observation well CRM-3 were 18.7 °C on December 2, 1993, and 0.6 °C from February 10–13, 1993. Maximum and minimum mean daily values for the municipal water-treatment plant were 17.6 °C on September 13, 1993, and 5.9 °C on April 10, 1993. Mean daily temperature values are tabulated at the end of this report in tables 23 through 27.

The water temperatures for observation well CRM-4 seem to follow the trend of water temperatures in the Cedar River. Water temperatures for municipal well Seminole 10 also follow the trend of water temperatures in the river but not as closely as those for observation well CRM-4. Water temperatures for observation well CRM-3 and the municipal water-treatment plant do not follow the variations in water temperatures for the river as the temperature in the river increases and decreases throughout the year.

Dissolved Oxygen

The Cedar River had a maximum concentration of dissolved oxygen of 15.2 mg/L on February 3, 1993, and a minimum concentration of 6.0 mg/L on August 20, 1993. Maximum and minimum concentrations for observation well CRM-4 were 12.3 mg/L on December 28, 1993, and 0.1 mg/L on September 2, 1993. Maximum and minimum concentrations for municipal well Seminole 10 were 11.5 mg/L on January 2, 1994, and 0.4 mg/L from February 1–3, February 10, August 1–5 and 17–23, and September 11–13 and 15–18, 1993. Maximum and minimum concentrations for observation well CRM-3 were 3.1 mg/L on February 10, 1993, and 0.2 mg/L from February 14–16, November 10, 25, 26, and 28, December 3–5, 1993, and on January 31, 1994. Maximum and minimum concentrations for the municipal water-treatment plant were 11.2 mg/L on July 17, 1993, and 0.4 mg/L on February 25, 1993. Mean daily concentration values of dissolved oxygen are tabulated at the end of this report in tables 28 through 32.

Concentrations of dissolved oxygen in the river tend to be higher than the dissolved-oxygen concentrations in water from observation well CRM-4, municipal well Seminole 10, observation well CRM-3, and the water-treatment plant. The trend of dissolved-oxygen concentration in well CRM-4 is similar to the concentrations in the river but in smaller quantities. Concentrations in well Seminole 10 are similar to concentrations in well CRM-4 except during May through September. Dissolved-oxygen concentrations in well CRM-3 were fairly stable throughout the study period.

Microscopic Particulate Analysis

Microscopic particulate data were collected using the method outlined by the U. S. Environmental Protection Agency (USEPA) to determine if a ground-water source is GWUDI according to the SWTR (Vasconcelos and Harris, 1992). Prior to sampling, municipal wells were pumped for a minium of 1 week to assure sufficient time for aquifer conditions to stabilize. Samples were collected from the Cedar River, municipal wells East 1 and 19, West 6, and Seminole 2, 3, 10, 14, and 16, and the Cedar Rapids municipal water-treatment plant during April 1993, a period of above-normal flow. Additional samples for the river and Seminole wells 10, 14, and 16 were collected throughout the study period. Samples collected during a period of high flow, when several wells were inundated, are important because the alluvial aquifer could be at a higher risk of contamination by surface water during this period. Samples were collected by USGS personnel and sent to the laboratory of Analytical Services, Inc., in Essex Junction, Vermont, for MPA.

Analysis of 29 samples found no *Giardia* cysts or *Crytosporidium* oocysts in water collected from municipal wells and the municipal water-treatment plant (table 3). A total of five *Giardia* cysts and four *Crytosporidium* oocysts were detected in the Cedar River samples, some with and some without internal structure.

Chlorophyll-containing algae (table 3) were detected in all but one of the wells sampled. The algae counts in the selected wells generally were insignificant compared to the algae counts in the river water. The largest counts occurred during flooding in April 1993. Counts of algae found in samples from the municipal water-treatment plant and municipal wells Seminole 3, 14, and 16 ranged from 1.9×10^3 to 7.9×10^4 per 100 gal of water during this time, three orders of magnitude higher than normally found. In comparison, the river samples contained algae counts of 1.6×10^7 to 3.8×10^7 per 100 gal of water, whereas samples from municipal wells East 1 and 9, West 6, and Seminole 2 and 10 contained counts ranging from 1 to 16 per 100 gal.

Table 3. Results of microscopic particulate analysis for primary indicators in water from study area, December 1992 through November 1993

[Values are counts per 100 gallons of water, except as noted; I, inundated at the time of sampling; ND, not detected]

Municipal wells or sampling site (figs. 6 and 7)	Date (month-day-year)	*Giardia* cysts	*Crypto-sporidium* oocysts	Vegetative debris	Diatoms	Algae	Protozoa	Insects	Insect parts
Cedar River	12-07-92	2	ND	$1.0x10^3$	$1.2x10^4$	$7.4x10^6$	$1.7x10^6$	ND	ND
	04-06-93	1	3	$1.1x10^3$	$5.7x10^5$	$1.8x10^7$	$1.2x10^6$	ND	ND
	04-13-93	ND	ND	$1.0x10^3$	$5.1x10^5$	$3.4x10^7$	$1.9x10^6$	ND	ND
	04-26-93	ND	ND	$1.0x10^3$	$2.7x10^3$	$1.6x10^7$	$7.8x10^5$	ND	ND
	08-02-93	ND	1	ND	ND	$2.3x10^5$	$6.4x10^3$	ND	ND
	11-16-93	2	ND	ND	$3.3x10^3$	$6.0x10^7$	ND	ND	ND
Cedar Rapids municipal water-treatment plant	04-06-93	ND	ND	2	1	$7.9x10^4$	$1.8x10^2$	ND	ND
	04-07-93	ND	ND	ND	1	$1.9x10^4$	16	ND	ND
	04-08-93	ND	ND	ND	ND	$1.1x10^4$	ND	ND	ND
	04-26-93	ND	ND	4	ND	$2.7x10^4$	$4.1x10^3$	ND	ND
Cedar Rapids municipal wells									
East 1	04-14-93	ND	ND	1	ND	16	$2.0x10^3$	ND	ND
East 19	04-26-93 I	ND	ND	ND	2	8	$2.4x10^3$	ND	ND
West 6	04-15-93	ND	ND	ND	ND	1	$3.5x10^4$	ND	ND
	04-26-93	ND	ND	ND	ND	4	63	ND	ND
Seminole 2	04-15-93 I	ND	ND	ND	ND	8	$4.1x10^3$	ND	ND
Seminole 3	04-15-93 I	ND	ND	ND	8	$1.9x10^3$	$2.0x10^3$	ND	ND
	09-22-93	ND	ND	ND	ND	22	ND	ND	ND
	11-16-93	ND	ND	ND	ND	35	29	ND	ND

Table 3. Results of microscopic particulate analysis for primary indicators in water from study area, December 1992 through November 1993—Continued

Municipal wells or sampling site (figs. 6 and 7)	Date (month-day-year)	*Giardia* cysts	*Crypto-sporidium* oocysts	Vegetative debris	Diatoms	Algae	Protozoa	Insects	Insect parts
			Cedar River municipal wells—Continued						
Seminole 10	12-08-92	ND	ND	1	ND	8	4	ND	ND
	04-13-93	ND	ND	ND	2	9	$2.4x10^3$	ND	ND
	09-22-93	ND	ND	ND	ND	ND	$3.6x10^3$	ND	ND
	11-16-93	ND	ND	ND	ND	25	$6.5x10^2$	ND	ND
Seminole 14	04-06-93 I	ND	ND	ND	ND	$4.0x10^3$	36	ND	ND
	08-02-93	ND	ND	ND	ND	34	ND	ND	ND
	11-16-93	ND	ND	ND	ND	2	17	ND	ND
Seminole 16	04-06-93 I	ND	ND	ND	ND	$3.7x10^3$	$2.0x10^2$	ND	ND
	04-07-93 I	ND	ND	ND	ND	$1.6x10^4$	7	ND	ND
	08-02-93	ND	ND	ND	ND	47	ND	ND	ND
	11-16-93	ND	ND	ND	ND	2	3	ND	ND

Diatoms (table 3) were found only in samples from three wells and the municipal water-treatment plant during the period of flooding. The counts ranged from 1 to 8 compared to counts ranging from 2.7 x 10^3 to 5.7 x 10^7 per 100 gal in the river samples throughout the period of sampling. The count of rotifers found in the wells also was small compared to those found in the river samples (table 4). Some free-living rotifers have highly specialized food habits not associated with surface water if sufficient organic debris, fungi, and bacteria are present as a food supply (Vasconcelos and Harris, 1992). Vegetative debris (table 4), spores, pollen, crustaceans, crustacean eggs, nematodes, nematode eggs, amoebae, and invertebrate eggs (table 5) all showed very small counts in the well samples compared to the larger counts in the river samples. No insects or insect parts were found in any of the samples collected (table 4). Results for volume of sample filtered, turbidity, filter color, pH of sample, and amorphous debris are presented in table 5. Turbidity of water from the wells sampled is generally less than the turbidity of the river except where wells have a high occurrence of iron bacteria.

EFFECT OF THE CEDAR RIVER ON SELECTED WATER-QUALITY PROPERTIES AND CONSTITUENTS OF THE ALLUVIAL AQUIFER

Variations in the specific conductance, pH, temperature, and dissolved-oxygen concentrations of water in the alluvial aquifer can be related to the Cedar River. Before addressing these relations, some aspects of water-quality variations in the Cedar River and traveltimes of water in the alluvial aquifer are discussed.

Specific conductance, pH, and the concentration of dissolved oxygen change inversely with changes in river stage or discharge (Schulmeyer, 1991). Increases in discharge of the Cedar River resulting from runoff had an inverse effect on the values of specific conductance, pH, and concentration of dissolved oxygen in the river as a result of dilution (figs. 11, 12, and 13). Precipitation, resulting in overland flow generally has a smaller specific conductance and pH, ranging from 5 to 74 µS/cm and 4.0 to 7.3 pH (Southhard and others, 1994), respectively, compared to the specific conductance and pH of ground water in alluvial and bedrock aquifers, which ranges from 390 to 1,800 µS/cm and 6.8 to 8.0 pH (Wahl and Bunker, 1986). Because the Cedar River can receive a major part of its flow from ground-water contribution, especially during periods of below-normal precipitation, the specific-conductance, pH, and dissolved-oxygen values of river water can be similar to values measured in the ground water. When runoff occurs dilution takes place. With a large amount of runoff, substantial decreases in values of specific conductance, pH, and dissolved oxygen for water from the Cedar River can take place. Subsequently, these changes can be seen in the alluvial aquifer as water from the river moves toward municipal well Seminole 10 over a period of time.

Water-quality properties and constituents of water pumped from the alluvial aquifer change as water flows from the Cedar River to municipal well Seminole 10 as a result of drawdown. The amount of time needed for water to travel through the aquifer could be an indication of the susceptibility of the alluvial aquifer to surface-water effects. *Giardia* cysts have a period of viability dependent on length of time in the environment and temperature (Wilson and others, 1992). Viability is largely lost in about 20 days in water at 20 °C, 30 days in water at 10 °C, and 90 days in water of only a few degrees Celsius (Wilson and others, 1992). Traveltime represents the residence time the water has in contact with the aquifer material, which may enhance the filtering efficiency of the aquifer material.

The most notable example of change started on February 28, 1993, in the Cedar River for specific conductance, pH, and dissolved oxygen. The values for specific conductance and pH and the concentration of dissolved oxygen decreased with a corresponding increase in the discharge of the river. This decrease is subsequently seen in observation well CRM-4, municipal well Seminole 10, and to a lesser extent in observation well CRM-3 and the municipal water-treatment plant. A traveltime for water moving from the Cedar River to other sampling sites can be estimated from the data. A traveltime is estimated by determining from the plotted or tabulated data when a change starts in the river and counting the days until correlative changes occur at other at sampling sites.

Table 4. Results of microscopic particulate analysis for secondary indicators in water from study area, December 1992 through November 1993

[Values are counts per 100 gallons of water, except as noted; I, inundated at time of sampling; ND, not detected]

Municipal well or sampling site (figs. 6 and 7)	Date (month-day-year	Spores	Pollen	Crusta-ceans	Crust-acean eggs	Nema-todes	Nema-tode eggs	Rotifers	Rotifer eggs	Amoebae	Inverte-brate eggs
Cedar River	12-07-92	$4.3x10^2$	$5.6x10^3$	ND	ND	$1.1x10^3$	$4.3x10^2$	$1.6x10^3$	$2.1x10^3$	$1.1x10^3$	$2.1x10^3$
	04-06-93	$6.5x10^3$	$1.6x110^4$	ND	ND	$7.3x10^3$	$3.8x10^2$	$3.8x10^2$	$3.8x10^2$	$1.1x10^3$	$3.8x10^2$
	04-13-93	$3.6x10^3$	$1.1x10^4$	$5.2x10^2$	ND	$3.6x10^3$	ND	$1.0x10^3$	$2.1x10^4$	$1.0x10^3$	$5.2x10^2$
	04-26-93	$1.3x10^3$	$9.3x10^3$	$3.3x10^2$	ND	$1.0x10^3$	ND	$1.7x10^3$	ND	ND	$6.7x10^2$
	08-02-93	$1.4x10^4$	$8.8x10^3$	ND	ND	$4.4x10^3$	ND	$1.6x10^3$	ND	ND	$1.2x10^3$
	11-16-93	ND	ND	ND	ND	ND	ND	$1.0x10^5$	ND	ND	ND
Cedar Rapids municipal water-treatment plant	04-06-93	ND	3	ND	ND	20	26	1	ND	ND	ND
	04-07-93	ND	ND	ND	ND	10	17	5	1	ND	2
	04-08-93	ND	3	1	ND	3	1	3	ND	ND	1
	04-26-93	1	9	ND	ND	12	ND	92	ND	1	11
Cedar Rapids municipal wells											
East 1	04-14-93	ND	10	1	ND	ND	ND	ND	ND	ND	2
East 19	04-26-93 I	3	20	ND	ND	1	ND	3	ND	ND	3
West 6	04-15-93	ND	1	ND	ND	ND	ND	ND	ND	ND	ND
	04-26-93	ND	5	ND	ND	ND	ND	ND	ND	ND	1
Seminole 2	04-15-93 I	ND	ND	ND	ND	ND	ND	ND	ND	ND	2
Seminole 3	04-15-93 I	3	7	ND	ND	4	ND	1	1	8	2
	09-22-93	2	ND	ND	ND	ND	ND	1	ND	ND	1
	11-18-93	1	ND	ND	ND	ND	ND	NF	NF	ND	ND

Table 4. Results of microscopic particulate analysis for secondary indicators in water from study area, December 1992 through November 1993—Continued

Municipal well or sampling site (figs. 6 and 7)	Date (month-day-year	Spores	Pollen	Crusta-ceans	Crust-acean eggs	Nema-todes	Nema-tode eggs	Rotifers	Rotifer eggs	Amoebae	Inverte-brate eggs
Cedar River municipal wells —Continued											
Seminole 10	12-08-92	1	1	ND	ND	ND	ND	ND	ND	8	ND
	04-13-93	2	18	ND	ND	2	1	ND	ND	ND	2
	09-24-93	ND	1	ND	ND	1	ND	39	ND	ND	ND
	11-16-93	ND	ND	ND	ND	ND	ND	17	ND	ND	ND
Seminole 14	04-06-93 I	1	1	ND	ND	1	ND	ND	ND	1	ND
	08-02-93	ND	2	ND	ND	ND	ND	ND	ND	ND	ND
	11-16-93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Seminole 16	04-06-93 I	1	2	ND	ND	3	ND	2	ND	ND	2
	04-07-93 I	ND	6	ND	ND	3	ND	ND	ND	ND	ND
	08-02-93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	11-16-93	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 5. Results of microscopic particulate analysis for selected water-quality properties and selected secondary indicators in water from study area, December 1992 through November 1993

[Values are counts per 100 gallons of water, except as noted; amorphous debris, organic detritus, and sand sizes are greater than 5 micrometers; confluent, large concentration of amorphous debris; f, size is 1–5 micrometers; vf, size is less than 1 micrometer; I, inundated at time of sampling; NTU, national turbidity units; begin/end, values at beginning and end of sample collection; ND, not detected; NS, not sampled]

Municipal well or sampling site (figs. 6 and 7)	Date (month-day-year	Volume filtered (gallons)	Turbidity (NTU)		Filter color	pH (standard unit)		Amorphous debris
			begin	end		begin	end	
Cedar River	12-07-92	93	15	12	dark brown	8.3	8.3	confluent
	04-06-93	158	48	54	dark brown	7.7	7.8	confluent
	04-13-93	130	22	21	dark brown	8.1	8.1	$2.4x10^6$
	04-26-93	130	65	66	brown	8.1	8.1	confluent
	08-02-93	100	85	94	brown	8.0	8.2	confluent
	11-16-93	150	7.2	6.4	brown	7.9	8.3	vf confluent
Cedar Rapids municipal water-treatment plant	04-06-93	1,343	4.6	4.7	dark orange	7.4	7.5	confluent
	04-07-93	1,720	4.7	9.0	orange	7.5	7.7	confluent
	04-08-93	478	9.0	.60	orange	7.7	7.5	confluent
	04-26-93	552	2.8	3.4	orange	7.6	7.6	confluent
Cedar Rapids municipal wells								
East 1	04-14-93	1,342	113	8.4	orange	7.6	7.4	confluent
East 19	04-26-93 I	1,222	1.1	1.4	light tan	7.5	7.5	confluent
West 6	04-15-93	1,358	1.2	.72	peach	7.6	7.6	16
	04-26-93	1,196	.73	1.7	light tan	7.5	7.5	confluent
Seminole 2	04-15-93 I	1,377	.79	.45	light tan	7.6	7.6	$4.1x10^3$
Seminole 3	04-15-93 I	1,633	.75	.82	light tan	7.6	7.6	$2.7x10^3$
	09-22-93	3,388	.18	NS	light tan	8.3	NS	confluent
	11-16-93	1,261	.09	NS	tan	7.0	7.0	$7.7x10^2$

Table 5. Results of microscopic particulate analysis for selected water-quality properties and selected secondary indicators in water from study area, December 1992 through November 1993—Continued

Municipal well or sampling site (figs. 6 and 7)	Date (month-day-year	Volume filtered (gallons)	Turbidity (NTU)		Filter color	pH (standard unit)		Amorphous debris
			begin	end		begin	end	
Cedar Rapids municipal wells—Continued								
Seminole 10	12-08-92	1,178	0.71	0.28	pale tan	7.8	7.8	confluent
	04-13-93	1,380	1.1	.84	light tan	7.8	7.8	confluent
	09-22-93	1,430	.18	NS	light tan	8.4	8.3	$1.6x10^4$
	11-16-93	1,163	.14	.09	tan	7.2	7.1	f confluent
Seminole 14	04-06-93 I	1,200	53	15	orange	7.5	7.4	confluent
	08-02-93	1,265	8.9	2.3	orange	7.6	7.4	confluent
	11-16-93	1,092	15.8	.98	orange	7.1	6.8	f confluent
Seminole 16	04-06-93 I	1,235	98	12	orange	7.3	7.4	confluent
	04-07-93 I	1,340	12	11	orange	7.3	7.6	confluent
	08-02-93	1,200	17	53	orange	7.5	7.5	confluent
	11-16-93	1,133	21	.85	orange	7.1	6.8	f confluent

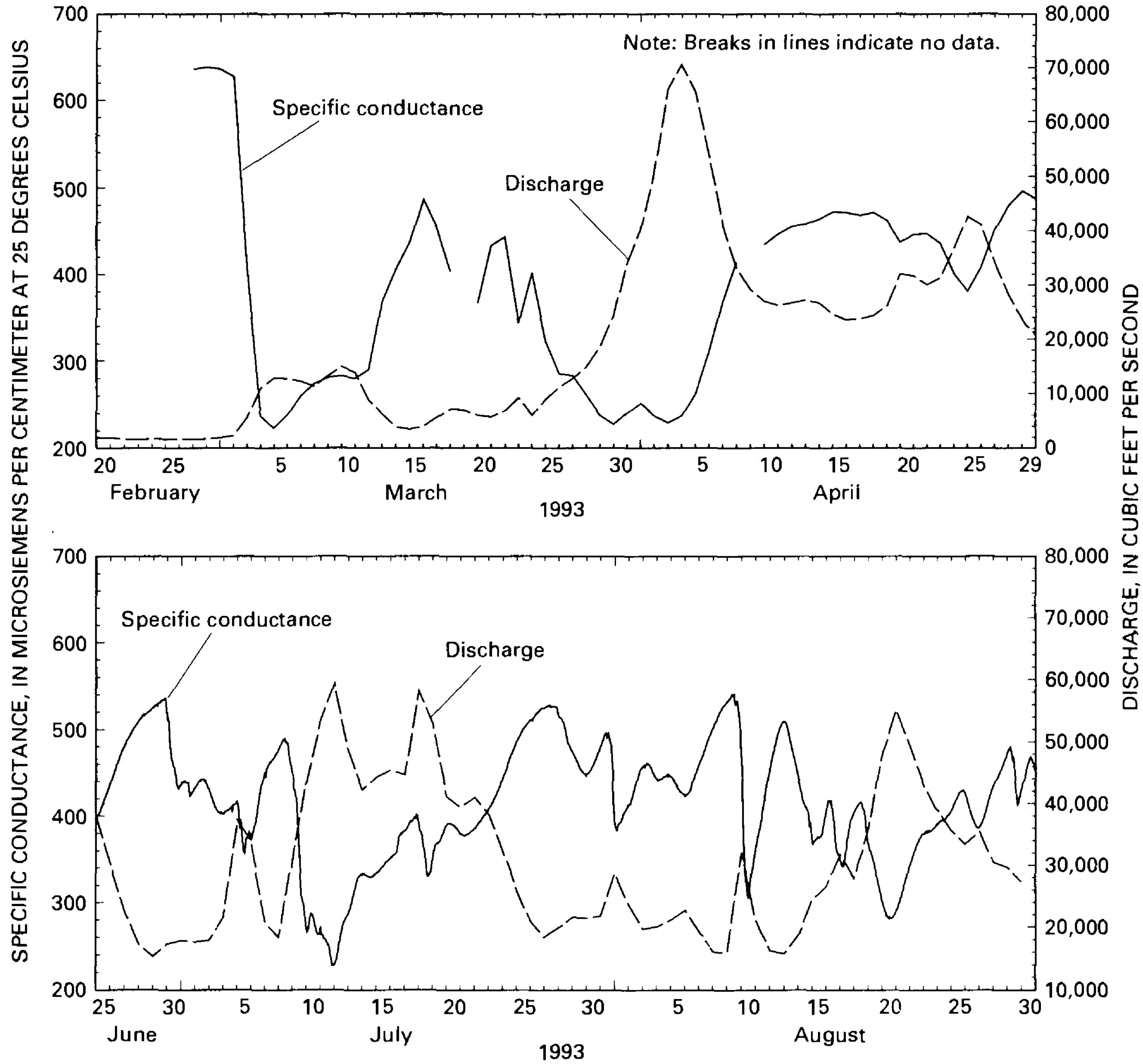


Figure 11. Specific conductance and discharge for the Cedar River at Cedar Rapids gaging station from February 20 through April 29 and June 25 through August 30, 1993.

Specific Conductance

Specific-conductance values for the Cedar River started to decrease on February 28, 1993, with a subsequent decrease in values at observation well CRM-4 on March 4, 1993, and at municipal well Seminole 10 on March 7, 1993 (fig. 14). Water of lower specific conductance took 4 days to travel to well CRM-4 and

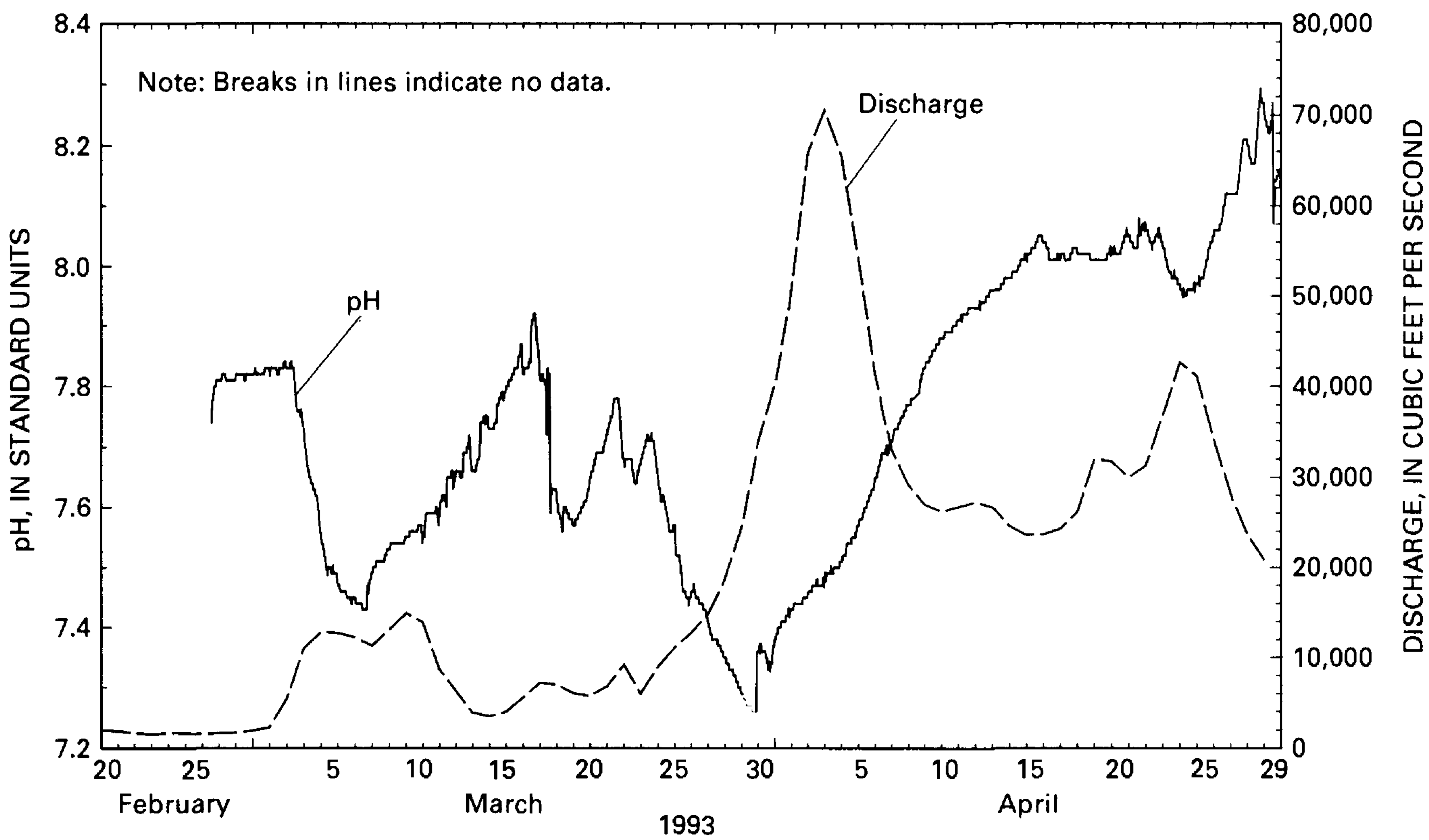


Figure 12. pH and discharge of the Cedar River at Cedar Rapids gaging station from February 20 through April 29, 1993.

7 days to travel to well Seminole 10. Three other selected events are shown starting on March 5 and October 2, 1993, and January 2, 1994, for the Cedar River. Traveltimes to well CRM-4 were 5, 5, and 4 days for observable changes to start at well CRM-4 and 12, 7, and 9 days to start at well Seminole 10, respectively. Water at observation well CRM-3 had an estimated traveltime of 29 days from the river on February 28, 1993, based on a correlative change that occurred on March 29, 1993 (fig. 15). Water entering the municipal water-treatment plant generally follows the trend of specific-conductance values for the river, but abrupt changes that occur in the river are not apparent in the water-treatment plant and no correlation of changes was possible from the data.

pH

There is no obvious correlation between the change in pH of the Cedar River that can be traced

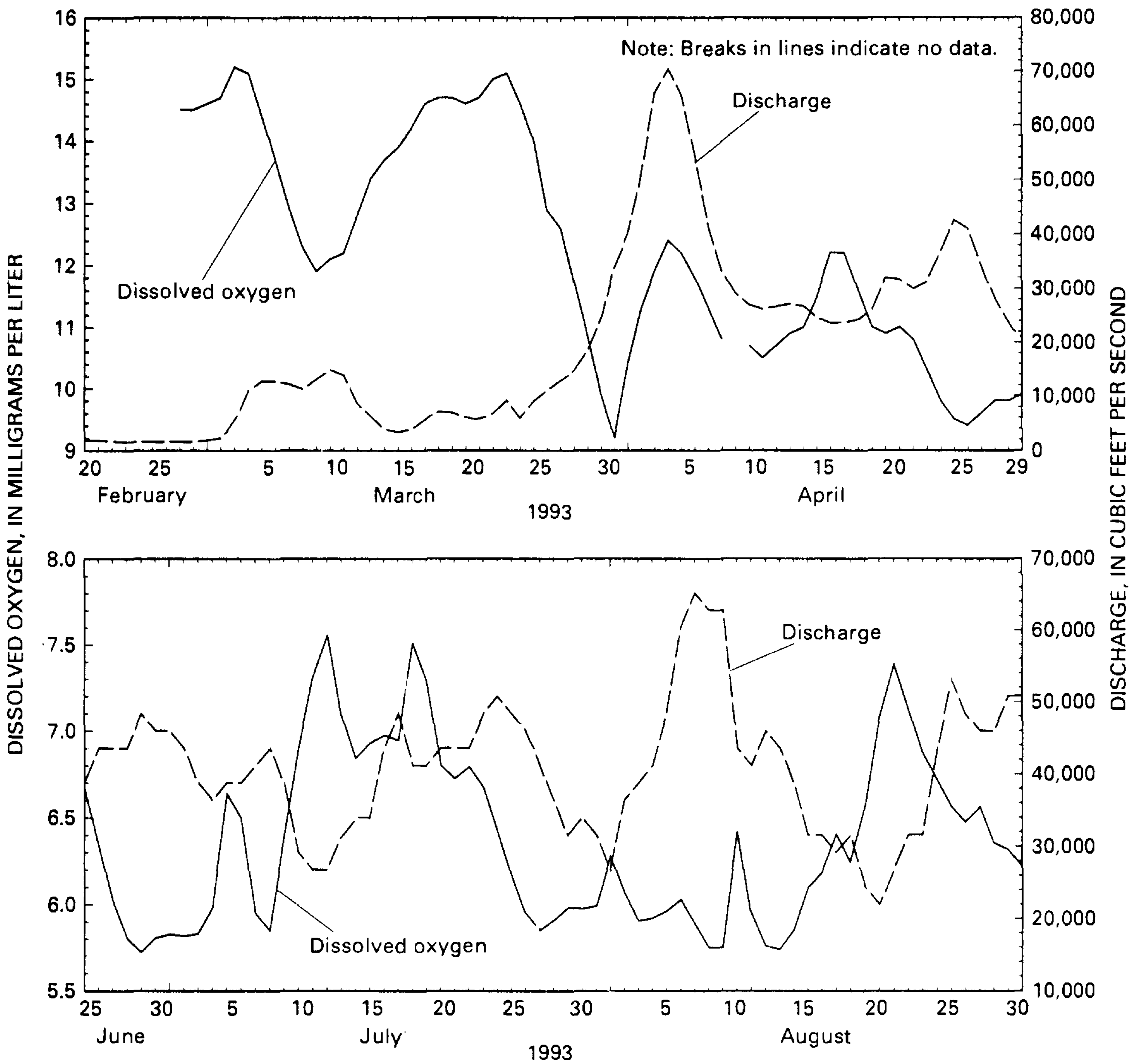


Figure 13. Dissolved oxygen and discharge of the Cedar River at Cedar Rapids gaging station from February 20 through April 30 and June 25 through August 30, 1993.

through the aquifer to municipal well Seminole 10 (fig. 16). This probably is due to the buffering capability of the aquifer material as water flows through the aquifer.

Temperature

Water temperature in the Cedar River followed the seasonal fluctuations of air temperature, colder in the winter and warmer in the summer. Temperatures of ground water tended to be more stable and depended on several factors: (1) the porosity of the aquifer, (2) the specific heat of the aquifer material, (3) the temperature of the ground water in storage, (4) the temperature of water in the river, and (5) the amount of mixing that occurred (Schneider, 1962). Water temperature for the Cedar River, observation well CRM-4, and municipal well Seminole 10 are shown in

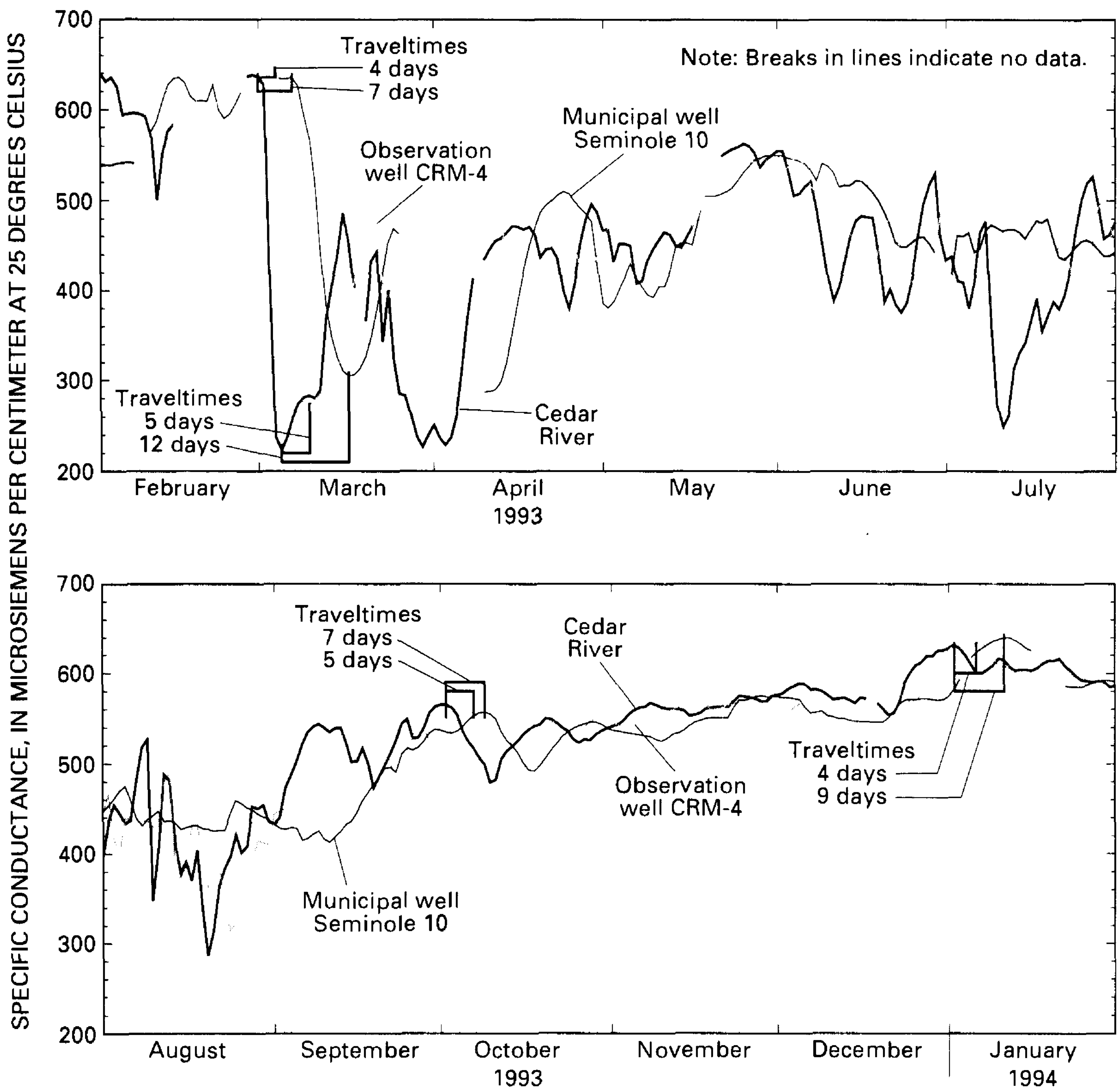


Figure 14. Specific conductance of water from the Cedar River, observation well CRM-4, and Cedar Rapids municipal well Seminole 10, and estimated traveltimes of water from the river to observation well CRM-4 and municipal well Seminole 10, February 1, 1993, through January 31, 1994.

figure 17. Figure 18 shows temperature for the Cedar River, observation well CRM-3, and water-treatment plant.

On March 24, 1993, the water temperature increased in the river, and a corresponding increase was observed in observation well CRM-4 on March 31, 1993 (fig. 17). Thus, the traveltime of water from the Cedar River to observation well CRM-4 is estimated to be 8 days. Similar estimates of traveltime from the Cedar River to observation well CRM-4 were made for August 27 to September 3, 1993, and from October 8 to October 15, 1993; both events had traveltimes of 7 days. Traveltimes for March 24 to April 11, 1993, August 27 to September 13, 1993, and October 8 to October 18, 1993, ranged from 10 to 17 days. The traveltimes are not long enough to have a substantial

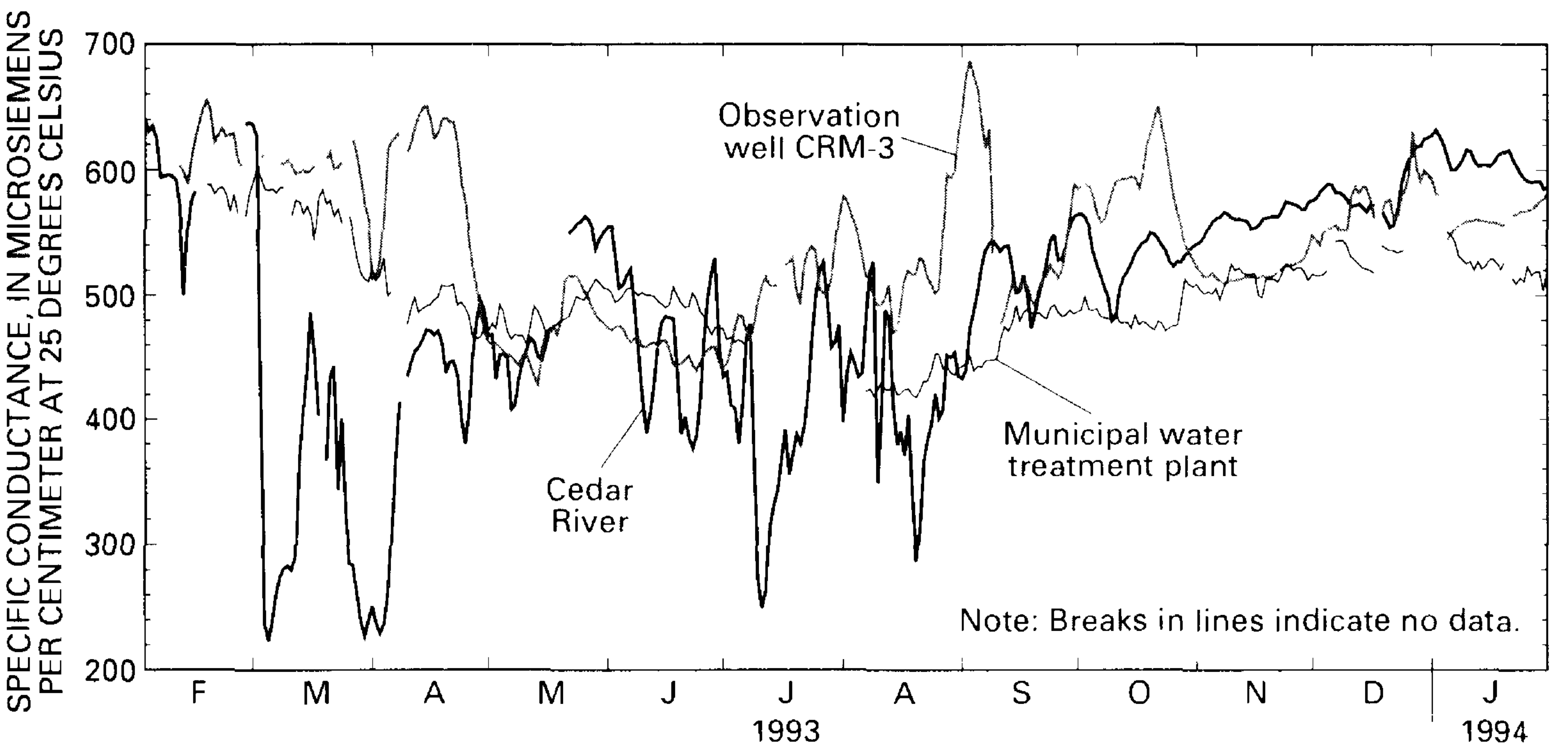


Figure 15. Specific conductance of water from the Cedar River, observation well CMR-3, and the municipal water-treatment plant, February 1, 1993, through January 31, 1994.

effect on the viability of *Giardia* cysts in water pumped by municipal well Seminole 10.

Water temperatures for observation well CRM-3 (fig. 18) do not corollate to the temperatures in the Cedar River. The maximum temperature for water in well CRM-3 was reached on December 2, 1993, at 18.7 ^{o}C while the river water was at 0.8 ^{o}C.

Water temperature measured at the water-treatment plant (fig. 18) changed slowly from a minimum on April 10, 1993, to a maximum on September 13, 1993. A traveltime is estimated from March 24, 1993, when the water temperature in the river started to warm, to the minimum temperature observed at the water-treatment plant on April 10, 1993 (17 days). Traveltime from the maximum water temperature in the river on August 27, 1993, to the maximum water temperature on September 13, 1993, at the water-treatment plant is also 17 days. This is the same traveltime as the traveltime to municipal well Seminole 10 in April and in August. There were no rapid changes in water temperature observed at the municipal water-treatment plant.

Dissolved Oxygen

In a stream, dissolved oxygen is a function of the equilibrium concentration of dissolved oxygen and is controlled mainly by pressure and temperature at the contact between the atmosphere and the water surface (Hem, 1989). Some aquatic organisms require oxygen and may deplete concentrations of dissolved oxygen, whereas other organisms may increase the dissolved-oxygen concentration through photosynthesis. Concentrations of dissolved oxygen in ground water usually are the result of recharge to the aquifer, and concentrations can be similar to those of surface water (Hem, 1989). Dissolved-oxygen concentrations in water from the Cedar River, observation well CRM-4, and municipal well Seminole 10 are shown in figure 19, and in water from the Cedar River, observation well CRM-3, and municipal water-treatment plant are shown in figure 20.

Dissolved-oxygen concentrations in water from the Cedar River shows seasonal trends (fig. 19). During the colder winter months, the concentration of dissolved oxygen is about 14 to 15 mg/L. During the summer months, dissolved-oxygen concentrations average 7 to 9 mg/L (table 28). Colder water can hold more dissolved oxygen than warmer water. Diurnal fluctuations were present throughout the study and probably result from biological activity. Dissolved-oxygen concentrations in water from observation well

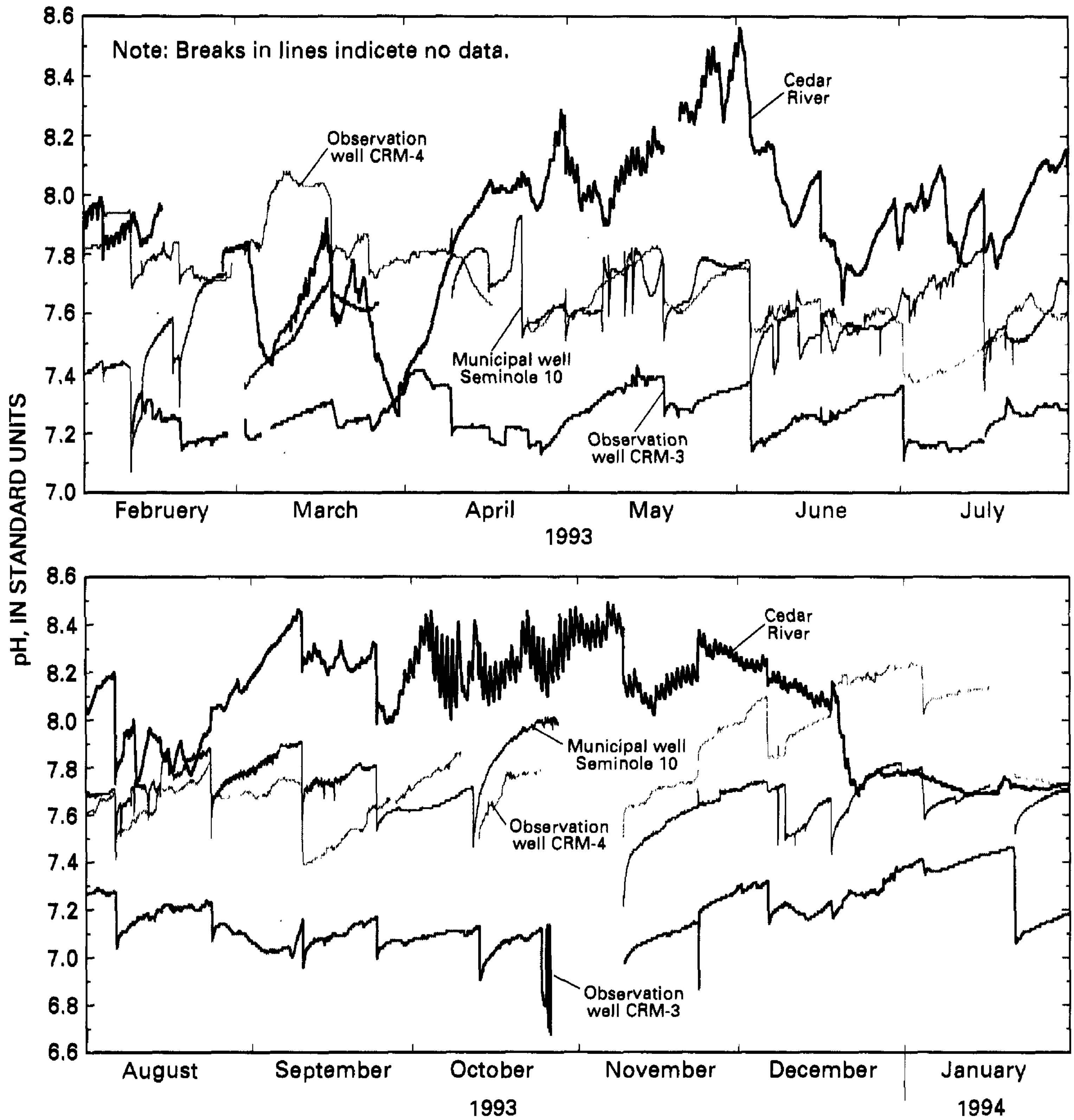


Figure 16. pH of water from the Cedar River, observation wells CRM-3 and CRM-4, and Cedar Rapids municipal well Seminole 10, February 1, 1993, through January 31, 1994.

CRM-4 and CRM-3 and municipal well Seminole 10 are dependent on the biological activity in the alluvial aquifer material and the movement of surface water through the material. The concentration of dissolved oxygen has been found to decrease abruptly in the first 50–65 ft of sediments as a result of mineralization of dissolved organic compounds by microorganisms (Bourg and Bertin, 1993). This could account for the observed decrease of about 2 to 4 mg/L in the dissolved-oxygen concentration between the river and observation well CRM-4 (fig. 19) throughout the study period.

On March 9, 1993, the decreasing concentration of dissolved oxygen in water from the river ceased and

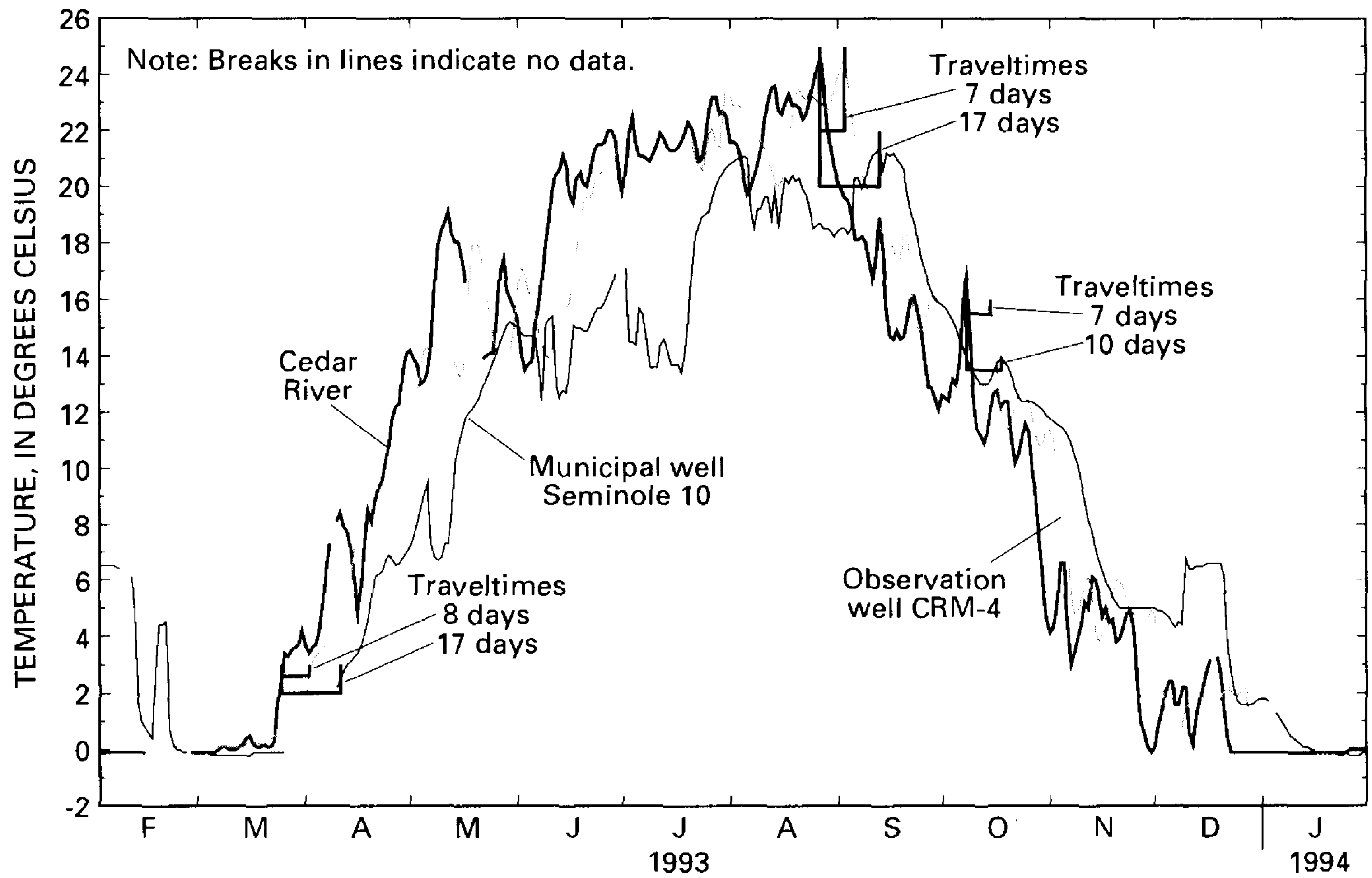


Figure 17. Temperature of water from the Cedar River, observation well CRM-4, and Cedar Rapids municipal well Seminole 10, and estimated traveltimes of water from the river to observation well CRM-4 and municipal well Seminole 10, February 1, 1993, through January 31, 1994.

started to increase. This change was observed on March 15, 1993, for observation well CRM-4 and on March 17 for municipal well Seminole 10 (fig. 19). Traveltimes based on these changes were 6 and 8 days, respectively. On November 1, 1993, the river concentration of dissolved oxygen stopped increasing. This change was observed on November 6, 1993, at well CRM-4 and on November 8, 1993, at well Seminole 10, indicating ground-water traveltimes of 5 and 7 days, respectively.

The concentrations of dissolved oxygen in water from observation well CRM-3 (fig. 20) showed very little change compared with well CRM-4. This could be due to ground water of low concentrations of dissolved oxygen seeping up from a deeper aquifer. No traveltimes based on dissolved oxygen could be determined between the river and well CRM-3.

Dissolved-oxygen concentrations in water from the water-treatment plant show only small changes (fig. 20). There are three peaks shown on the graph (fig. 20) for the water-treatment plant on May 10, June 23, and November 14, 1993, which could be a result of changes in the river on April 17, May 26, and November 1, 1993, respectively. These changes indicate traveltimes from the river to the water-treatment plant of 23, 28, and 13 days, respectively. The larger concentrations between July 17 and August 5, 1993, could be the result of algal growths in the pipe of the aeration tower in which the multiprobe was placed.

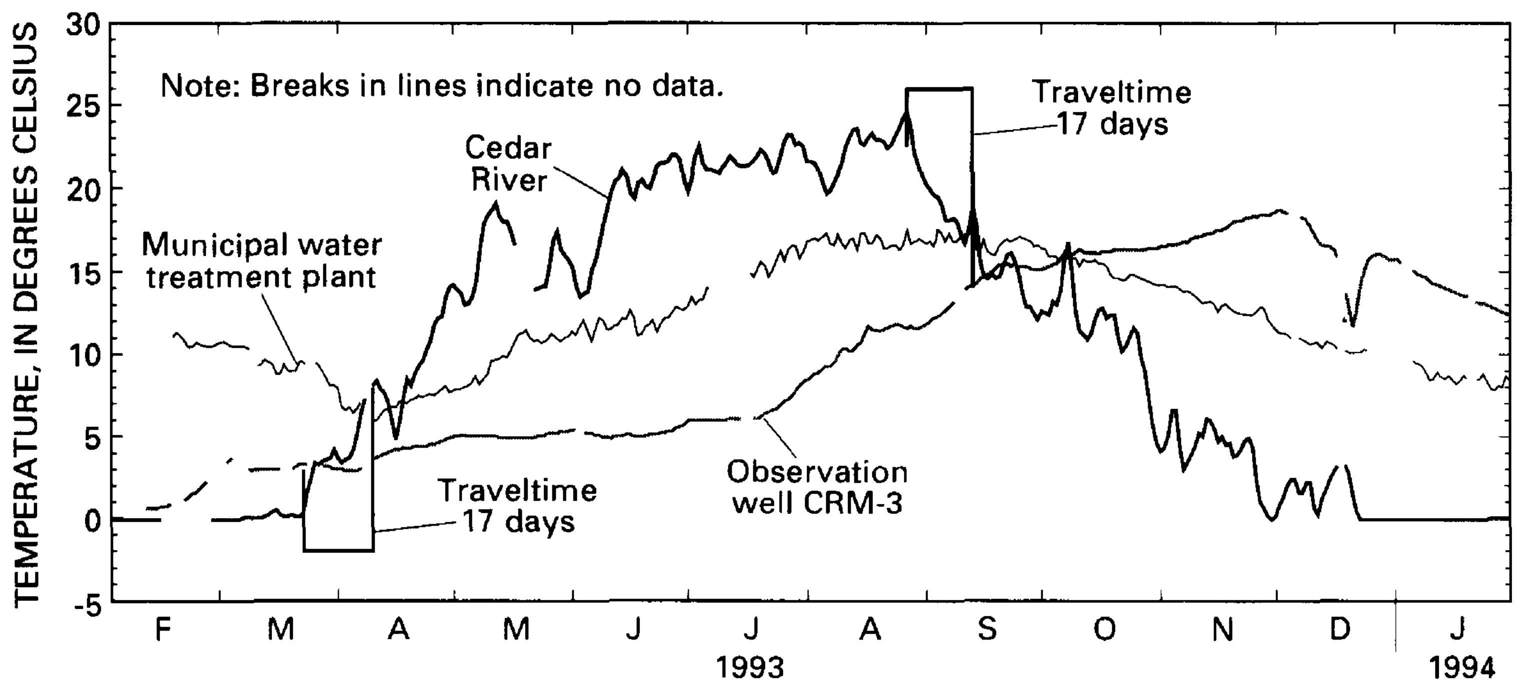


Figure 18. Temperature of water from the Cedar River, observation well CRM-3, and the municipal water-treatment plant, and estimated traveltimes of water from the river to observation well CRM-3, February 1, 1993, through January 31, 1994.

ASSESSMENT OF RELATIVE RISK OF ALLUVIAL AQUIFER TO CONTAMINATION BY PATHOGENS

The above-normal streamflow and precipitation during the study increased the effect of the Cedar River on the alluvial ground-water system and the potential for contamination by a pathogen. The increase in runoff could increase the amount of animal wastes reaching streams that could contribute to increased numbers of biogenic pathogens in the surface water. Several municipal wells were inundated for considerable periods of time during this study. With wells inundated, there could be a shorter path—from the ground surface down to the well screen—for biogenic pathogens to travel. However, several of the wells are completed through a silty clay and clay layer in the East Well Field (fig. 3) and a fine sandy silt layer in Seminole Well Field (fig. 5). These layers of relatively low hydraulic conductivity could help in restricting the movement of biogenic pathogens through the aquifer to the well.

The dissolved-oxygen data indicate that anaerobic conditions were not present in the alluvial aquifer in the vicinity of observation well CRM-4 and municipal well Seminole 10. This lack of anaerobic conditions could allow a very active microbiological community to develop that could aid in the natural filtration process that occurs in the alluvial aquifer. Investigators are finding that microbial activity and diversity are much greater than once thought in aquifers and that lake bottoms, streambeds, and soil zones are similar to the biologically active surface layer, known as the schmutzdecke, in slow, sand-filter systems (Boria and others, 1992). This layer is thought to allow perdition to occur as part of the filtering process (Boria and others, 1992). The filtration process itself is complex and involves a combination of straining, interception, sedimentation, Brownian diffusion, hydrodynamic retardation, and surface-interaction forces (Boria and others, 1992). Ground-water supplies in porous-media (sand and gravel) aquifers that induce recharge from surface water through pumping generally can be considered low-risk situations for *Giardia* contamination (Boria and others, 1992).

Data from MPA were used to determine the relative risk factor of water from the municipal wells tested and the raw water prior to treatment at the municipal water-treatment plant. This is done by determining the numerical range of each of the bio-

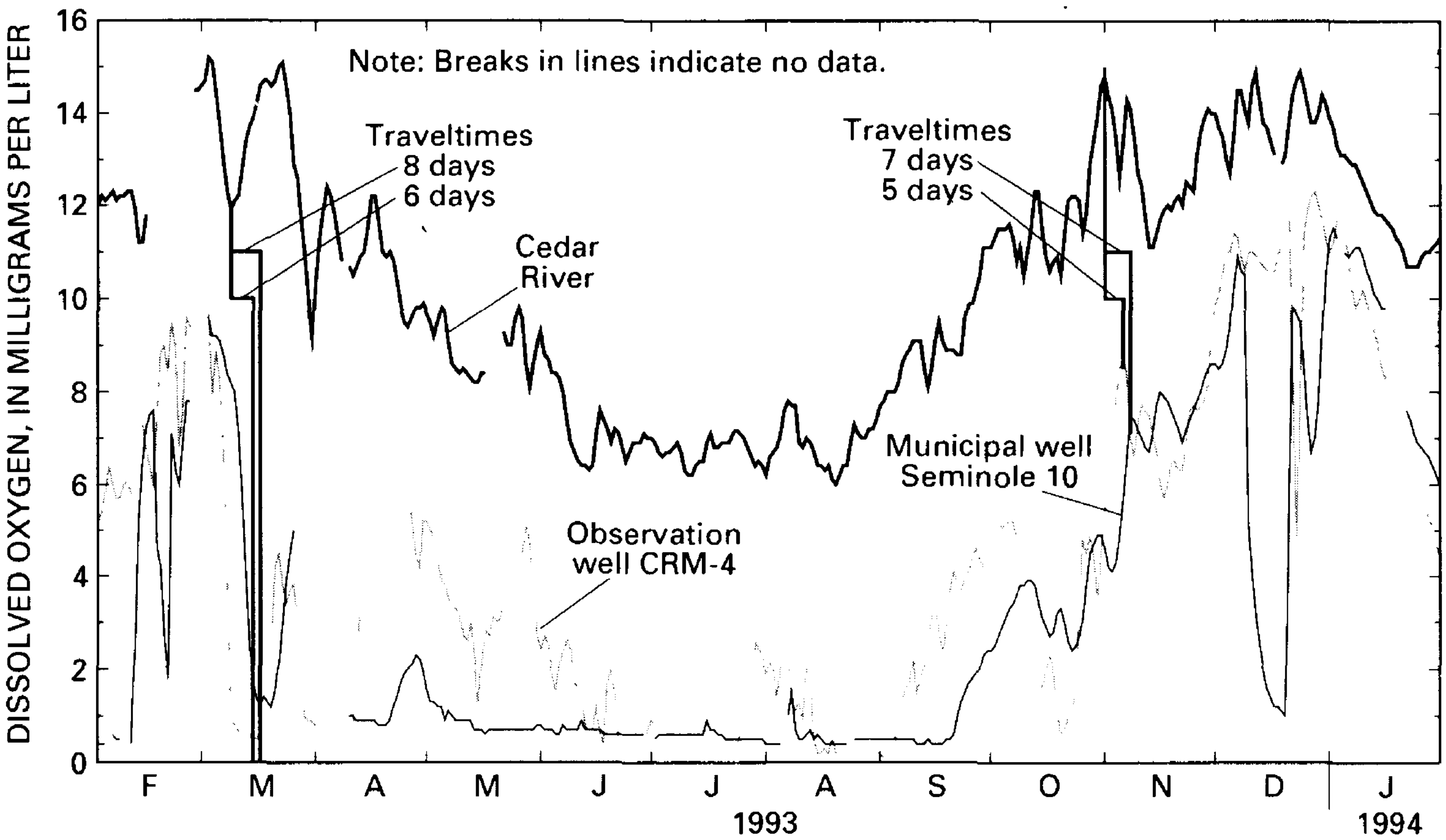


Figure 19. Concentrations of dissolved oxygen in water from the Cedar River, observation well CRM-4, and Cedar Rapids municipal well Seminole 10, and estimated traveltimes for water from the river to observation well CRM-4 and municipal well Seminole 10, February 1, 1993, through January 31, 1994.

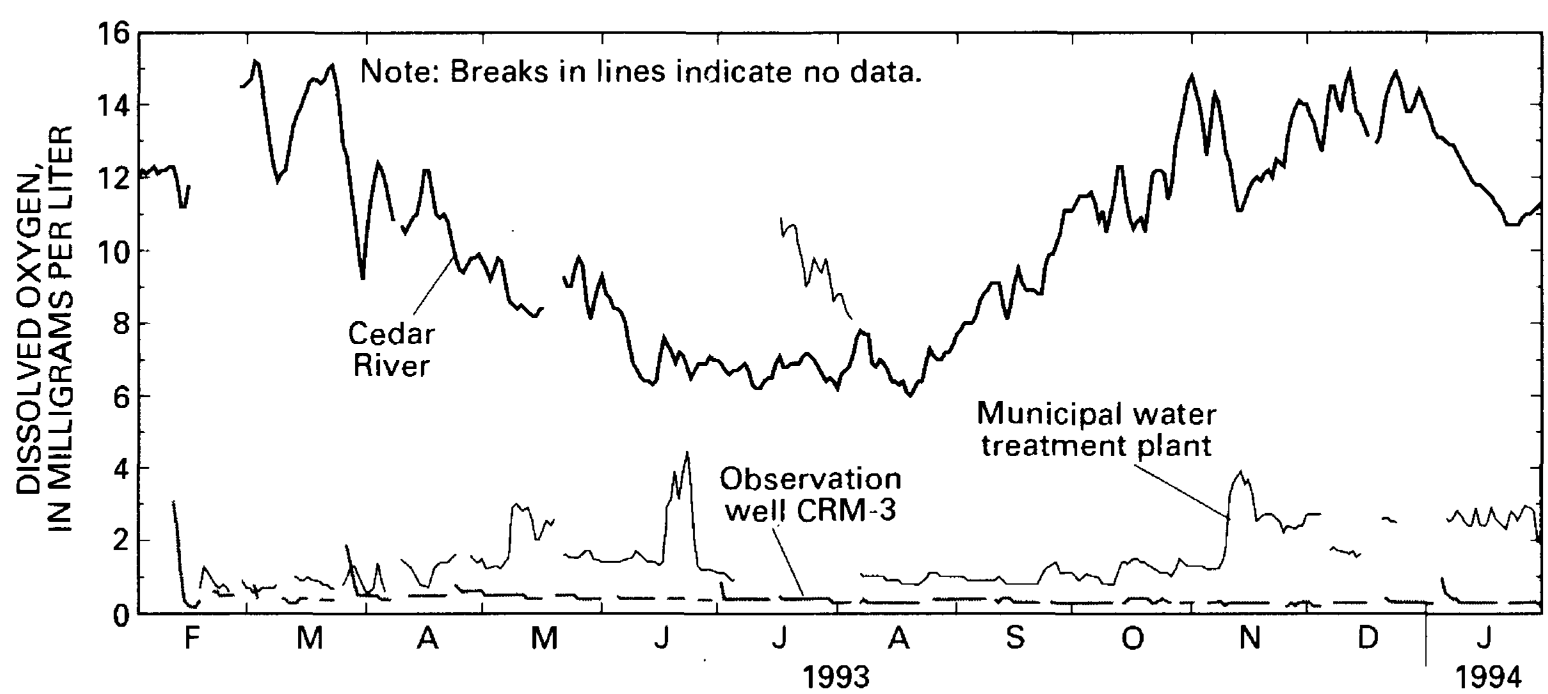


Figure 20. Concentrations of dissolved oxygen in water from the Cedar River, observation well CRM-3, and the Cedar Rapids municipal water-treatment plant, February 1, 1993, through January 31, 1994.

Table 6. Risk of surface-water contamination as determined by microscopic particulate analysis of water in the study area, December 1992 through November 1993

[Information provided by Tom Noth of the Cedar Rapids Municipal Water Department]

Municipal wells or sampling site (figs. 6 and 7)	Date (month-day-year)	Risk factor	Risk of surface-water contamination
Cedar River	12-07-92	77	High risk
	04-06-93	57	High risk
	04-13-93	37	High risk
	04-26-93	37	High risk
	08-02-93	18	Moderate risk
	11-16-93	74	High risk
Cedar Rapids municipal water-treatment plant	04-06-93	21	High risk
	04-07-93	21	High risk
	04-08-93	15	Moderate risk
	04-26-93	17	Moderate risk
Cedar Rapids municipal wells			
East 1	04-14-93	4	Low risk
East 19	04-26-93	5	Low risk
West 6	04-15-93	4	Low risk
	04-26-93	4	Low risk
Seminole 2	04-15-93	4	Low risk
Seminole 3	04-15-93	21	High risk
	09-22-93	10	Moderate risk
	11-16-93	9	Low risk
Seminole 10	12-08-92	0	Low risk
	04-13-93	10	Moderate risk
	09-22-93	2	Low risk
	11-16-93	10	Moderate risk
Seminole 14	04-06-93	14	Moderate risk
	08-02-93	9	Low risk
	11-16-93	4	Low risk
Seminole 16	04-06-93	14	Moderate risk
	04-07-93	14	Moderate risk
	08-02-93	9	Low risk
	11-16-93	4	Low risk

indicators tabulated in table 33 for a particular sample from tables 3 and 4. A rating of extremely heavy (EH), heavy (H), moderate (M), rare (R), or not significant (NS) is assigned to each bio-indicator of the sample. A numerical value then is assigned from table 34 for each bio-indicator according to its rating, and a sum is determined for the numerical values. A relative risk factor is determined from the scale at the bottom of table 34. A detailed explanation of the procedure is described in U.S. Environmental Protection Agency (1989).

Following this procedure, the river was evaluated to be at high risk (table 6) for the period of study due to the presence of *Giardia* cysts and *Cryptosporidium* oocysts and large counts of algae, diatoms, and rotifers (table 3 and 4). Of the eight municipal wells tested during the April 1993 flooding, municipal well Seminole 3 had a high-risk factor, three other wells had a moderate-risk factor, and four wells had a low-risk factor (table 6). Five of the eight wells were inundated during this time (table 4), one at high risk, two at moderate risk, and two at low risk. For the remainder of the study period two wells had a moderate-risk factor at different times, and the rest of the wells sampled had a low-risk factor.

To measure the efficiency of the filtering process of the alluvial aquifer a log-reduction rate is used (Clancy, 1992). Using the particulate concentrations in table 4 for the wells and the river at concurrent times, a log-reduction rate can be calculated (table 7). The log-reduction rate is calculated for an indicator by taking the log of the number of counts for the surface-water source (surface water) minus the log of the number of counts for the well. The log-reduction rate was calculated for vegetative debris, diatoms, and algae. Indicators that were not detected in both ground water and surface water were not used. If a ground-water sample had no detection for one of the indicators tested, a value of 1 was assumed to calculate the log-reduction rate.

The data for selected municipal wells tested show at least a three-log (99.9-percent) reduction between the river and the wells (table 7). A three-log (99.9-percent) reduction of algae is likely to achieve a three-log (99.9-percent) reduction in *Giardia* cysts (Boria and others, 1992). The log reduction for algae for municipal well Seminole 3 was 4.3 when it received its high-risk rating on April 15, 1993. To date (1994), there has been no record of an outbreak of waterborne disease in the City of Cedar Rapids (John North, City of Cedar Rapids Water Department, oral commun., 1994). A three-log (99.9-percent) reduction is required by the USEPA and the Iowa Department of Natural Resources for filtration and disinfection (U.S. Environmental Protection Agency, 1989; Iowa Administrative Code, 1992). The log-reduction data obtained in this study show that the natural filtration of the alluvial aquifer is very effective.

The presence of algae in some of the wells could indicate an inadequate surface seal around the casing. Another possibility could be macropores caused by tree roots, which could enhance vertical seepage to the aquifer from flooded areas. Municipal wells Seminole 14 and 16 are near heavily wooded areas. The count of algae detected at the water-treatment plant in April 1993 was higher than at all of the eight wells sampled during April 1993 (table 3). Some of the wells tested had counts of less than 20 per 100 gal. Because the water sampled at the water-treatment plant is a mixture of water from many wells, the count of algae might be expected to be lower than the results from most individual wells, but this is not the case. Algae growing inside the pipe of the aeration tower, where the sample was collected, could be one explanation. The log reduction for the municipal water-treatment plant compared to the river water was less than three for 3 of 4 samples of algae and 2 of 4 samples of vegetative debris.

Counts of protozoa in samples are similar to those for algae. Large counts are found in the river with smaller counts for the wells and water-treatment plant. Larger counts were measured during the flooding in March of 1993 than at other times of the year.

SUMMARY

Alluvial aquifers adjacent to large streams are important sources of water for many municipalities. Alluvial aquifers can have large transmissivities and hydraulic conductivities, which make them very desirable for water supply because large amounts of water can be withdrawn. The Surface Water Treatment Rule under the 1986 Amendment to the Clean Water Act requires that public-water supplies be evaluated for susceptibility to surface-water effects (U.S. Environmental Protection Agency, 1989). The ground-water source is evaluated for biogenic material and monitored for selected water-quality properties and constituents to determine the effect of surface water on the water supply.

Table 7. Filtration efficiency calculated as a log-reduction rate between the Cedar River and selected municipal wells and the Cedar Rapids municipal water-treatment plant, December 1992 through November 1993

[Values are counts per 100 gallons of water; log-reduction rate is the log of the value for ground water minus the log of the value for surface water; SW, surface water; GW, ground water; ND, not detected]

Municipal well or water-treatment plant (figs. 6 and 7)	Date (month-day-year)	Vegetative debris		Log-reduction rate	Diatoms		Log-reduction rate	Algae		Log reduction rate
		SW	GW		SW	GW		SW	GW	
Seminole 2	04-15-93	$1.0x10^3$	ND	3.0	$5.1x10^5$	ND	5.7	$3.4x10^7$	8	6.6
Seminole 3	04-15-93	$1.0x10^3$	ND	3.0	$5.1x10^5$	8	4.8	$3.4x10^7$	$1.9x10^3$	4.3
	11-16-93	ND	ND		$3.3x10^3$	ND	3.5	$6.0x10^7$	35	6.2
Seminole 10	12-07-92	$1.0x10^3$	1	3.0	$1.2x10^4$	ND	4.0	$7.4x10^6$	8	6.0
	04-13-93	$1.0x10^3$	ND	3.0	$5.1x10^5$	2	5.4	$3.4x10^7$	9	6.6
	11-16-93	ND	ND		$3.3x10^3$	ND	3.5	$6.0x10^7$	25	6.4
Seminole14	04-06-93	$1.1x10^3$	ND	3.0	$5.7x10^5$	ND	5.8	$1.8x10^7$	$4.0x10^3$	3.7
	08-02-93	ND	ND		ND	ND		$2.3x10^5$	34	3.8
	11-16-93	ND	ND		$3.3x10^3$	ND	3.5	$6.0x10^7$	2	7.5
Seminole 16	04-06-93	$1.1x10^3$	ND	3.0	$5.7x10^5$	ND	5.8	$1.8x10^7$	$3.7x10^3$	3.7
	04-07-93	$1.1x10^3$	ND	3.0	$5.7x10^5$	ND	5.8	$1.8x10^7$	$1.6x10^4$	3.1
	08-02-93	ND	ND		ND	ND		$2.3x10^5$	47	3.7
	11-16-93	ND	ND		ND	ND	3.5	$6.0x10^7$	2	7.5
Water-treatment plant	04-06-93	$1.1x10^3$	2	2.7	$5.7x10^5$	1	5.8	$1.8x10^7$	$7.9x10^4$	2.4
	04-07-93	$1.1x10^3$	ND	3.0	$5.7x10^5$	1	5.8	$1.8x10^7$	$1.9x10^4$	3.0
	04-08-93	$1.1x10^3$	ND	3.0	$5.7x10^5$	ND	5.8	$1.8x10^7$	$2.7x10^4$	2.8
	04-26-93	$1.0x10^3$	4	2.4	$2.7x10^3$	ND	3.4	$1.6x10^7$	$2.7x10^4$	2.8

The City of Cedar Rapids uses the alluvial aquifer adjacent to the Cedar River for its drinking-water supply. The alluvial aquifer is hydraulically connected to the Cedar River, bedrock, and upland areas in the study area. The city has three well fields in use along the Cedar River (figs. 6 and 7) with a total of 53 municipal wells (table 2). The three well fields all have a similar lithologic sequence and hydraulic properties. A multiprobe instrument was used to continuously monitor water levels and selected water-quality properties and constituents in the Cedar River, observation wells CRM-3 and CRM-4, municipal well Seminole 10 (fig. 9), and selected water-quality properties and constituents at the municipal water-treatment plant (fig. 6).

Selected water-quality properties and constituents of the river changed inversely with changes in river stage or discharge (Schulmeyer, 1991). Selected water-quality properties and constituents of the alluvial aquifer changed as water flowed from the Cedar River to municipal well Seminole 10 as a result of drawdown. The values of specific conductance, pH, temperature, and dissolved oxygen for observation well CRM-4 and municipal well Seminole 10 generally follow the trends of values for the Cedar River. Values of specific conductance, pH, temperature, and dissolved oxygen at observation well CRM-3 and the municipal water-treatment plant show very little correlation with values for the Cedar River. The traveltime of water through the aquifer could be an indication of the susceptibility of the aquifer to surface-water effects. Estimated traveltimes from Cedar River to municipal well Seminole 10 ranged from 7 to 17 days. The data indicate that ground water has a short residence time in the aquifer before it is pumped out for consumption. Traveltimes were not long enough to have a substantial effect on the viability of *Giardia* cysts.

The above-normal conditions of streamflow and precipitation present during the study could have increased the effect that the Cedar River had on the alluvial aquifer and the possibility of contamination by a pathogen. The dissolved-oxygen data indicate that anaerobic conditions are not present in the alluvial aquifer in the vicinity of observation well CRM-4 and municipal well Seminole 10. This lack of anaerobic conditions could allow a very active microbiological community to develop, which could aid in the natural filtration process that occurs in the alluvial aquifer. Microscopic particulate data were collected using the method outlined by the USEPA to determine if a ground-water source is GWUDI according to the SWTR (Vasconcelos and Harris, 1992). Analysis of 29 samples found no *Giardia* cysts or *Crytosporidium* oocysts in water collected from municipal wells and the municipal water-treatment plant.

Data from the MPA were used to determine the relative risk factor of the ground-water source and the log-reduction rate, a measure of the efficiency of the filtering process of the alluvial aquifer. Using MPA data it was determined that, of the eight municipal wells tested during the April 1993 flooding, one municipal well, Seminole 3, had a high-risk factor, three other wells had a moderate-risk factor, and four wells had a low-risk factor. Data indicate that the aquifer is filtering out large numbers of algae, diatoms, rotifers, and nematodes as well as filtering out *Cryptosporidium*, *Giardia* and other protozoa. The filtering efficiency of the aquifer is equivalent to a 3 log-reduction rate or 99.99-percent reduction in particulates.

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Table 8. Mean daily water levels in the Cedar River at the surface-water monitoring site, February 1, 1993, through January 31, 1994

[Water levels given in feet above sea level; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	717.07	716.35	725.25	719.90	717.93	720.60	721.79	721.57	717.26	717.28	718.56	718.34
2	717.20	716.09	727.56	719.65	718.08	720.46	720.86	721.33	717.48	717.19	717.32	718.84
3	717.18	717.97	730.14	720.19	718.70	720.49	720.36	721.40	717.16	716.86	716.97	718.80
4	717.32	720.74	730.49	719.93	719.25	721.08	720.69	720.99	717.00	716.53	716.64	718.80
5	717.22	721.44	729.35	720.52	719.74	723.01	720.82	720.60	717.24	716.83	716.50	718.56
6	717.04	721.52	727.28	720.88	719.92	722.40	720.97	720.04	717.00	717.15	716.80	718.38
7	716.78	722.06	724.74	721.78	719.94	721.02	720.41	719.48	716.78	717.05	716.82	718.51
8	716.95	723.01	722.90	722.21	720.14	720.69	719.43	718.88	716.56	717.20	716.80	718.45
9	716.88	722.24	---	722.12	720.89	723.05	719.02	718.32	717.12	717.34	716.42	718.43
10	717.23	721.02	721.75	721.74	721.66	724.90	722.40	718.47	717.85	717.24	716.58	718.15
11	717.78	720.87	721.52	721.36	722.65	726.42	720.72	718.15	717.84	716.94	717.05	718.33
12	717.19	719.41	721.90	720.73	723.49	727.14	719.45	717.58	717.59	716.79	716.54	718.05
13	717.06	717.72	721.83	720.67	723.33	725.55	719.59	717.59	717.57	716.59	716.42	717.94
14	717.16	717.64	721.40	720.58	722.81	724.88	720.33	718.06	717.38	716.88	716.52	718.05
15	---	717.02	720.76	720.91	722.16	725.33	721.53	718.76	717.17	717.24	716.68	718.15
16	---	716.76	720.81	720.89	721.28	725.33	721.90	718.79	717.03	717.26	716.90	717.67
17	---	718.26	721.22	720.30	720.86	725.08	722.64	718.77	717.02	717.23	716.78	717.65
18	---	718.70	721.17	---	720.98	727.09	722.10	719.05	717.19	717.02	---	717.84
19	---	718.17	721.16	---	721.36	725.88	723.75	719.05	717.21	716.81	716.71	717.74
20	---	717.87	722.61	---	722.73	724.44	726.00	718.66	717.00	716.97	716.67	717.95
21	---	717.68	722.88	---	722.44	724.35	727.02	718.74	717.16	716.88	716.52	717.67
22	---	717.85	722.34	718.23	723.22	724.51	725.74	718.58	717.34	717.10	716.65	717.44
23	---	718.65	722.21	717.84	724.13	723.76	724.63	718.60	717.10	716.92	717.89	717.26
24	---	717.63	723.21	717.97	724.66	722.59	724.05	718.22	716.82	717.10	718.74	717.28
25	---	718.85	724.85	718.15	724.35	721.26	723.51	717.97	716.74	717.14	718.10	717.29
26	---	719.79	724.61	717.96	722.98	720.39	723.17	718.49	716.83	717.03	717.90	717.35
27	716.65	720.22	722.94	717.71	721.42	719.73	723.41	718.57	716.69	716.79	718.32	716.92
28	716.55	720.68	721.79	718.00	720.40	720.13	722.50	718.44	716.26	716.79	718.53	716.95
29	---	721.41	720.84	718.36	719.74	720.72	722.13	718.33	717.04	717.07	718.44	717.20
30	---	722.41	720.25	717.94	720.38	720.68	721.47	717.69	717.23	717.88	718.54	717.67
31	---	723.70	---	718.03	---	720.69	721.65	---	717.23	---	718.35	717.55
Mean	717.08	719.47	723.44	719.80	721.39	723.02	722.07	718.97	717.13	717.04	717.26	717.91
Maximum	717.78	723.70	730.49	722.21	724.66	727.14	727.02	721.57	717.85	717.88	718.74	718.84
Minimum	716.55	716.09	720.25	717.71	717.93	719.73	719.02	717.58	716.26	716.53	716.42	716.92

Table 9. Mean daily water levels in observation well CRM-4, February 1, 1993, through January 31, 1994
[Water levels given in feet above sea level; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	717.33	---	---	718.26	716.40	---	---	---	716.38	716.49	715.99	715.51
2	717.45	---	---	717.98	716.47	---	---	---	716.57	716.39	715.05	715.99
3	717.44	---	---	718.42	717.13	---	719.42	---	716.22	716.08	714.71	716.04
4	717.55	---	---	718.16	717.67	---	719.69	---	716.05	715.56	714.34	---
5	717.43	---	---	718.70	718.19	---	---	---	716.24	715.60	714.10	715.97
6	717.26	---	---	719.03	718.44	---	---	719.32	715.97	715.88	714.37	715.77
7	717.00	---	---	---	---	---	---	718.84	715.76	715.74	714.38	715.99
8	717.17	---	---	---	---	---	---	718.42	715.55	715.90	714.60	715.78
9	---	---	---	---	719.16	---	---	717.80	716.06	715.68	714.31	715.73
10	---	---	---	---	---	---	---	717.84	---	715.23	715.97	715.43
11	---	---	---	---	---	---	---	717.44	---	714.94	716.41	715.63
12	---	---	---	---	---	---	---	716.82	---	714.77	715.90	715.35
13	---	---	---	---	---	---	---	716.77	---	714.38	715.80	715.24
14	---	---	---	719.22	---	---	---	717.39	716.48	714.70	715.90	715.38
15	---	---	719.10	719.53	---	---	---	717.86	716.27	715.04	716.06	715.54
16	---	---	719.13	719.51	---	---	---	717.94	716.09	715.09	716.27	715.00
17	---	---	---	718.89	---	---	---	717.90	716.07	715.32	716.17	715.01
18	---	---	---	718.16	---	---	---	718.12	716.21	715.14	716.11	---
19	---	---	---	717.71	---	---	---	718.13	716.23	714.87	716.11	---
20	---	---	---	717.30	---	---	---	717.73	716.03	714.97	716.05	---
21	---	---	---	717.01	---	---	---	717.52	716.16	714.73	714.63	---
22	---	---	---	716.70	---	---	---	717.13	716.19	714.95	713.90	714.41
23	---	---	---	716.29	---	---	---	717.14	715.87	714.76	714.75	714.19
24	---	---	---	716.42	---	---	---	716.97	715.60	714.94	715.73	714.30
25	---	---	---	716.62	---	---	---	716.80	715.51	714.94	715.41	714.38
26	---	717.14	---	716.44	---	---	---	717.24	715.66	714.81	715.17	714.36
27	---	717.53	---	716.22	---	719.15	---	717.30	715.76	714.54	715.66	713.92
28	---	718.03	---	716.49	---	719.37	---	717.19	715.66	714.53	715.82	713.92
29	---	718.80	---	716.82	719.22	---	---	717.14	716.36	714.78	715.70	714.17
30	---	---	718.73	716.39	---	---	---	716.56	716.49	715.40	715.76	714.60
31	---	---	---	716.48	---	---	---	---	716.47	---	715.55	714.59
Mean	717.33	717.87	718.99	717.61	717.83	719.26	719.55	717.57	716.07	715.20	715.38	715.08
Maximum	717.55	718.80	719.13	719.53	719.22	719.37	719.69	719.32	716.57	716.49	716.41	716.04
Minimum	717.00	717.14	718.73	716.22	716.40	719.15	719.42	716.56	715.51	714.38	713.90	713.92

Table 10. Mean daily water levels in municipal well Seminole 10, February 1, 1993, through January 31, 1994

[Water levels given in feet above sea level; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	---	---	702.35	704.16	---	710.31	711.40	705.74	704.37	704.05	701.27
2	---	---	---	702.12	704.08	710.06	709.57	711.13	705.90	704.36	703.22	701.80
3	---	698.43	---	702.49	704.90	719.49	709.17	711.15	705.51	704.03	702.95	702.17
4	---	700.82	---	702.31	705.43	720.03	709.37	710.61	705.35	703.57	702.42	---
5	---	701.79	---	702.83	706.23	722.03	709.47	710.29	705.62	703.70	702.21	702.11
6	---	701.89	---	703.13	706.69	721.41	709.53	708.66	705.19	703.80	702.53	701.86
7	---	702.13	---	718.19	711.52	720.02	715.74	708.55	704.88	703.55	702.67	702.63
8	---	702.70	---	722.10	716.53	719.71	720.12	708.86	704.74	703.73	704.36	701.27
9	---	702.85	---	722.05	704.85	721.96	713.71	708.30	705.25	703.82	704.69	701.14
10	715.73	703.05	703.55	721.74	705.62	723.89	716.20	708.24	705.77	703.65	715.52	700.87
11	709.21	702.90	703.33	721.29	706.41	725.38	711.45	707.84	705.89	703.46	716.01	701.35
12	699.76	701.67	703.82	718.18	717.59	726.11	712.82	707.19	705.78	703.23	715.45	701.14
13	699.41	700.27	703.98	714.06	723.01	724.49	716.85	706.87	705.87	702.57	715.34	701.09
14	699.46	699.81	703.66	705.59	722.29	723.87	711.73	708.99	705.63	702.54	715.42	701.48
15	699.39	699.06	703.19	705.76	721.51	724.31	721.69	708.43	705.34	702.89	715.66	702.02
16	699.18	698.68	703.26	705.87	712.83	724.27	715.55	709.19	705.06	703.24	715.87	701.18
17	709.77	699.49	703.74	705.68	706.72	724.02	711.19	708.97	705.05	703.72	715.78	---
18	714.80	699.93	703.66	705.32	708.41	726.02	711.13	709.16	705.13	703.57	715.75	---
19	714.23	699.36	703.82	705.09	708.54	724.81	712.67	709.15	705.20	703.09	715.82	---
20	714.11	699.03	703.85	704.73	709.52	717.80	715.14	708.82	704.94	703.20	715.79	---
21	696.82	698.82	703.74	704.49	709.38	713.79	715.65	707.70	705.10	703.04	706.36	---
22	697.00	699.04	703.76	703.95	710.14	712.27	714.68	706.43	705.09	703.56	700.57	698.94
23	697.61	699.78	703.29	703.49	710.89	711.73	713.75	706.45	704.80	703.35	701.39	698.63
24	697.64	699.04	704.27	703.93	711.42	710.47	713.38	705.72	704.63	703.56	702.40	699.29
25	697.31	699.74	705.72	704.16	711.16	709.43	713.06	705.23	704.55	703.33	700.87	699.96
26	697.52	698.72	705.77	704.02	709.97	708.83	712.71	705.76	704.61	703.20	700.71	699.37
27	---	---	704.38	703.88	708.81	708.46	712.97	705.78	704.54	703.02	702.16	698.96
28	---	---	703.77	704.04	707.97	709.04	712.17	705.48	703.90	702.97	702.28	698.87
29	---	---	703.08	704.24	707.32	709.70	711.83	705.45	704.26	703.15	702.09	699.17
30	---	---	702.67	703.84	---	709.47	711.13	705.44	704.33	703.61	701.95	699.57
31	---	---	---	704.08	---	709.28	711.32	---	704.32	---	701.33	700.02
Mean	703.47	700.37	703.82	707.58	710.13	717.74	713.10	708.04	705.10	703.43	707.21	700.65
Maximum	715.73	703.05	705.77	722.10	723.01	726.11	721.69	711.40	705.90	704.37	716.01	702.63
Minimum	696.82	698.43	702.67	702.12	704.08	708.46	709.17	705.23	703.90	702.54	700.57	698.63

Table 11. Mean daily water levels in observation well CRM-3, February 1, 1993, through January 31, 1994

[Water levels given in feet above sea level; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	---	724.21	719.11	717.33	720.35	721.16	721.06	716.55	715.58	715.74	715.82
2	---	---	726.68	718.80	717.37	720.17	720.37	720.80	716.76	715.50	715.00	716.26
3	---	715.38	729.22	719.21	717.90	720.33	719.93	720.87	716.34	715.22	714.62	716.32
4	---	718.27	729.55	718.95	718.37	720.90	720.16	720.47	716.15	714.59	714.26	---
5	---	---	728.48	719.52	718.85	722.88	720.24	720.17	716.31	715.12	714.02	716.28
6	---	---	726.49	719.86	719.10	722.36	720.30	719.59	716.06	715.41	714.24	716.09
7	---	---	723.94	721.72	719.51	721.03	720.40	719.07	715.86	715.30	714.18	716.26
8	---	721.00	722.02	722.62	720.17	720.66	720.12	718.61	715.64	715.43	714.35	716.12
9	---	720.49	---	722.61	719.94	722.79	719.15	717.95	716.10	715.45	714.00	716.05
10	716.51	719.39	720.88	722.26	720.82	724.70	721.94	717.84	716.80	715.19	715.19	715.78
11	716.33	719.49	720.59	721.85	721.88	726.24	720.35	717.33	716.91	714.83	715.64	715.91
12	715.07	718.30	721.00	721.15	723.71	727.00	719.49	716.74	716.81	714.68	715.15	715.66
13	714.93	716.72	720.96	720.73	724.03	725.39	719.84	716.73	716.68	714.38	715.03	715.56
14	714.99	716.19	720.51	719.92	723.53	724.68	719.82	717.27	716.27	714.66	715.15	715.67
15	714.89	715.47	719.94	720.22	722.94	725.18	721.59	717.73	716.08	715.03	715.31	715.82
16	714.75	715.20	719.98	720.21	721.44	---	721.55	717.78	715.90	715.08	715.50	715.33
17	715.72	716.28	720.31	719.61	720.49	724.81	721.97	717.72	715.88	715.14	715.43	715.33
18	716.18	---	720.24	719.01	720.63	726.86	721.48	717.91	715.99	714.80	---	715.45
19	716.15	---	720.27	718.74	720.97	725.66	723.08	717.93	716.02	714.49	715.46	715.29
20	716.02	715.91	721.56	718.35	722.21	724.27	725.40	717.58	715.83	714.57	715.33	715.43
21	714.18	715.68	721.91	718.07	722.08	724.21	726.47	717.48	715.96	714.37	714.76	---
22	714.50	715.69	721.47	717.68	722.96	724.28	725.13	717.17	716.00	714.57	714.27	714.65
23	714.80	716.61	721.33	717.27	723.91	723.53	724.02	717.19	715.73	714.49	715.07	714.46
24	714.79	715.86	722.34	717.38	724.50	722.38	723.55	717.11	715.47	714.76	716.11	714.54
25	714.42	---	724.03	717.56	724.18	721.18	723.13	717.01	715.39	714.77	715.86	714.62
26	714.70	---	723.88	717.39	722.84	720.39	722.71	717.42	715.50	714.63	715.58	714.61
27	---	718.15	722.29	717.17	721.45	719.63	723.02	717.50	715.59	714.37	715.98	714.18
28	---	718.65	721.16	717.40	720.37	719.84	722.13	717.48	715.05	714.36	716.11	714.23
29	---	719.43	720.26	717.70	719.71	720.28	721.71	717.50	715.44	714.60	715.98	714.45
30	---	720.56	719.57	717.32	720.19	720.24	721.07	716.99	715.57	715.17	716.04	714.89
31	---	722.21	---	717.38	---	720.18	721.11	---	715.55	---	715.86	714.84
Mean	715.23	717.77	722.59	719.25	721.11	722.75	721.69	718.13	716.01	714.88	715.17	715.38
Maximum	716.51	722.21	729.55	722.62	724.50	727.00	726.47	721.06	716.91	715.58	716.11	716.32
Minimum	714.18	715.20	719.57	717.17	717.33	719.63	719.15	716.73	715.05	714.36	714.00	714.18

Table 12. Water-level measurements for observation wells CRM-3, CRM-4, and CRM-6, February 1993 through January 1994

[Water-level measurements, in feet above sea level, made using a steel tape and measured to 0.01 ft; ---, no data]

Date (month-day-year)	Observation well CRM-3		Observation well CRM-4		Observation well CRM-6	
	Time (24-hour)	Water level	Time (24-hour)	Water level	Time (24-hour	Water level
02-04-93	---	---	1510	717.46	---	---
02-09-93[1]	1350	717.49	1100	716.80	---	---
02-11-93	---	---	1455	716.11	---	---
02-18-93[1]	1425	716.36	1310	716.93	---	---
03-02-93	1510	714.73	1310	714.54	---	---
03-18-93	1255	716.43	1135	716.31	---	---
03-25-93	1145	717.35	0855	717.24	---	---
04-09-93	1530	722.14	1522	721.46	---	---
04-23-93	1415	722.30	1235	721.67	---	---
06-03-93	1350	718.53	1140	718.09	---	---
06-16-93	1220	721.33	1115	721.00	---	---
07-01-93	1310	720.98	1115	720.70	---	---
08-24-93	1135	724.47	0915	724.22	---	---
09-10-93	1120	718.80	0905	718.57	---	---
10-12-93	---	---	0850	717.19	---	---
10-13-93	1215	717.40	1015	716.95	---	---
10-28-93	1145	716.47	0955	716.04	---	---
11-04-93	1230	716.21	1200	715.86	0856	720.78
11-09-93	1235	716.00	1025	715.58	---	---
11-23-93	1130	715.59	0950	715.35	---	---
12-06-93	1305	715.17	1025	714.88	---	---
12-20-93[1]	1200	716.62	1100	717.12	0930	721.06
01-04-94	1145	717.06	1045	716.69	---	---
01-21-94	1400	715.26	1330	714.86	---	---
02-19-94	0830	715.60	0830	715.47	0830	719.92

[1] Municipal well Seminole 10 was not operating on this day.

Table 13. Mean daily specific conductance of water from the Cedar River, surface-water monitoring site, February 1, 1993, through January 31, 1994

[Specific conductance given in microsiemens per centimeter at 25 degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	640	636	251	467	555	434	397	433	565	541	576	628
2	631	627	237	468	555	438	436	440	565	543	578	632
3	635	408	229	432	533	411	454	473	562	547	583	627
4	625	237	237	452	506	409	445	487	554	554	586	620
5	594	223	262	452	508	380	434	502	536	559	589	610
6	595	238	310	450	516	411	437	521	525	562	588	600
7	596	260	368	408	521	464	480	535	517	563	582	600
8	595	274	414	411	491	477	518	541	507	567	582	604
9	592	281	---	433	454	358	527	544	499	565	580	609
10	571	283	434	446	416	273	348	540	479	562	576	616
11	500	280	446	456	389	249	408	535	482	561	571	615
12	553	290	455	465	405	262	488	539	505	561	572	607
13	576	369	458	462	430	314	481	540	514	560	573	603
14	583	406	464	450	460	331	411	523	519	559	570	604
15	---	437	472	448	478	342	379	502	525	553	567	604
16	---	486	471	459	483	367	391	503	533	554	573	603
17	---	454	468	471	482	392	370	517	538	556	572	606
18	---	403	471	---	481	355	404	500	542	561	---	611
19	---	---	462	---	442	372	337	473	543	562	567	614
20	---	366	437	---	388	388	286	486	550	563	561	614
21	---	433	446	---	402	380	314	499	549	563	554	616
22	---	443	447	549	385	396	365	512	545	563	556	609
23	---	343	436	553	376	424	384	526	540	569	568	603
24	---	401	400	557	387	466	397	544	536	575	589	597
25	---	323	380	559	415	500	421	549	527	574	600	593
26	---	285	408	563	461	519	401	528	523	573	609	591
27	636	283	451	560	497	526	408	529	527	572	612	590
28	638	261	479	553	518	496	452	539	526	569	619	591
29	---	238	496	537	530	458	450	556	532	569	619	591
30	---	227	487	545	460	462	454	563	536	575	625	585
31	---	240	---	550	---	476	435	---	539	---	626	586
Mean	597	348	406	487	464	404	417	516	530	562	584	606
Maximum	640	636	496	563	555	526	527	563	565	575	626	632
Minimum	500	223	229	408	376	249	286	433	479	541	554	585

Table 14. Mean daily specific conductance of water from observation well CRM-4, February 1, 1993, through January 31, 1994

[Specific conductance given in microsiemens per centimeter at 25 degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	581	---	332	453	530	511	443	444	524	546	560	626
2	581	---	312	469	532	523	466	447	524	543	557	631
3	585	644	300	480	538	---	414	449	537	541	558	632
4	594	645	287	485	546	---	405	445	549	543	563	---
5	604	624	283	477	548	---	439	437	554	544	566	630
6	612	464	283	460	536	---	439	436	556	544	554	634
7	618	330	285	472	516	---	435	457	556	549	548	634
8	623	291	293	474	507	---	436	477	550	556	552	628
9	---	275	---	476	510	---	437	496	538	558	555	616
10	625	272	294	479	516	---	429	513	---	558	556	608
11	628	279	321	477	493	---	430	525	---	558	555	607
12	628	286	388	476	470	---	480	530	---	560	557	609
13	618	292	450	476	467	---	490	532	---	562	557	613
14	582	303	478	479	462	---	379	532	485	563	557	619
15	539	314	488	475	458	518	373	532	481	565	557	623
16	560	330	488	478	450	510	387	533	493	566	557	618
17	574	363	---	471	421	504	431	536	512	566	557	614
18	584	415	---	482	406	503	432	525	523	565	565	---
19	593	446	---	505	445	503	388	508	531	560	571	---
20	590	479	---	516	478	493	361	504	539	561	571	---
21	596	497	---	526	478	442	387	508	545	562	570	---
22	611	469	---	534	471	438	387	502	549	565	571	624
23	627	408	---	539	439	429	345	480	551	566	576	627
24	655	391	467	542	413	390	315	495	556	568	575	628
25	658	418	466	544	411	392	323	513	553	567	568	628
26	654	452	453	543	403	409	355	531	546	567	570	623
27	651	415	426	543	395	453	380	541	540	565	576	617
28	---	415	404	543	404	493	394	538	546	565	590	612
29	---	381	417	546	439	502	415	526	550	566	604	609
30	---	351	438	545	486	478	412	524	549	565	611	608
31	---	342	---	542	---	447	410	---	550	---	619	606
Mean	607	400	380	500	472	470	407	501	537	559	568	620
Maximum	658	645	488	546	548	523	490	541	556	568	619	634
Minimum	539	272	283	453	395	390	315	436	481	541	548	606

Table 15. Mean daily specific conductance of water from municipal well Seminole 10, February 1, 1993, through January 31, 1994

[Specific conductance given in microsiemens per centimeter at 25 degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	538	---	---	386	550	---	447	432	537	537	574	575
2	539	---	---	381	550	418	453	428	535	536	573	583
3	539	636	---	388	547	461	461	427	534	535	573	593
4	541	635	---	402	546	460	470	429	536	534	572	---
5	542	634	---	416	544	464	475	428	541	533	571	617
6	542	634	---	430	541	443	459	415	548	532	562	623
7	541	635	---	414	533	447	440	417	553	531	556	628
8	---	626	---	404	522	467	431	422	556	530	557	632
9	---	596	---	395	541	473	438	425	557	527	558	636
10	575	571	287	393	538	470	442	416	555	525	553	638
11	587	520	288	405	531	466	447	413	549	528	552	640
12	608	445	290	405	515	468	436	419	535	533	550	640
13	627	383	299	422	517	468	437	425	526	534	550	637
14	634	348	321	448	517	465	434	433	520	537	548	633
15	635	325	355	453	522	458	427	436	512	542	547	628
16	630	310	390	453	521	468	429	446	501	546	547	625
17	615	305	423	451	516	478	431	459	493	548	547	---
18	609	306	450	478	509	476	431	468	492	550	546	---
19	610	313	470	505	500	480	428	477	498	551	546	---
20	609	326	487	505	488	458	427	485	506	551	546	---
21	627	349	495	505	473	438	425	495	515	551	551	---
22	600	381	500	507	454	435	426	496	522	551	558	586
23	590	417	506	510	449	441	426	491	530	562	566	585
24	595	453	510	514	449	449	444	510	535	570	570	585
25	606	469	508	522	454	455	459	517	539	570	571	585
26	619	463	499	531	459	456	456	515	542	572	571	587
27	---	---	492	538	460	453	451	518	544	574	572	589
28	---	---	486	545	453	446	449	525	546	575	572	591
29	---	---	477	547	443	439	444	534	546	574	571	592
30	---	---	429	550	---	439	441	538	544	574	570	592
31	---	---	---	550	---	443	438	---	540	---	571	591
Mean	590	462	427	463	505	456	442	461	532	547	560	608
Maximum	635	636	510	550	550	480	475	538	557	575	574	640
Minimum	538	305	287	381	443	418	425	413	492	525	546	575

Table 16. Mean daily specific conductance for water from observation well CRM-3, February 1, 1993, through January 31, 1994
[Specific conductance given in microsiemens per centimeter at 25 degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	---	513	462	474	441	579	647	585	523	548	592
2	---	---	513	460	472	445	575	674	587	519	545	581
3	---	610	528	461	474	457	565	687	588	515	540	580
4	---	613	566	458	476	473	557	675	587	515	550	---
5	---	---	616	455	473	484	548	665	579	518	553	544
6	---	---	623	452	466	483	533	640	565	514	554	549
7	---	---	626	451	462	471	515	617	558	512	556	553
8	---	605	630	447	465	465	515	633	561	510	552	556
9	---	605	---	444	465	477	499	533	573	511	553	557
10	604	608	614	451	459	494	492	---	583	512	552	559
11	598	604	622	453	458	506	492	476	591	512	579	559
12	588	597	634	443	461	515	498	485	592	513	587	560
13	608	598	643	435	462	508	509	497	593	514	582	560
14	624	600	649	426	459	507	470	509	593	515	587	559
15	637	598	650	455	463	508	472	505	595	515	586	559
16	648	600	640	470	464	---	490	507	594	515	575	558
17	655	604	625	469	456	523	511	511	585	514	561	558
18	647	---	629	475	444	526	520	508	598	516	---	557
19	622	---	640	468	443	530	517	496	620	515	568	556
20	628	609	641	480	445	504	517	492	630	515	575	556
21	633	614	638	512	448	492	530	505	642	516	577	---
22	627	601	638	516	451	524	528	514	651	519	561	564
23	628	602	621	515	444	535	515	516	634	521	564	565
24	629	606	589	516	439	539	509	524	618	523	579	567
25	609	---	575	510	446	535	501	519	596	524	584	567
26	603	---	546	503	452	505	505	514	577	524	596	568
27	---	624	524	498	456	501	546	520	564	526	631	569
28	---	611	507	490	458	502	597	536	554	527	602	572
29	---	592	486	484	458	513	594	565	541	530	590	575
30	---	572	471	480	446	542	600	588	535	537	600	577
31	---	559	---	478	---	563	629	---	529	---	596	581
Mean	623	601	593	472	458	502	530	554	587	518	573	564
Maximum	655	624	650	516	476	563	629	687	651	537	631	592
Minimum	588	559	471	426	439	441	470	476	529	510	540	544

Table 17. Mean daily specific conductance of water from the Cedar Rapids municipal water-treatment plant, February 1, 1993, through January 31, 1994

[Specific conductance given in microsiemens per centimeter at 25 degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	590	522	471	505	473	---	443	487	509	517	---
2	---	602	512	477	502	464	---	445	488	504	516	---
3	---	594	516	473	494	466	---	451	499	501	516	---
4	---	585	530	492	496	462	---	439	488	503	517	---
5	---	584	499	486	500	464	---	443	488	501	520	551
6	---	585	503	471	505	462	---	442	489	506	---	548
7	---	582	---	464	506	459	422	447	483	496	543	543
8	---	586	---	468	503	---	425	448	482	506	544	531
9	---	586	---	467	500	---	419	448	481	513	544	528
10	---	---	476	467	502	---	424	449	480	525	540	525
11	---	564	489	460	500	---	430	465	486	520	531	527
12	---	576	498	475	500	---	424	475	478	522	528	520
13	---	575	486	491	499	---	424	471	478	518	525	527
14	---	565	489	487	495	---	430	478	478	517	522	521
15	---	571	491	479	493	---	420	492	473	517	521	523
16	---	564	492	470	490	---	421	479	484	518	520	528
17	588	544	496	473	492	---	424	486	476	500	518	529
18	588	578	498	474	507	---	425	489	479	498	---	525
19	581	584	508	477	500	---	420	486	477	513	540	521
20	585	573	507	480	494	---	418	485	474	513	538	526
21	586	576	507	481	490	---	423	486	472	513	536	---
22	581	563	509	483	491	---	431	483	479	511	536	514
23	567	569	492	491	502	---	431	481	477	517	534	509
24	580	557	494	499	497	---	440	490	471	525	535	514
25	566	---	490	497	487	---	453	492	474	524	536	511
26	---	563	483	496	483	---	453	486	475	520	---	523
27	563	549	466	502	475	---	441	483	476	522	---	516
28	581	530	465	508	468	---	443	484	493	522	---	519
29	---	518	466	513	474	---	438	488	513	519	---	519
30	---	513	474	510	473	---	436	485	509	512	---	504
31	---	511	---	506	---	---	441	---	507	---	---	519
Mean	579	567	495	483	494	464	430	471	484	513	529	524
Maximum	588	602	530	513	507	473	453	492	513	525	544	551
Minimum	563	511	465	460	468	459	418	439	471	496	516	504

Table 18. Mean daily pH of water from the Cedar River, surface-water monitoring site, February 1, 1993, through January 31, 1994
[pH given in standard units; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	7.9	7.8	7.4	8.1	8.5	7.9	8.0	8.2	8.2	8.4	8.2	7.8
2	7.9	7.8	7.4	8.1	8.5	8.0	8.1	8.2	8.3	8.4	8.2	7.8
3	8.0	7.8	7.5	8.0	8.3	8.0	8.1	8.3	8.4	8.4	8.2	7.8
4	7.9	7.6	7.5	8.0	8.2	8.0	8.2	8.3	8.4	8.4	8.2	7.8
5	7.8	7.5	7.5	8.0	8.2	8.0	8.2	8.3	8.3	8.4	8.2	7.8
6	7.8	7.5	7.6	8.0	8.2	8.0	8.0	8.3	8.2	8.4	8.2	7.7
7	7.9	7.4	7.7	7.9	8.2	8.0	7.8	8.4	8.2	8.4	8.2	7.7
8	7.9	7.5	7.7	7.9	8.1	8.1	7.9	8.4	8.1	8.4	8.2	7.7
9	7.9	7.5	---	8.0	8.0	8.0	8.0	8.4	8.2	8.3	8.2	7.7
10	7.9	7.6	7.9	8.0	7.9	7.9	7.8	8.3	8.2	8.1	8.1	7.7
11	7.8	7.6	7.9	8.1	7.9	7.8	7.8	8.3	8.2	8.2	8.2	7.7
12	7.8	7.6	7.9	8.1	7.9	7.8	7.9	8.3	8.3	8.1	8.1	7.7
13	7.9	7.7	7.9	8.1	8.0	7.9	7.9	8.3	8.3	8.1	8.1	7.7
14	7.9	7.7	8.0	8.1	8.0	8.0	7.9	8.2	8.2	8.1	8.1	7.7
15	---	7.8	8.0	8.1	8.1	8.0	7.8	8.2	8.1	8.1	8.1	7.7
16	---	7.8	8.0	8.2	8.0	7.9	7.8	8.2	8.2	8.1	8.1	7.7
17	---	7.9	8.0	8.2	7.9	7.8	7.8	8.3	8.2	8.1	8.1	7.7
18	---	7.7	8.0	---	7.8	7.8	7.9	8.3	8.2	8.2	---	7.7
19	---	7.6	8.0	---	7.8	7.8	7.8	8.2	8.2	8.2	8.1	7.7
20	---	7.6	8.0	---	7.7	7.9	7.8	8.2	8.2	8.2	7.9	7.7
21	---	7.7	8.0	---	7.8	7.9	7.8	8.2	8.3	8.2	7.8	7.7
22	---	7.7	8.0	8.3	7.7	7.9	7.9	8.2	8.4	8.2	7.7	7.7
23	---	7.7	8.0	8.3	7.7	8.0	7.9	8.3	8.3	8.3	7.7	7.7
24	---	7.7	8.0	8.3	7.8	8.0	8.0	8.2	8.2	8.3	7.7	7.7
25	---	7.6	8.0	8.3	7.8	8.0	8.1	8.0	8.2	8.3	7.8	7.7
26	---	7.5	8.0	8.4	7.9	8.1	8.1	8.0	8.2	8.3	7.8	7.7
27	7.8	7.4	8.1	8.5	7.9	8.1	8.1	8.0	8.2	8.3	7.8	7.7
28	7.8	7.4	8.2	8.4	7.9	8.1	8.1	8.1	8.3	8.3	7.8	7.7
29	---	7.3	8.2	8.3	8.0	8.1	8.1	8.2	8.3	8.3	7.8	7.7
30	---	7.3	8.2	8.4	7.9	8.1	8.1	8.2	8.4	8.3	7.8	7.7
31	---	7.4	---	8.4	---	8.1	8.2	---	8.4	---	7.8	7.7
Mean	7.9	7.6	7.9	8.2	8.0	8.0	8.0	8.2	8.3	8.3	8.0	7.7
Maximum	8.0	7.9	8.2	8.5	8.5	8.1	8.2	8.4	8.4	8.4	8.2	7.8
Minimum	7.8	7.3	7.4	7.9	7.7	7.8	7.8	8.0	8.1	8.1	7.7	7.7

Table 19. Mean daily pH of water from observation well CRM-4, February 1, 1993, through January 31, 1994
[pH given in standard units; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	7.8	---	7.8	7.6	7.8	7.5	7.6	7.7	7.7	---	8.0	8.2
2	7.8	---	7.8	7.6	7.8	7.4	7.6	7.7	7.7	---	8.0	8.2
3	7.8	7.8	7.8	7.6	7.6	7.4	7.7	7.7	7.8	---	8.0	8.2
4	7.9	7.8	7.8	7.6	7.5	7.4	7.7	7.7	7.8	---	8.1	---
5	7.9	7.8	7.8	7.6	7.6	7.4	7.7	7.7	7.8	---	8.1	8.1
6	7.9	7.9	7.8	7.7	7.6	7.4	7.6	7.8	7.8	---	8.0	8.1
7	7.9	8.0	7.8	7.7	7.6	7.4	7.5	7.8	7.8	---	7.8	8.1
8	7.9	8.0	7.8	7.7	7.6	7.4	7.5	7.7	7.8	---	7.9	8.1
9	7.9	8.1	---	7.7	7.6	7.4	7.6	7.7	7.9	---	7.9	8.1
10	7.7	8.1	7.8	7.7	7.6	7.4	7.6	7.5	---	7.6	7.9	8.1
11	7.7	8.1	7.8	7.7	7.6	7.4	7.6	7.4	---	7.6	7.9	8.1
12	7.8	8.0	7.7	7.8	7.6	7.4	7.6	7.4	---	7.6	8.0	8.1
13	7.8	8.0	7.7	7.8	7.6	7.5	7.6	7.4	---	7.7	8.0	8.1
14	7.8	8.0	7.7	7.8	7.6	7.5	7.7	7.4	7.6	7.7	8.0	8.1
15	7.8	8.0	7.7	7.8	7.6	7.5	7.7	7.5	7.6	7.7	8.0	8.1
16	7.8	8.0	7.6	7.8	7.6	7.5	7.7	7.5	7.6	7.7	8.0	8.1
17	7.8	8.0	---	7.8	7.6	7.5	7.7	7.5	7.7	7.7	8.0	8.1
18	7.8	7.9	---	7.7	7.6	7.5	7.7	7.5	7.8	7.7	8.1	---
19	7.7	7.8	---	7.6	7.6	7.5	7.7	7.5	7.8	7.7	8.2	---
20	7.8	7.8	---	7.6	7.6	7.6	7.7	7.5	7.8	7.7	8.2	---
21	7.7	7.8	---	7.6	7.5	7.6	7.7	7.5	7.8	7.7	8.2	---
22	7.7	7.8	---	7.6	7.5	7.6	7.8	7.6	7.8	7.7	8.2	7.8
23	7.7	7.8	---	7.6	7.5	7.6	7.8	7.6	7.8	7.8	8.2	7.8
24	7.7	7.9	7.5	7.7	7.6	7.7	7.7	7.6	7.8	7.9	8.2	7.7
25	7.7	7.8	7.6	7.7	7.6	7.7	7.7	7.6	7.8	7.9	8.2	7.7
26	7.7	7.7	7.6	7.7	7.6	7.6	7.7	7.7	---	7.9	8.2	7.7
27	7.7	7.7	7.6	7.7	7.6	7.6	7.7	7.7	---	8.0	8.2	7.7
28	---	7.8	7.6	7.7	7.6	7.6	7.7	7.7	---	8.0	8.2	7.7
29	---	7.8	7.6	7.7	7.6	7.6	7.7	7.7	---	8.0	8.2	7.7
30	---	7.8	7.6	7.7	7.6	7.6	7.7	7.7	---	8.0	8.2	7.7
31	---	7.8	---	7.8	---	7.6	7.7	---	---	---	8.2	7.7
Mean	7.8	7.9	7.7	7.7	7.6	7.5	7.7	7.6	7.8	7.8	8.1	8.0
Maximum	7.9	8.1	7.8	7.8	7.8	7.7	7.8	7.8	7.9	8.0	8.2	8.2
Minimum	7.7	7.5	7.6	7.5	7.4	7.5	7.4	7.6	7.6	7.8	7.7	7.7

Table 20. Mean daily pH of water from municipal well Seminole 10, February 1, 1993, through January 31, 1994

[pH, given in standard units; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	7.4	---	---	7.6	7.8	---	7.7	7.8	7.6	---	7.7	7.8
2	7.4	---	---	7.6	7.8	7.6	7.7	7.8	7.6	---	7.7	7.8
3	7.4	7.4	---	7.6	7.6	7.6	7.7	7.8	7.6	---	7.7	7.8
4	7.4	7.4	---	7.6	7.5	7.7	7.7	7.8	7.6	---	7.7	---
5	7.4	7.4	---	7.6	7.5	7.7	7.7	7.9	7.6	---	7.7	7.6
6	7.4	7.4	---	7.6	7.5	7.7	7.6	7.9	7.6	---	7.7	7.6
7	7.4	7.5	---	7.7	7.5	7.7	7.6	7.9	7.7	---	7.7	7.7
8	---	7.5	---	7.7	7.5	7.7	7.7	7.9	7.7	---	7.7	7.7
9	---	7.5	---	7.7	7.6	7.7	7.7	7.9	7.7	---	7.7	7.7
10	7.2	7.5	7.7	7.7	7.6	7.7	7.7	7.8	7.7	7.4	7.5	7.7
11	7.3	7.5	7.8	7.7	7.6	7.7	7.7	7.7	7.7	7.4	7.5	7.7
12	7.5	7.5	7.8	7.8	7.5	7.8	7.7	7.7	7.6	7.5	7.5	7.7
13	7.5	7.6	7.8	7.8	7.5	7.8	7.7	7.7	7.7	7.5	7.6	7.7
14	7.5	7.6	7.8	7.8	7.5	7.8	7.7	7.7	7.7	7.5	7.6	7.7
15	7.5	7.6	7.8	7.7	7.5	7.8	7.8	7.7	7.8	7.5	7.6	7.7
16	7.6	7.7	7.7	7.7	7.6	7.6	7.8	7.7	7.8	7.5	7.6	7.7
17	7.5	7.7	7.7	7.7	7.6	7.5	7.8	7.8	7.9	7.6	7.7	---
18	7.4	7.7	7.7	7.7	7.5	7.5	7.8	7.8	7.9	7.6	7.6	---
19	7.5	7.7	7.7	7.6	7.5	7.6	7.8	7.8	7.9	7.6	7.6	---
20	7.6	7.6	7.8	7.6	7.5	7.5	7.8	7.8	7.9	7.6	7.6	---
21	7.6	7.6	7.9	7.6	7.6	7.5	7.9	7.8	8.0	7.6	7.6	---
22	7.7	7.6	7.7	7.6	7.6	7.5	7.9	7.8	8.0	7.6	7.7	7.6
23	7.7	7.6	7.6	7.7	7.6	7.5	7.9	7.8	8.0	7.6	7.7	7.6
24	7.7	7.6	7.6	7.7	7.5	7.5	7.7	7.6	8.0	7.6	7.7	7.6
25	7.7	7.6	7.6	7.8	7.6	7.5	7.7	7.6	8.0	7.7	7.8	7.6
26	7.7	7.6	7.6	7.8	7.6	7.6	7.7	7.6	8.0	7.7	7.8	7.7
27	---	---	7.6	7.8	7.5	7.6	7.7	7.6	8.0	7.7	7.8	7.7
28	---	---	7.6	7.8	7.6	7.6	7.8	7.6	---	7.7	7.8	7.7
29	---	---	7.6	7.8	7.6	7.7	7.8	7.6	---	7.7	7.8	7.7
30	---	---	7.6	7.8	---	7.7	7.8	7.6	---	7.7	7.8	7.7
31	---	---	---	7.8	---	7.7	7.8	---	---	---	7.8	7.7
Mean	7.5	7.6	7.7	7.7	7.6	7.6	7.7	7.7	7.8	7.6	7.7	7.7
Maximum	7.7	7.7	7.9	7.8	7.8	7.8	7.9	7.9	8.0	7.7	7.8	7.8
Minimum	7.2	7.4	7.6	7.6	7.5	7.5	7.6	7.6	7.6	7.4	7.5	7.6

Table 21. Mean daily pH of water from observation well CRM-3, February 1, 1993, through January 31, 1994
[pH, given in standard units; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	---	7.4	7.3	7.4	7.3	7.3	7.1	7.1	---	7.3	7.4
2	---	---	7.4	7.3	7.4	7.2	7.3	7.0	7.1	---	7.3	7.4
3	---	7.2	7.4	7.3	7.3	7.2	7.3	7.0	7.1	---	7.3	7.4
4	---	7.2	7.4	7.3	7.2	7.2	7.3	7.0	7.1	---	7.3	---
5	---	---	7.4	7.3	7.2	7.2	7.3	7.0	7.1	---	7.3	7.4
6	---	---	7.4	7.3	7.2	7.2	7.2	7.0	7.1	---	7.2	7.4
7	---	---	7.4	7.3	7.2	7.2	7.1	7.0	7.1	---	7.2	7.4
8	---	7.2	7.4	7.3	7.2	7.2	7.1	7.0	7.1	---	7.2	7.4
9	---	7.2	---	7.3	7.2	7.2	7.1	7.1	7.1	---	7.2	7.4
10	7.3	7.2	7.2	7.3	7.2	7.1	7.2	---	7.1	7.0	7.2	7.4
11	7.3	7.3	7.2	7.4	7.2	7.1	7.2	7.0	7.1	7.0	7.2	7.4
12	7.3	7.3	7.2	7.4	7.2	7.1	7.2	7.1	7.1	7.1	7.2	7.4
13	7.3	7.3	7.2	7.4	7.3	7.2	7.2	7.1	7.0	7.1	7.2	7.4
14	7.3	7.3	7.2	7.4	7.3	7.2	7.2	7.1	7.0	7.1	7.2	7.4
15	7.2	7.3	7.2	7.4	7.3	7.2	7.2	7.1	7.0	7.1	7.2	7.4
16	7.2	7.3	7.2	7.4	7.2	7.2	7.2	7.1	7.0	7.1	7.2	7.4
17	7.3	7.3	7.2	7.4	7.2	7.2	7.2	7.1	7.1	7.1	7.2	7.4
18	7.2	---	7.2	7.3	7.3	7.2	7.2	7.1	7.1	7.1	---	7.4
19	7.2	---	7.2	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.2	7.4
20	7.2	7.2	7.2	7.3	7.3	7.3	7.2	7.1	7.1	7.1	7.2	7.5
21	7.2	7.2	7.2	7.3	7.3	7.3	7.2	7.1	7.1	7.1	7.3	---
22	7.2	7.2	7.2	7.3	7.3	7.3	7.2	7.1	7.1	7.1	7.3	7.1
23	7.2	7.2	7.2	7.3	7.3	7.3	7.2	7.2	7.1	7.2	7.3	7.1
24	7.2	7.2	7.2	7.3	7.3	7.3	7.2	7.1	7.1	7.2	7.3	7.1
25	7.2	---	7.2	7.3	7.3	7.3	7.1	7.0	6.9	7.2	7.3	7.1
26	7.2	---	7.1	7.3	7.3	7.3	7.1	7.1	---	7.2	7.3	7.1
27	---	7.3	7.2	7.3	7.3	7.3	7.1	7.1	---	7.2	7.3	7.1
28	---	7.3	7.2	7.3	7.3	7.3	7.1	7.1	---	7.3	7.3	7.2
29	---	7.3	7.2	7.3	7.3	7.3	7.1	7.1	---	7.3	7.3	7.2
30	---	7.3	7.2	7.3	7.3	7.3	7.1	7.1	---	7.3	7.4	7.2
31	---	7.3	---	7.3	---	7.3	7.1	---	---	---	7.4	7.2
Mean	7.2	7.3	7.3	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.3	7.3
Maximum	7.3	7.3	7.4	7.4	7.4	7.3	7.3	7.2	7.1	7.3	7.4	7.5
Minimum	7.2	7.2	7.1	7.3	7.2	7.1	7.1	7.0	6.9	7.0	7.2	7.1

Table 22. Mean daily pH of water from the Cedar Rapids municipal water-treatment plant, February 1, 1993, through January 31, 1994

[pH given in standard units; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	7.3	7.3	7.2	7.5	7.4	---	---	6.9	7.3	7.3	---
2	---	7.3	7.3	7.2	7.5	7.4	---	---	6.9	7.3	7.3	---
3	---	7.3	7.3	7.2	7.4	7.4	---	---	6.9	7.3	7.3	---
4	---	7.3	7.3	7.2	7.3	7.4	---	---	7.0	7.3	7.3	---
5	---	7.3	7.3	7.2	7.3	7.4	---	---	7.0	7.3	7.3	6.3
6	---	7.3	7.4	7.2	7.3	7.4	---	---	7.0	7.3	---	6.3
7	---	7.3	---	7.2	7.3	7.4	7.2	---	7.0	7.3	7.3	6.3
8	---	7.3	---	7.3	7.3	---	7.2	---	7.0	7.4	7.3	6.3
9	---	7.3	---	7.3	7.3	---	7.2	---	7.0	7.3	7.3	6.3
10	---	---	7.3	7.3	7.3	---	7.2	---	7.0	7.2	7.3	6.3
11	---	7.3	7.4	7.2	7.3	---	7.2	7.2	7.0	7.3	7.3	6.3
12	---	7.3	7.3	7.2	7.3	---	7.2	7.2	7.0	7.3	7.3	6.3
13	---	7.3	7.3	7.2	7.3	---	7.2	7.2	7.1	7.3	7.3	6.3
14	---	7.3	7.3	7.2	7.3	---	7.2	7.2	7.3	7.3	7.3	6.3
15	---	7.3	7.3	7.2	7.3	---	7.2	7.2	7.3	7.3	7.3	6.3
16	---	7.3	7.4	7.2	7.3	---	7.2	7.3	7.3	7.3	7.3	6.4
17	7.2	7.3	7.4	7.2	7.3	---	7.2	7.3	7.3	7.3	7.3	6.4
18	7.2	7.3	7.4	7.2	7.3	---	7.2	7.3	7.3	7.3	---	6.4
19	7.2	7.3	7.4	7.2	7.3	---	7.2	7.3	7.3	7.3	7.2	6.4
20	7.2	7.3	7.4	7.2	7.3	---	7.2	7.3	7.3	7.3	7.3	6.4
21	7.2	7.3	7.4	7.3	7.3	---	7.2	7.3	7.3	7.3	7.3	---
22	7.2	7.3	7.4	7.5	7.3	---	7.2	7.3	7.3	7.3	7.3	6.4
23	7.2	7.3	7.4	7.5	7.3	---	7.2	7.2	7.3	7.2	7.3	6.4
24	7.2	7.3	7.4	7.5	7.3	---	7.0	7.1	7.3	7.2	7.4	6.4
25	7.3	---	7.4	7.5	7.3	---	6.7	7.1	7.3	7.2	7.3	6.4
26	7.3	7.3	7.4	7.5	7.3	---	6.7	7.1	7.3	7.2	---	6.4
27	7.3	7.3	7.3	7.5	7.3	---	---	7.0	7.3	7.2	---	6.4
28	7.3	7.3	7.2	7.5	7.4	---	---	6.9	7.3	7.2	---	6.4
29	---	7.3	7.2	7.5	7.3	---	---	6.9	7.3	7.3	---	6.4
30	---	7.3	7.2	7.5	7.4	---	---	6.9	7.3	7.3	---	6.4
31	---	7.3	---	7.5	---	---	---	---	7.3	---	---	6.4
Mean	7.2	7.3	7.3	7.3	7.3	7.4	7.1	7.2	7.2	7.3	7.3	6.4
Maximum	7.3	7.3	7.4	7.5	7.5	7.4	7.2	7.3	7.3	7.4	7.4	6.4
Minimum	7.2	7.3	7.2	7.2	7.3	7.4	6.7	6.9	6.9	7.2	7.2	6.3

Table 23. Mean daily temperature of water from the Cedar River, surface-water monitoring site, February 1, 1993, through January 31, 1994

[Temperatures given in degrees Celsius; ---, no date]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	-0.1	-0.1	3.7	14.2	15.3	19.8	21.6	20.2	12.6	4.1	0.1	-0.1
2	-.1	-.1	3.4	13.9	14.1	20.6	21.6	19.9	12.5	4.3	.8	-.1
3	-.1	-.1	3.6	13.7	13.5	21.9	21.5	19.6	12.4	5.0	1.3	-.1
4	-.1	-.1	3.7	13.0	13.7	22.5	21.1	19.5	13.2	6.6	2.0	-.1
5	-.1	-.1	4.2	13.1	13.8	21.5	20.3	19.0	13.0	6.6	2.4	-.1
6	-.1	-.1	5.2	13.5	15.1	21.1	19.7	18.1	13.8	4.4	2.4	-.1
7	-.1	0	6.4	14.4	15.7	21.1	19.9	18.1	15.6	3.0	1.6	-.1
8	-.1	.1	7.3	16.4	16.7	21.0	20.4	18.2	16.8	3.4	1.6	-.1
9	-.1	.1	---	17.9	17.9	20.9	20.9	18.0	15.0	3.9	2.2	-.1
10	-.1	0	8.1	18.4	18.8	21.2	21.4	17.3	12.6	4.4	2.2	-.1
11	-.1	0	8.4	18.7	19.8	21.5	22.4	16.7	11.4	5.2	.6	-.1
12	-.1	0	7.9	19.1	20.4	21.9	23.0	17.5	11.2	5.0	.2	-.1
13	-.1	.1	7.7	18.3	20.6	21.7	23.5	18.9	10.9	6.1	1.2	-.1
14	-.1	.2	7.1	18.0	21.1	21.4	23.6	17.7	11.3	6.0	1.7	-.1
15	---	.4	6.0	18.0	20.7	21.3	22.7	15.6	12.1	5.5	2.3	-.1
16	---	.5	4.8	17.4	19.7	21.3	22.6	14.7	12.7	4.7	2.8	-.1
17	---	.2	5.9	16.6	19.4	21.4	23.0	14.6	12.8	5.0	3.2	-.1
18	---	.1	7.4	---	20.3	21.6	23.3	14.9	12.2	4.5	---	-.1
19	---	.1	8.5	---	20.5	21.9	22.9	14.6	12.4	4.6	3.3	-.1
20	---	.2	8.1	---	20.1	22.3	22.9	14.7	12.4	3.8	2.7	-.1
21	---	.1	8.8	---	20.0	22.1	22.8	15.3	11.1	3.9	1.5	-.1
22	---	.1	9.3	13.9	20.7	21.6	22.4	16.0	10.2	4.3	.4	-.1
23	---	.3	9.6	14.0	21.3	20.9	22.6	16.1	10.5	4.8	-.1	-.1
24	---	1.6	10.3	14.1	21.5	21.0	23.1	15.6	11.1	4.9	-.1	-.1
25	---	2.5	10.8	14.1	21.5	21.8	23.6	14.9	11.6	4.3	-.1	-.1
26	---	3.4	11.8	15.3	21.6	22.7	24.2	13.7	11.3	2.3	-.1	0
27	-.1	3.3	12.2	16.9	22.0	23.2	24.6	12.9	9.8	1.0	-.1	0
28	-.1	3.5	12.3	17.4	22.0	23.2	23.8	12.9	9.0	.6	-.1	0
29	---	3.6	13.5	16.3	21.7	22.6	22.1	12.5	7.3	.1	-.1	0
30	---	3.7	14.1	16.0	20.5	22.7	21.4	12.1	5.7	-.1	-.1	0
31	---	4.2	---	15.7	---	22.5	20.7	---	4.6	---	-.1	0
Mean	-.1	.9	7.9	15.9	19.0	21.7	22.2	16.3	11.6	4.1	1.2	-.1
Maximum	-.1	4.2	14.1	19.1	22.0	23.2	24.6	20.2	16.8	6.6	3.3	0
Minimum	-.1	-.1	3.4	13.0	13.5	19.8	19.7	12.1	4.6	-.1	-.1	-.1

Table 24. Mean daily temperature of water from observation well CRM-4, February 1, 1993, through January 31, 1994

[Temperatures given in degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	0.9	---	1.8	11.5	16.3	---	23.3	23.9	15.3	11.4	4.7	0.1
2	.9	---	2.6	12.1	17.1	---	22.9	24.4	14.6	11.1	3.8	.1
3	.9	0.1	3.1	12.5	16.8	---	22.8	24.5	13.8	10.3	2.5	.1
4	.9	.1	3.3	13.6	16.4	---	22.9	23.8	13.3	9.4	1.5	---
5	.9	.1	3.5	14.2	16.0	---	22.0	22.6	13.0	8.2	.8	.1
6	.9	.1	3.6	14.3	15.6	---	21.8	21.7	12.8	6.8	.4	.1
7	.9	.1	3.7	14.1	14.9	---	21.8	21.0	12.6	5.6	.2	.1
8	.9	.1	3.9	14.1	14.4	---	21.7	20.5	12.6	4.8	.3	.1
9	.9	.1	---	14.1	14.0	---	21.7	20.1	12.6	4.8	.8	.1
10	.8	.1	4.0	14.1	13.9	---	21.6	19.8	---	5.3	1.5	.1
11	.7	.1	3.9	14.1	14.3	---	21.3	19.6	---	5.9	1.7	.1
12	.4	.1	4.1	14.0	15.2	---	20.8	19.1	---	6.1	1.8	.1
13	.2	.1	4.7	14.0	15.4	---	20.6	18.6	---	5.5	1.8	.1
14	.1	.1	5.9	13.7	15.6	---	20.2	18.3	15.6	4.3	1.9	.1
15	.1	.2	7.2	13.3	15.7	---	20.0	18.3	15.9	3.8	1.9	.1
16	.1	.2	8.0	13.3	15.9	---	20.2	18.2	15.0	4.1	1.9	.1
17	.1	.2	---	14.1	16.8	22.0	20.8	17.8	13.4	4.6	1.8	.1
18	.1	.3	---	16.5	17.8	21.9	21.6	17.3	12.2	5.1	1.9	---
19	.1	.2	---	18.0	18.6	21.9	22.6	17.5	11.6	5.6	1.8	---
20	.1	.2	---	18.1	19.4	21.9	23.3	18.4	11.4	6.0	1.8	---
21	.1	.3	---	17.8	19.7	21.6	23.5	18.3	11.6	6.0	2.1	---
22	.1	.4	---	17.1	19.6	21.0	23.2	16.7	12.1	5.7	2.3	.1
23	.1	.5	---	16.3	20.0	20.7	23.1	15.3	12.6	5.3	2.0	.1
24	.1	.5	8.2	15.5	20.4	20.6	23.4	15.0	12.7	5.0	1.9	.1
25	.1	.4	8.4	14.7	20.5	21.1	23.2	14.9	12.6	4.8	1.9	.1
26	.1	.3	8.7	14.1	20.4	21.9	23.1	15.1	12.4	4.5	2.2	.1
27	.1	.3	9.2	14.1	20.3	22.1	23.0	15.7	11.9	4.2	2.4	.1
28	---	.3	9.6	14.1	20.5	21.5	22.9	16.1	11.2	4.3	1.5	.1
29	---	.4	10.1	14.2	21.0	21.4	22.7	16.1	10.8	4.6	.6	.1
30	---	.6	10.6	14.3	21.5	22.6	22.9	15.8	10.9	4.9	.2	.1
31	---	1.1	---	15.0	---	23.5	23.4	---	11.3	---	.1	.1
Mean	.4	.3	5.8	14.5	17.5	21.7	22.2	18.8	12.8	5.9	1.7	.1
Maximum	.9	1.1	10.6	18.1	21.5	23.5	23.5	24.5	15.9	11.4	4.7	.1
Minimum	.1	.1	1.8	11.5	13.9	20.6	20.0	14.9	10.8	3.8	.1	.1

Table 25. Mean daily temperature of water from municipal well Seminole 10, February 1, 1993, through January 31, 1994

[Temperatures given in degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	6.5	---	---	7.2	15.0	---	20.8	18.4	15.8	11.8	5.0	1.8
2	6.5	---	---	7.5	14.8	17.1	20.9	18.5	15.7	11.7	4.9	1.8
3	6.5	-0.1	---	8.0	14.7	14.5	21.0	18.5	15.5	11.6	4.9	1.7
4	6.5	-.1	---	8.5	14.7	14.5	21.0	18.3	15.3	11.5	4.8	---
5	6.5	-.2	---	9.0	14.7	14.4	21.1	18.5	15.0	11.4	4.7	1.3
6	6.4	-.2	---	9.5	14.7	15.7	21.0	20.3	14.6	11.2	4.5	1.1
7	6.4	-.2	---	7.3	13.7	15.5	19.2	20.3	14.3	10.9	4.3	.9
8	---	-.2	---	6.8	12.4	14.6	18.5	19.9	13.9	10.5	4.5	.7
9	---	-.2	---	6.7	15.1	13.6	19.2	20.2	13.6	10.1	4.4	.5
10	6.1	-.2	2.2	6.8	15.3	13.6	19.2	20.8	13.4	9.5	6.8	.4
11	5.1	-.2	2.5	7.3	15.4	13.6	19.6	21.1	13.2	8.9	6.4	.3
12	1.7	-.2	2.8	7.3	13.1	14.4	19.6	21.2	13.0	8.2	6.4	.2
13	1.0	-.2	3.0	8.3	12.5	14.6	18.8	21.4	13.0	7.8	6.5	.1
14	.8	-.2	3.1	10.2	12.8	14.2	19.9	20.6	13.0	7.2	6.5	.1
15	.6	-.2	3.3	10.8	12.7	13.7	18.5	21.2	13.2	6.7	6.5	0
16	.4	-.2	3.4	11.3	13.8	13.7	19.5	21.1	13.5	6.3	6.6	0
17	2.9	-.1	3.7	11.8	15.1	13.7	20.3	21.2	13.8	5.9	6.6	---
18	4.4	-.1	4.1	12.0	15.0	13.4	20.1	21.0	13.9	5.7	6.6	---
19	4.4	-.1	4.6	12.1	15.0	14.1	20.4	20.8	13.8	5.4	6.6	---
20	4.5	-.1	5.4	12.3	14.9	15.2	20.2	20.6	13.6	5.2	6.6	---
21	.7	-.1	6.1	12.5	14.9	17.0	20.3	19.8	13.3	5.0	6.1	---
22	.2	-.1	6.2	12.9	15.2	18.2	19.9	19.1	12.9	5.0	3.8	-.1
23	0	-.1	6.3	13.2	15.5	18.6	19.7	18.7	12.6	5.0	2.7	-.2
24	0	-.1	6.7	13.5	15.7	18.9	19.2	18.1	12.4	5.0	2.0	-.2
25	-.1	-.1	6.9	13.8	15.7	19.0	18.5	17.4	12.4	5.0	1.7	-.1
26	-.1	-.1	6.7	14.1	15.9	19.1	18.6	17.0	12.4	5.0	1.6	-.2
27	---	---	6.5	14.5	16.2	19.6	18.7	16.6	12.4	5.0	1.6	-.2
28	---	---	6.6	14.8	16.5	20.0	18.5	16.3	12.3	5.0	1.6	-.2
29	---	---	6.8	15.1	16.9	20.3	18.5	16.0	12.2	5.0	1.6	-.2
30	---	---	7.0	15.2	---	20.5	18.4	15.9	12.1	5.0	1.7	-.1
31	---	---	---	15.1	---	20.7	18.2	---	11.9	---	1.8	-.1
Mean	3.2	-.2	4.9	10.8	14.8	16.2	19.6	19.3	13.5	7.6	4.5	.4
Maximum	6.5	-.1	7.0	15.2	16.9	20.7	21.1	21.4	15.8	11.8	6.8	1.8
Minimum	-.1	-.2	2.2	6.7	12.4	13.4	18.2	15.9	11.9	5.0	1.6	-.2

Table 26. Mean daily temperature of water from observation well CRM-3, February 1, 1993, through January 31, 1994

[Temperatures given in degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	---	3.0	5.0	5.4	5.9	8.5	11.8	15.1	16.5	18.6	15.7
2	---	---	3.0	5.0	5.4	6.0	8.6	12.0	15.2	16.5	18.7	15.6
3	---	3.4	2.9	5.1	---	6.0	8.8	12.2	15.3	16.6	18.6	15.4
4	---	3.6	2.9	5.1	5.3	6.0	8.9	12.3	15.4	16.6	18.5	---
5	---	---	2.9	5.0	5.2	6.0	9.1	12.5	15.5	16.6	18.4	15.1
6	---	---	2.9	5.0	5.2	6.0	9.3	12.7	15.7	16.7	---	15.0
7	---	---	3.0	5.0	5.1	6.0	9.3	12.9	15.8	16.8	18.3	14.8
8	---	3.1	3.2	5.0	5.1	6.0	9.5	13.2	15.9	16.8	18.2	14.7
9	---	3.0	---	5.0	5.0	6.0	9.9	13.4	16.0	17.0	18.0	14.6
10	0.6	3.0	3.6	5.0	5.0	6.0	10.3	---	16.2	17.1	17.7	14.4
11	.6	3.0	3.7	5.0	4.9	6.0	10.4	13.9	16.3	17.1	17.2	14.3
12	.6	3.0	3.8	5.0	5.0	6.1	10.2	14.0	16.2	17.2	16.8	14.2
13	.6	3.0	3.9	4.9	5.0	6.1	10.3	14.2	16.1	17.3	16.6	14.1
14	.7	3.0	4.0	4.9	5.0	6.1	10.6	14.3	16.1	17.3	16.5	14.0
15	.7	3.0	4.1	4.9	5.1	6.1	10.7	14.6	16.1	17.4	16.5	13.9
16	.8	3.0	4.2	4.9	5.1	---	11.3	14.7	16.1	17.5	16.3	13.8
17	.9	3.0	4.2	4.9	5.0	6.1	11.7	14.9	16.2	17.5	15.8	13.7
18	---	---	4.3	4.9	5.0	6.1	11.5	15.0	16.2	17.7	---	13.6
19	1.0	---	4.3	4.9	5.0	6.1	11.4	15.2	16.2	17.8	13.9	13.5
20	1.1	3.0	4.3	4.9	5.0	6.2	11.4	15.4	16.3	18.0	12.6	13.5
21	1.3	3.1	4.4	4.9	5.1	6.4	11.5	15.4	16.3	18.1	11.6	---
22	1.5	3.3	4.4	4.9	5.1	6.5	11.6	15.4	16.3	18.1	12.6	13.2
23	1.6	3.3	4.4	5.0	5.1	6.6	11.7	15.3	16.3	18.2	14.2	13.1
24	1.8	3.3	4.4	5.0	5.2	6.7	11.8	15.4	16.3	18.2	15.1	13.1
25	2.0	---	4.5	5.1	5.2	6.9	11.8	15.3	16.3	18.3	15.7	13.0
26	2.3	---	4.5	5.2	5.3	7.1	11.7	15.3	16.3	18.3	15.9	12.9
27	---	3.3	4.6	5.2	5.3	7.3	11.6	15.3	16.3	18.4	16.0	12.8
28	---	3.2	4.7	5.2	5.5	7.5	11.7	15.2	16.3	18.4	16.0	12.7
29	---	3.2	4.8	5.3	5.6	7.8	11.6	15.1	16.4	18.4	15.9	12.6
30	---	3.1	4.9	5.3	5.7	8.1	11.6	15.1	16.4	18.5	15.8	12.5
31	---	3.0	---	5.3	---	8.3	11.7	---	16.4	---	15.7	12.4
Mean	1.1	3.1	3.9	5.0	5.2	6.5	10.6	14.2	16.0	17.5	16.3	13.9
Maximum	2.3	3.6	4.9	5.3	5.7	8.3	11.8	15.4	16.4	18.5	18.7	15.7
Minimum	.6	3.0	2.9	4.9	4.9	5.9	8.5	11.8	15.1	16.5	11.6	12.4

Table 27. Mean daily temperature of water from the Cedar Rapids municipal water-treatment plant, February 1, 1993, through January 31, 1994

[Temperatures given in degrees Celsius; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	10.7	8.0	7.8	11.4	12.9	16.8	16.7	16.4	14.2	11.5	---
2	---	10.8	6.8	7.9	11.2	13.5	16.9	16.8	16.3	14.2	11.3	---
3	---	10.7	6.6	7.9	11.8	13.0	17.0	16.5	15.9	14.1	11.3	---
4	---	10.5	6.8	8.0	12.0	13.3	16.9	17.5	15.9	14.1	11.2	---
5	---	10.5	6.4	8.1	11.3	13.3	17.1	17.3	15.8	14.1	11.0	9.7
6	---	10.5	6.7	8.3	10.8	14.0	17.3	16.8	15.6	14.0	---	9.5
7	---	10.5	7.2	8.7	11.5	14.0	16.7	17.3	16.2	13.8	11.0	9.4
8	---	10.5	---	8.2	12.2	---	16.6	16.8	15.9	13.8	10.9	9.3
9	---	10.3	---	8.5	12.1	---	17.3	16.8	15.8	13.7	10.8	8.9
10	---	---	5.9	8.8	11.5	---	16.7	17.1	15.8	13.5	10.6	8.4
11	---	9.3	6.0	9.6	11.5	---	16.4	17.2	15.3	13.4	10.7	8.5
12	---	9.4	6.3	9.7	11.7	---	16.9	17.2	15.7	13.1	10.7	8.9
13	---	9.7	6.6	9.7	11.8	---	17.0	17.6	15.6	13.2	10.4	8.6
14	---	9.5	6.7	9.9	12.2	---	16.3	16.3	15.6	13.2	10.7	8.5
15	---	9.4	6.8	9.8	12.1	---	17.3	16.2	15.7	13.0	10.7	8.7
16	---	8.8	6.8	10.3	12.7	---	17.3	17.0	15.5	12.6	10.6	8.4
17	11.0	8.8	7.1	10.7	12.2	15.0	16.7	16.2	15.5	13.0	10.3	8.2
18	11.4	9.4	7.1	11.2	11.1	14.7	16.7	16.0	15.3	13.1	---	8.4
19	11.1	9.0	7.0	11.3	11.2	15.1	17.2	16.0	14.8	12.8	10.2	8.7
20	10.9	9.0	7.2	11.5	11.7	15.6	17.0	16.6	14.6	12.7	10.1	8.4
21	10.5	9.0	7.3	11.0	11.8	15.3	16.4	16.8	14.6	12.5	10.1	---
22	10.4	9.6	7.5	10.8	12.0	14.7	16.4	16.9	14.5	12.5	10.1	8.4
23	10.8	9.5	7.4	10.9	11.3	15.1	16.6	16.8	14.5	12.4	10.1	8.5
24	10.6	9.3	7.5	10.7	11.9	15.7	16.6	16.9	14.8	12.4	10.3	8.8
25	10.6	---	7.6	10.8	12.2	16.3	16.3	17.1	14.8	12.4	10.2	8.4
26	10.5	9.5	7.5	11.1	12.2	15.6	16.6	17.0	14.7	12.6	---	7.9
27	10.5	9.4	7.7	11.2	12.6	16.3	17.5	16.9	14.6	12.9	---	7.8
28	10.6	8.9	7.9	11.0	12.9	16.6	16.7	16.8	14.5	12.8	---	8.1
29	---	8.5	8.1	10.8	12.7	16.5	16.8	16.5	14.4	12.1	---	8.0
30	---	8.0	7.7	11.0	12.7	15.8	17.0	16.6	14.3	11.8	---	8.7
31	---	8.1	---	11.1	---	16.2	16.9	---	14.2	---	---	8.4
Mean	10.7	9.6	7.1	9.9	11.9	14.9	16.8	16.8	15.3	13.1	10.6	8.6
Maximum	11.4	10.8	8.1	11.5	12.9	16.6	17.5	17.6	16.4	14.2	11.5	9.7
Minimum	10.4	8.0	5.9	7.8	10.8	12.9	16.3	16.0	14.2	11.8	10.1	7.8

Table 28. Mean daily concentration of dissolved oxygen in water from the Cedar River, surface-water monitoring site, February 1, 1993, through January 31, 1994

[Dissolved-oxygen concentration given in milligrams per liter; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	12.0	14.6	10.4	9.7	9.3	7.0	6.2	7.7	11.1	14.8	14.0	13.9
2	12.2	14.7	11.3	9.5	8.8	6.9	6.6	7.8	11.3	14.4	13.7	13.7
3	12.1	15.2	11.9	9.2	8.7	6.7	6.7	8.0	11.5	14.1	13.5	13.3
4	12.2	15.1	12.4	9.5	8.4	6.6	6.8	8.0	11.5	13.5	13.0	13.1
5	12.3	14.4	12.2	9.8	8.4	6.7	7.1	8.0	11.5	12.6	12.7	13.1
6	12.1	13.7	11.8	9.7	8.3	6.7	7.6	8.2	11.6	13.4	13.5	13.0
7	12.2	12.9	11.3	9.1	8.0	6.8	7.8	8.6	11.3	14.3	14.5	12.9
8	12.2	12.3	10.8	8.6	7.4	6.9	7.7	8.8	10.8	14.1	14.5	12.9
9	12.3	11.9	---	8.5	6.9	6.7	7.7	8.9	11.1	13.5	14.1	12.7
10	12.3	12.1	10.7	8.4	6.7	6.3	6.9	9.1	10.5	12.7	13.8	12.5
11	11.9	12.2	10.5	8.5	6.5	6.2	6.8	9.1	11.0	12.4	14.6	12.3
12	11.2	12.8	10.7	8.4	6.4	6.2	7.0	9.1	11.5	11.7	14.9	12.1
13	11.2	13.4	10.9	8.3	6.4	6.4	6.9	8.5	12.3	11.1	14.3	11.9
14	11.8	13.7	11.0	8.2	6.3	6.5	6.7	8.1	12.3	11.1	13.8	11.8
15	---	13.9	11.5	8.2	6.4	6.5	6.4	8.5	11.5	11.4	13.7	11.8
16	---	14.2	12.2	8.4	7.1	6.9	6.4	9.1	10.9	11.7	13.4	11.7
17	---	14.6	12.2	8.4	7.6	7.1	6.3	9.5	10.6	11.9	13.1	11.6
18	---	14.7	11.6	---	7.4	6.8	6.4	9.1	10.8	12.0	---	11.5
19	---	14.7	11.0	---	7.2	6.8	6.1	8.9	10.9	11.9	12.9	11.3
20	---	14.6	10.9	---	6.9	6.9	6.0	8.9	10.5	12.1	13.1	11.2
21	---	14.7	11.0	---	7.2	6.9	6.2	8.9	11.3	12.2	13.8	11.0
22	---	15.0	10.8	9.3	7.1	6.9	6.4	8.8	12.1	12.0	14.4	10.7
23	---	15.1	10.3	9.0	6.8	7.1	6.4	8.8	12.2	12.5	14.7	10.7
24	---	14.6	9.8	9.0	6.5	7.2	6.9	9.6	12.2	12.4	14.9	10.7
25	---	14.0	9.5	9.5	6.7	7.1	7.3	9.9	12.1	12.3	14.6	10.7
26	---	12.9	9.4	9.8	6.9	7.0	7.1	9.9	11.4	13.1	14.2	10.9
27	14.5	12.6	9.6	9.6	6.9	6.8	7.0	10.2	11.8	13.6	13.8	11.0
28	14.5	11.7	9.8	8.6	6.9	6.6	7.0	10.5	12.9	13.9	13.8	11.0
29	---	10.9	9.8	8.1	7.1	6.4	7.2	11.1	13.4	14.1	14.0	11.1
30	---	9.9	9.9	8.6	7.0	6.5	7.2	11.1	13.9	14.0	14.4	11.2
31	---	9.2	---	9.0	---	6.4	7.4	---	14.6	---	14.2	11.3
Mean	12.3	13.4	10.9	8.9	7.3	6.7	6.8	9.0	11.7	12.8	13.9	11.9
Maximum	14.5	15.2	12.4	9.8	9.3	7.2	7.8	11.1	14.6	14.8	14.9	13.9
Minimum	11.2	9.2	9.4	8.1	6.3	6.2	6.0	7.7	10.5	11.1	12.7	10.7

Table 29. Mean daily concentrations of dissolved oxygen in water from observation well CRM-4, February 1, 1993, through January 31, 1994

[Dissolved-oxygen concentration given in milligrams per liter; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	5.2	---	0.8	5.2	2.4	0.9	1.9	0.2	4.3	5.4	9.9	11.0
2	5.4	---	.8	5.0	2.7	.8	2.1	.1	4.4	6.0	10.1	11.2
3	5.8	9.7	.8	4.8	2.5	---	2.0	.2	4.7	6.8	10.6	11.7
4	6.4	7.9	.8	4.3	1.9	---	1.4	.3	5.1	7.7	11.0	---
5	6.0	8.9	.8	3.9	1.5	---	2.0	.4	5.1	8.5	11.0	11.5
6	5.7	8.2	.8	3.8	2.1	---	2.2	1.0	5.2	8.7	11.4	10.9
7	5.7	6.6	.7	3.5	2.4	---	2.2	1.3	5.2	8.4	11.3	10.2
8	6.0	4.0	.7	3.3	2.6	---	1.3	1.6	4.8	7.0	10.9	9.8
9	6.1	1.1	---	3.3	2.4	---	1.1	1.7	4.9	6.6	10.6	10.0
10	5.8	.8	.8	3.1	1.7	---	1.3	---	---	7.3	11.0	10.2
11	---	.7	.8	2.7	1.6	---	.9	1.5	---	7.7	11.0	9.9
12	---	.6	1.3	2.6	1.5	---	2.0	1.8	---	7.6	10.9	9.7
13	7.4	.6	3.6	3.0	.8	---	1.9	2.0	---	7.5	10.8	9.4
14	6.8	.6	3.8	2.3	.7	---	.5	2.5	1.7	7.1	10.7	9.1
15	6.4	.5	4.8	1.2	.7	---	.2	3.2	1.6	6.7	10.6	8.6
16	6.0	.5	5.5	2.2	1.2	---	.2	3.2	1.9	6.0	10.6	8.3
17	7.5	.6	---	2.8	.6	.3	.3	2.7	2.3	5.7	10.6	8.4
18	8.8	---	---	2.7	.4	.3	.2	2.3	2.0	6.0	11.0	---
19	9.0	2.2	---	3.1	1.7	.3	.5	3.1	1.2	6.5	11.1	---
20	8.4	2.6	---	3.0	2.0	.3	.2	3.8	.6	6.5	---	---
21	9.5	4.2	---	3.1	1.5	.3	.2	4.1	.7	6.3	11.7	---
22	9.0	4.5	---	3.4	.5	.3	.2	3.8	.9	6.3	8.5	6.7
23	6.8	3.8	---	4.0	.4	.3	.2	3.7	1.1	6.9	4.8	6.5
24	7.6	3.4	7.1	4.3	.4	.3	.2	---	1.4	7.6	7.7	6.4
25	9.6	3.7	6.6	4.5	.3	.6	.2	4.1	3.5	7.7	11.4	6.0
26	9.4	3.8	6.1	4.5	.3	1.2	.2	4.4	4.8	7.6	11.9	5.7
27	9.3	3.1	5.2	4.5	.3	1.2	.2	4.6	4.5	7.7	12.2	5.5
28	---	2.0	4.5	5.1	.4	1.4	.2	4.4	4.9	7.8	12.3	5.3
29	---	1.0	4.2	4.7	.4	2.6	.2	4.2	4.4	8.2	12.0	5.0
30	---	.9	5.2	3.7	.7	2.4	.2	4.1	3.4	9.2	11.7	4.7
31	---	.9	---	2.7	---	2.3	.2	---	4.6	---	11.2	4.4
Mean	7.2	3.1	3.0	3.6	1.3	.9	.9	2.5	3.3	7.2	10.7	8.3
Maximum	9.6	9.7	7.1	5.2	2.7	2.6	2.2	4.6	5.2	9.2	12.3	11.7
Minimum	5.2	.5	.7	1.2	.3	.3	.2	.1	.6	5.4	4.8	4.4

Table 30. Mean daily concentration of dissolved oxygen in water from municipal well Seminole 10, February 1, 1993, through January 31, 1994

[Dissolved-oxygen concentration given in milligrams per liter; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	0.4	---	---	1.6	0.8	---	0.4	0.5	2.4	4.6	8.6	11.3
2	.4	---	---	1.3	.7	.5	.4	.5	2.5	4.2	8.5	11.5
3	.4	9.6	---	1.3	.7	.6	.4	.5	2.7	4.1	8.6	11.3
4	---	9.2	---	1.2	.7	.6	.4	.5	2.9	4.3	8.9	---
5	.6	9.2	---	1.2	.6	.6	.4	.5	3.1	4.9	9.4	11.0
6	.5	9.1	---	.9	.6	.6	---	.5	3.3	5.7	10.3	10.9
7	.5	8.8	---	1.1	.8	.6	1.0	.5	3.4	6.6	10.9	11.0
8	---	8.4	---	1.0	.7	.6	1.5	.5	3.6	7.5	10.6	11.1
9	---	8.2	---	.9	.7	.6	.7	.5	3.8	7.4	10.5	11.1
10	.4	8.0	1.0	.9	.7	.6	.5	.5	3.8	7.2	5.1	10.9
11	2.5	7.2	1.0	.9	.7	.6	.5	.4	3.9	7.0	4.0	10.6
12	5.2	5.8	.9	.9	.9	.6	.6	.4	3.9	6.8	3.1	10.4
13	6.4	4.0	.9	.9	.7	.6	.7	.4	3.8	6.7	2.5	10.1
14	7.2	2.5	.9	.7	.7	.6	.5	.5	3.4	7.1	2.0	10.0
15	7.5	1.8	.9	.7	.7	.6	.6	.4	3.1	7.7	1.6	9.8
16	7.6	1.4	.9	.7	.7	.9	.5	.4	2.9	8.0	1.4	9.8
17	4.6	1.2	.9	.6	.7	.7	.4	.4	2.7	7.9	1.2	---
18	4.2	1.4	.8	.7	.6	.7	.4	.4	2.8	7.8	1.2	---
19	2.6	1.3	.8	.7	.6	.6	.4	.5	3.2	7.6	1.1	---
20	1.9	1.2	.8	.7	.6	.6	.4	.5	3.3	7.4	1.0	---
21	7.1	1.5	.9	.7	.6	.5	.4	.6	3.0	7.2	5.6	---
22	6.3	2.1	1.2	.7	.6	.5	.4	1.0	2.6	6.9	9.8	7.6
23	6.0	3.0	1.4	.7	.6	.5	.4	1.3	2.4	7.2	9.7	7.4
24	6.9	3.9	1.7	.7	.6	.5	---	1.5	2.5	7.4	9.5	7.1
25	7.8	4.5	1.9	.7	.6	.5	.5	1.7	2.7	7.6	8.6	6.9
26	7.8	5.0	2.0	.7	.6	.5	.5	1.8	3.1	7.8	7.5	6.8
27	---	---	2.1	.7	.6	.5	.5	1.9	3.8	8.0	6.7	6.7
28	---	---	2.3	.7	.6	.5	.5	2.0	4.5	8.3	7.0	6.6
29	---	---	2.2	.7	.6	.5	.5	2.3	4.7	8.5	7.8	6.4
30	---	---	2.0	.7	---	.5	.5	2.4	4.9	8.6	9.3	6.2
31	---	---	---	.8	---	.5	.5	---	4.9	---	10.6	6.0
Mean	4.1	4.9	1.3	.9	.7	.6	.5	.9	3.3	6.9	6.5	9.1
Maximum	7.8	9.6	2.3	1.6	.9	.9	1.5	2.4	4.9	8.6	10.9	11.5
Minimum	.4	1.2	.8	.6	.6	.5	.4	.4	2.4	4.1	1.0	6.0

Table 31. Mean daily concentrations of dissolved oxygen in water from observation well CRM-3, February 1, 1993, through January 31, 1994

[Dissolved-oxygen concentration given in milligrams per liter; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	---	0.5	0.6	0.4	---	0.3	0.4	0.3	0.3	0.3	0.3
2	---	---	.5	.5	.4	0.9	.3	.4	.3	.3	.3	.3
3	---	0.8	.5	.5	---	.4	.3	.4	.3	.3	.2	.3
4	---	.4	.5	.5	---	.4	.3	.4	.3	---	.2	---
5	---	---	.4	.5	.5	.4	.3	.4	.3	.3	.2	1.0
6	---	---	.4	.5	.4	.4	---	.4	.3	.3	---	.6
7	---	---	.4	.5	.4	.4	.3	.4	.3	.3	.3	.5
8	---	---	.4	.5	.4	.4	.4	.4	.3	.3	.3	.4
9	---	---	---	.5	.4	.4	.3	.4	.3	.3	.3	.4
10	3.1	.4	---	.5	.4	.4	.3	---	.3	.2	.3	.3
11	2.4	.4	.5	.5	.4	.4	.3	.4	.3	.3	.3	.3
12	1.1	.3	.5	.5	.4	.4	.3	.3	.3	.3	.3	.3
13	.3	.3	.5	.4	.4	.4	.3	.4	---	.3	.3	.3
14	.2	.3	.5	.4	.4	.4	.3	.4	.3	.3	.3	.3
15	.2	.4	.5	.4	.4	.4	.3	.4	.3	.3	.3	.3
16	.2	.4	.5	.4	---	---	.3	.3	.4	.3	.3	.3
17	.4	.4	.5	.4	---	.5	.3	.3	.4	.3	.3	.3
18	---	---	.5	---	.4	.4	.3	.3	.4	.3	---	.3
19	---	---	.5	---	.4	.4	.3	.3	.4	.3	.4	.3
20	.6	.4	.5	.5	.4	.4	.3	.3	.4	.3	---	.3
21	.6	.4	.5	.5	.4	.4	.3	.3	.4	.3	.4	---
22	.5	.4	.5	.5	.4	.4	.3	.3	.3	.3	.4	.2
23	.5	.4	---	.5	.4	.4	.3	.3	.3	---	.3	.3
24	.5	.4	.8	.5	---	.4	---	---	.4	---	.3	.3
25	.5	---	.7	.5	.4	.4	.4	.4	.4	.2	.3	.3
26	.5	---	.6	.4	.4	.4	.4	.3	.3	.2	.3	.3
27	---	1.9	.6	.4	.4	.4	.4	.3	.3	.3	.3	.3
28	---	1.4	.6	.4	.4	.4	.4	.3	---	.2	.3	.3
29	---	.8	.6	.4	.4	.4	.4	.3	.3	.3	.3	.3
30	---	.5	.6	.4	.4	.4	.4	.3	.3	.3	.3	.3
31	---	.5	---	.4	---	.3	.4	---	.3	---	.3	.2
Mean	.8	.6	.5	.5	.4	.4	.3	.3	.3	.3	.3	.3
Maximum	3.1	1.9	.8	.6	.5	.9	.4	.4	.4	.3	.4	1.0
Minimum	.2	.3	.4	.4	.4	.3	.3	.3	.3	.2	.2	.2

Table 32. Mean daily concentrations of dissolved oxygen in the water from the Cedar Rapids municipal water-treatment plant, February 1, 1993, through January 31, 1994
[Dissolved-oxygen concentration given in milligrams per liter; ---, no data]

Day	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
1	---	0.7	0.6	1.5	1.4	1.1	8.8	1.0	1.1	1.3	2.7	---
2	---	.7	.6	1.2	1.4	1.1	8.8	1.0	1.0	1.3	2.7	---
3	---	.5	.7	1.2	1.4	1.1	8.4	1.0	.9	1.3	2.7	---
4	---	.6	1.4	1.3	1.4	1.0	8.2	.9	1.0	1.3	2.7	---
5	---	.7	.9	1.3	1.4	.9	8.1	.9	1.1	1.2	2.7	2.8
6	---	.7	.6	1.2	1.4	1.0	---	.9	1.0	1.2	---	2.7
7	---	.7	---	1.4	1.4	1.0	1.1	.9	1.0	1.2	1.7	2.5
8	---	.7	---	1.5	1.5	---	1.0	.9	1.0	1.2	1.8	2.6
9	---	.8	---	2.9	1.5	---	1.1	.9	.8	1.3	1.7	2.8
10	---	---	1.5	3.0	1.7	---	1.0	.9	.8	1.8	1.7	2.8
11	---	1.1	1.4	2.9	1.6	---	1.0	.9	.8	3.2	1.7	2.5
12	---	1.0	1.4	2.8	1.5	---	1.0	1.0	.8	3.6	1.6	2.4
13	---	1.0	1.2	2.9	1.4	---	1.0	1.0	1.1	3.7	1.7	2.4
14	---	1.0	1.0	2.6	1.4	---	.9	.8	1.4	3.9	1.5	2.9
15	---	.9	.8	2.0	1.4	---	.9	.8	1.4	3.5	1.6	2.4
16	---	.9	.8	2.0	1.3	---	.9	.8	1.3	3.7	1.6	2.3
17	0.7	1.0	.7	2.3	1.4	11.2	.9	.8	1.5	3.2	1.6	2.5
18	1.3	.9	1.0	2.5	2.9	10.3	.8	.8	1.5	2.5	---	2.9
19	1.1	.9	1.4	2.4	3.1	10.6	.8	.8	1.4	2.6	2.3	2.6
20	.9	.9	1.4	2.6	3.9	10.7	.8	.8	1.4	2.7	2.4	2.5
21	.8	.8	1.4	---	3.1	10.7	.8	.8	1.3	2.8	2.6	---
22	.7	.8	1.4	1.6	3.9	10.1	.8	.8	1.3	2.7	2.6	2.3
23	.8	.7	1.5	1.6	4.5	9.7	.8	1.0	1.2	---	2.5	2.8
24	.7	.7	1.6	1.5	3.8	9.0	.9	1.2	1.1	2.5	2.5	2.7
25	.4	---	1.6	1.5	2.1	9.3	1.1	1.3	1.1	2.2	2.4	2.5
26	---	.8	1.6	1.5	1.3	9.8	1.1	1.3	1.1	2.4	---	2.8
27	.6	.9	---	1.6	1.2	9.5	1.1	1.4	1.0	2.4	---	2.9
28	.9	1.3	1.6	1.7	1.2	9.4	1.0	1.1	1.2	2.3	---	2.9
29	---	1.3	1.4	1.7	1.2	9.8	1.0	1.1	1.5	2.4	---	2.8
30	---	1.1	1.4	1.5	1.2	9.3	1.0	1.1	1.4	2.4	---	1.9
31	---	.8	---	1.5	---	8.6	1.0	---	1.3	---	---	2.2
Mean	.8	.9	1.2	1.9	1.9	7.1	2.2	1.0	1.2	2.3	2.1	2.6
Maximum	1.3	1.3	1.6	3.0	4.5	11.2	8.8	1.4	1.5	3.9	2.7	2.9
Minimum	.4	.5	.6	1.2	1.2	.9	.8	.8	.8	1.2	1.5	1.9

Table 33. Numerical range of each primary bio-indicator (particulates) counted per 100 gallons of water
[EH, extremely heavy; H, heavy; M, moderate; R, rare; NS, not significant, >, greater than; <, less than; fromVasconcelos and Harris (1992)]

Indicators for surface water[1]	EH	H	M	R	NS
Giardia[2]	>30	16 – 30	6 – 15	1 – 5	<1
Coccidia[2]	>30	16 – 30	6 – 15	1 – 5	<1
Diatoms	>150	41 –149	11 – 40	1 – 10	<1
Other algae[3]	>300	96 –299	21 – 95	1 – 20	<1
Insects/larvae	>100	31 – 99	16 – 30	1 – 15	<1
Rotifers	>150	361 –149	21 – 60	1 – 20	<1
Plant debris[3]	>200	71 –200	26 – 70	1 – 25	<1

[1] According to U.S.Environmental Protection Agency, 1991, Guidance manual for compliance with the filtration and disinfection requirements for public water systems using surface-water sources, Washington D.C.

[2] If *Giardia* cysts or coccidia are found in any sample, irrespective of volume collected, score as though the sample was counted per 100 gallons.

[3] Chlorophyll containing.

Table 34. Relative surface-water risk factors associated with scoring of primary bio-indicators (particulates) present during microscopic particulate analysis of water from the study area
[EH, extremely heavy; H, heavy; M, moderate; R, rare; NS, not significant; from Vasconcelos and Harris (1992)]

Indicators for surface water[1]	Relative risk factor[2]				
	EH	H	M	R	NS
Giardia	40	30	25	20	0
Coccidia	35	30	25	20	0
Diatoms	16	13	11	6	0
Other algae	14	12	9	4	0
Insects/larvae	9	7	5	3	0
Rotifers	4	3	2	1	0
Plant debris	3	2	1	0	0

[1] According to U.S. Environmental Protection Agency, 1991, Guidance manual for compliance with the filtration and disinfection requirements for public water systems using surface-water sources, Washington D.C.

[2] Risk of surface-water contamination:
greater than or equal to 20, high risk;
10–19, moderate risk;
0–9 low risk.