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OTTUMWA WATER AND HYDRO

Ground Water near Ottumwa, Wapello County, Iowa

Water-Resources Investigations Report 99–4055

U.S. Department of the Interior
U.S. Geological Survey

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By RONALD L. KUZNIAR

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Iowa City, Iowa
1999

U.S. Department of the Interior

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CONVERSION FACTORS, ABBREVIATED WATER-QUALITY UNITS, AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
feet per second (ft/s)	30.48	centimeter per second
mile (mi)	1.609	kilometer
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
gallon per minute (gal/min)	0.06309	liter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch (in.)	25.4	millimeter

Abbreviated water-quality units used in this report: Chemical concentrations are given in metric units. Chemical concentration is given in milligrams per liter (mg/L). Milligrams per liter expresses the concentration of chemical constituents in solution as weight (milligrams) or solute per unit volume (liter) of water. For concentrations less than 7,000 mg/L, the numerical value of milligrams per liter is the same as for concentrations in part per million.

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.

Altitude, as used in this report, refers to distance above or below sea level.

Ground Water near Ottumwa, Wapello County, Iowa

By Ronald L. Kuzniar

Abstract

Ottumwa obtains its municipal water supply from the Des Moines River and from pools excavated in alluvial material near the river. Seasonal patterns of water quality in the Des Moines River and the level of treatment required for surface water were concerns that led to further investigation of ground-water sources. Whereas river flows are sufficient to meet current water demands, an additional source of water is desirable to supplement withdrawals from the river and the pools, especially during periods of degraded water quality in the Des Moines River.

Available hydrologic and geologic information was compiled from the scientific literature and previous studies. New thickness and lithology data for the unconsolidated materials in the Des Moines River Valley were collected for this study at selected sites from May 8, 1998, through July 16, 1998.

The alluvial deposits associated with the Des Moines River Valley at Ottumwa consist of stratified sand and gravel deposits of glacial and fluvial origin. The sand and gravel commonly are interbedded with clay and silt lenses.

Thicknesses of unconsolidated materials of the Des Moines River Valley in the study area range from slightly more than 10 to more than 70 feet. Saturated thicknesses of alluvial sand and gravel deposits range from 0 to about 30 feet.

Seismic-refraction data and test-hole results indicate little potential for development of large ground-water supplies from the unconsolidated materials of the Des Moines River Valley in the study area because of the limited vertical and areal distribution of sand and gravel.

Aquifers were divided into two categories on the basis of yield—major aquifers capable of sustaining individual-well pumping rates greater than 300 gallons per minute, and minor aquifers generally capable of sustaining rates of less than 300 gallons per minute. The major aquifers that can consistently sustain large yields are part of the Cambrian-Ordovician aquifer system and occur throughout the study area and Wapello County. The minor aquifers generally are available throughout most of Wapello County.

INTRODUCTION

Ottumwa obtains its municipal water supply from the Des Moines River and from pools excavated in alluvial material near the river. Withdrawals averaged 5.5 Mgal/d in 1997 (W. Marcus, Ottumwa Water and Hydro, oral commun., 1997). Future demand from commercial, industrial, and domestic users requires a dependable source of good quality water. The river provides water of acceptable quality about 80 percent of the time, and the pools are relied upon for the other 20 percent.

Seasonal patterns of water quality in the Des Moines River and the level of treatment required for surface water were concerns that led to further investigation of ground-water sources. Whereas river flows are sufficient to meet current water demands, an additional source of water is desirable to supplement withdrawals from the river and the pools, especially during periods of degraded water quality in the Des Moines River.

To help address concerns about future sources of water supply, the U.S. Geological Survey (USGS), in cooperation with Ottumwa Water and Hydro, conducted a study to provide information about the sources of ground water (unconsolidated and bedrock aquifers) in Wapello County, particularly the Ottumwa area. The objectives of the study were to: (1) describe the thickness and lithology of the unconsolidated materials in the Des Moines River Valley in the Ottumwa area and (2) briefly summarize available information on ground-water sources in the Wapello County area.

Purpose and Scope

The purpose of this report is to describe results of the study on ground-water sources in the Ottumwa area and Wapello County (fig. 1). Available hydrologic and geologic information was compiled from the scientific literature and previous studies. New thickness and lithology data for the unconsolidated materials in the Des Moines River Valley were collected for this study at selected sites from May 8, 1998, through July 16, 1998, and are presented in this report. A brief discussion of hydrologic characteristics and water quality based on data from selected previous studies is included.

The information can be used by water managers to evaluate the viability of alternate sources of water supply. Results also will provide improved understanding of ground-water resources in similar hydrogeologic settings.

Previous Investigations

Few studies related to the water resources associated with the unconsolidated materials in the study area have been conducted. On a broader scale, Norton (1897) describes the quality of water available from deep wells at selected locations in Iowa, including some within the study area. Water-use and conservation topics for the Des Moines River Basin are reported by the Iowa Natural Resources Council (1953). Information on the occurrence, availability, quality, and utilization of water in southeast Iowa is presented in Coble and Roberts (1971). The occurrence of ground water and associated water-quality data in Wapello County are presented by Witinok (1979). Information about water quality and geology is available for the Mississippian aquifer (Horick and Steinhilber, 1973), the Silurian-Devonian aquifer (Horick, 1984), and the Jordan aquifer (part of the Cambrian-Ordovician aquifer system) (Horick and Steinhilber, 1978). Detroy and Skelton (1983) summarize the quality of ground water for Quaternary aquifers in southern Iowa and northern Missouri. The recharge to and ground-water movement in the St. Peter and Jordan aquifers are evaluated by Burkart and Buchmiller (1990). A comprehensive summary of geology, geography, and hydrologic characteristics for the major aquifers in Iowa is presented by Olcott (1992).

The geology of Wapello County is described in Leonard (1902). Norton and others (1912) describe the topography and distribution of glacial materials in Wapello County. The bedrock topography of southeast Iowa is mapped by Hansen (1973). A soil survey prepared by U.S. Department of Agriculture (USDA) for Wapello County provides detailed information on soil types, drainage, and agricultural development (Seaholm, 1981). A localized study investigated sites near the Des Moines River within Ottumwa municipal limits by test boring to describe alluvial materials (Hydro Group, Inc., Ranney Division, written commun. to Ottumwa Water and Hydro, 1984).

Description of Study Area

Ottumwa, Iowa, is located in the valley of the Des Moines River and has an economy based on agriculture and light industry. Ottumwa is the county seat for Wapello County and has a population of about 24,500 (U.S. Department of Commerce, 1990).

Two major drainage systems receive runoff from Wapello County. About 70 percent of the county is drained by the Des Moines River and its tributaries, and 30 percent is drained by Cedar Creek, a tributary of the Skunk River. The flow of the Des Moines River has been regulated by the U.S. Army Corps of Engineers since 1969 at Lake Red Rock, located 48 mi upstream from Ottumwa. Prior to regulation, the average annual discharge of the Des Moines River at Ottumwa (USGS stream-gaging station identification number 05489500[1]) was 4,669 ft^3/s (Coble and Roberts, 1971). Since regulation began, average annual discharge at Ottumwa has been 8,271 ft^3/s (May and others, 1996). The width of the Des Moines River Valley is about 0.75 mi wide upstream from Ottumwa and

[1]Real-time stage and discharge data for this stream-gaging station can be accessed through the Internet at:
http://wwwdiaiwc.cr.usgs.gov/data.html

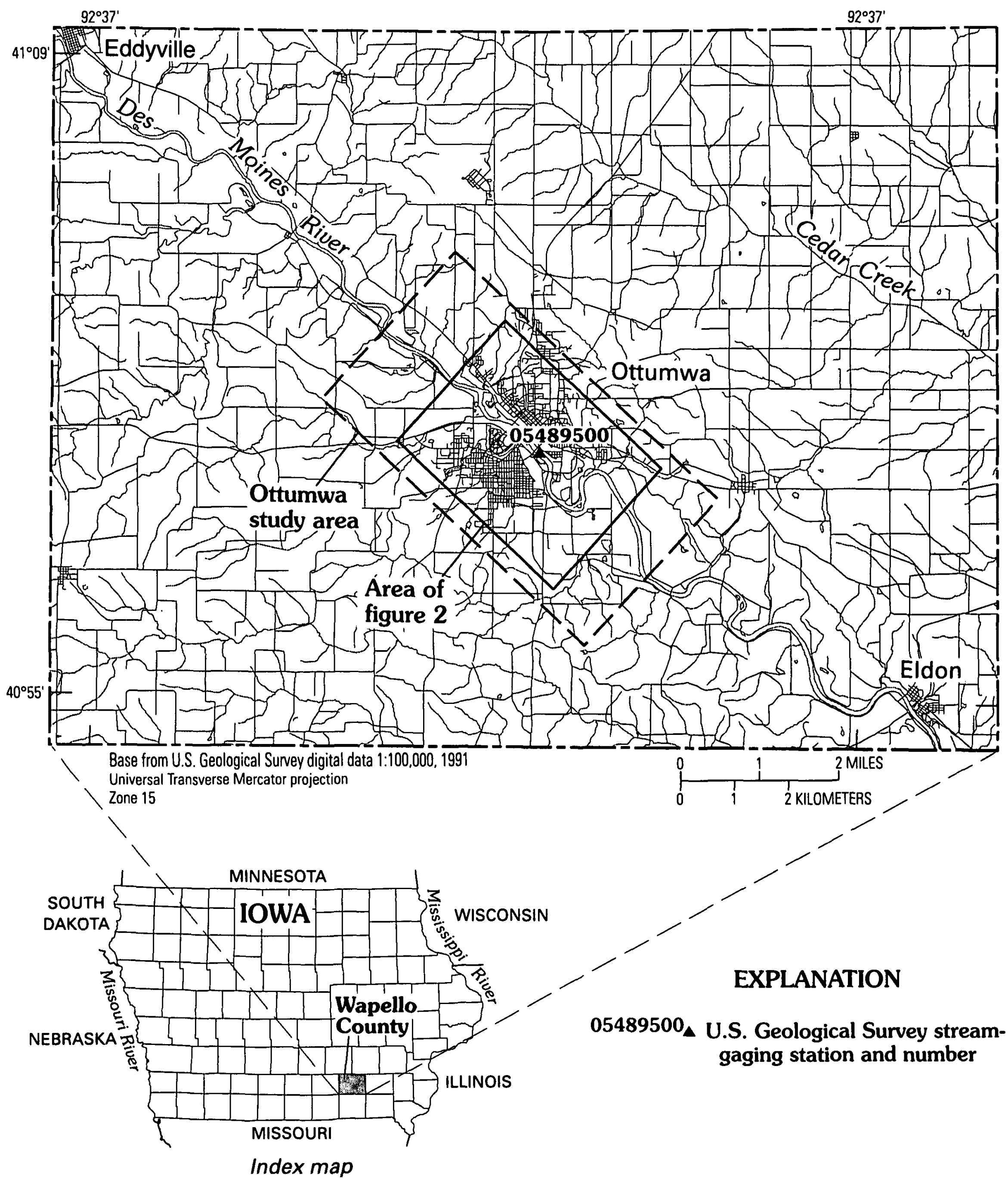


Figure 1. Location of Wapello County and Ottumwa study area in Iowa.

gradually widens to about 1.25 mi downstream from Ottumwa.

The topography of Wapello County is dominated by nearly level to slightly rolling hills in the upland areas. Total altitude change from the upland areas to the Des Moines River Valley is about 150 ft. The land-surface altitude of the river valley in the Ottumwa area varies from about 640 to 650 ft above sea level, and adjacent upland areas rise to about 800 ft.

Wapello County is covered mostly by unconsolidated materials of glacial or alluvial origin. The thickness of these materials ranges from zero (in small areas where bedrock is exposed) to about 320 ft. The underlying bedrock is layered sedimentary rocks hundreds of feet thick. This geologic framework contains the hydrogeologic units described in table 1.

Acknowledgments

The author thanks the city of Ottumwa, Wapello County, and the Wapello Rural Water Association for assistance in gathering technical information. The author also thanks Peter Schulmeyer and Brian Lanning, USGS, for assisting with data collection and compilation. The author is grateful to landowners in the Ottumwa area who granted access to their property for collection of data.

Table 1. Description of hydrogeologic units in southeast Iowa

Hydrogeologic unit[1]	General thickness (feet)[1] (approximate in Wapello County)	Age of rock unit[2]	Potential well yield (gallons per minute)	Lithology[1]
Alluvial, glacial-drift, and buried-channel aquifers	0–320	Quaternary	0–100 or greater	Sand, gravel, silt, clay, boulders, and till
Confining unit	0–370	Pennsylvanian	Very small	Shale, sandstone, siltstone, limestone, and coal
Mississippian aquifer	(30–500)	Mississippian	20–50	Limestone, dolomite, and shale (gypsum and anhydrite occur locally)
Confining unit	0–425	Devonian	Very small	Siltstone, limestone, shale, dolomite, and siltstone
Silurian-Devonian aquifer	(300–400)	Devonian and Silurian	20–50	Limestone, dolomite, and shale
Confining unit	150–600	Ordovician	Very small	Dolomite, shale, chert, limestone, and sandstone
Cambrian-Ordovician aquifer system				
Cambrian-Ordovician aquifer	550–750			
St. Peter aquifer	(0–50)	Ordovician	50–300	Sandstone
Prairie du Chien aquifer (confining unit in upper part; aquifer in lower part)	(400)		No data	Dolomite and sandstone
Jordan aquifer	(60–100)	Cambrian	1,000 or greater[3]	Sandstone
Confining unit	540	Cambrian	Very small	Dolomite, siltstone, and sandstone
Dresbach aquifer[4]		Cambrian		
Ironton-Galesville aquifer	50–150		No data	Sandstone
Confining unit	no data		Very small	Shale, siltstone, and sandstone
Mt. Simon aquifer	(100–250)		No data	Sandstone

[1]Modified from Coble and Roberts (1971), Horick and Steinhilber (1978), and Olcott (1992).
[2]Age classification of rock units are those of the Iowa Department of Natural Resources, Geological Survey Bureau.
[3]Generally includes the lower part of the overlying Prairie du Chien aquifer.
[4]Not considered an aquifer in southeast Iowa (Coble, 1971).

DESCRIPTION OF ALLUVIAL DEPOSITS AT OTTUMWA

The alluvial deposits associated with the Des Moines River Valley at Ottumwa consist of stratified sand and gravel deposits of glacial and fluvial origin. The sand and gravel commonly are interbedded with clay and silt lenses.

Collection of Seismic-Refraction and Test-Hole Data

Surface geophysics (seismic-refraction method) and test-hole drilling were used to collect geologic information for the unconsolidated material in the Des Moines River Valley. Seismic refraction was used to determine the depth to bedrock below land surface, to estimate thickness of unconsolidated materials, and to aid in selecting locations for some of the test holes drilled for this study. Test holes were drilled to determine thickness and lithology of the unconsolidated material.

For the seismic-refraction method, the contact between consolidated material (bedrock) and unconsolidated material (glacial) was determined from a contrast in seismic velocity. Seismic-refraction velocities ranged from about 1,000 ft/s in unsaturated, unconsolidated materials to about 15,000 ft/s in the Mississippian-age limestone bedrock. The refraction system consisted of a 12-channel seismograph, geophones (receivers), energy source, and related equipment. Geophones were placed in lines 550 ft long in the areas of interest, and seismic energy was supplied by striking a steel plate with a triggered hammer. Local site conditions in the urban environment precluded the use of a stronger energy source, such as explosives. Data were recorded on seismograms and then downloaded onto computer disk. Onsite calculations of the data, made on the basis of equations given by Haeni (1988), were used to maximize the quality of data-collection geometries. However, the limited energy source and equipment that determined the source-offset distance affected data quality. Final processing of the data was done using a modeling program, SIPT2V3.2 (Rimrock Geophysics, Inc., 1992). Over 8,800 linear ft of seismic-refraction data were collected during May 1998. Seismic data were collected at sections *A–A'* through *H–H'* shown in figure 2. The latitude-longitude of the data-collection points were determined by a global positioning system (GPS) for later use in plotting with geographical information system (GIS) coverages.

A total of 21 test holes were drilled during the study (fig. 3), with an average depth of 38 ft. All test holes were drilled with 4.25-in. outside-diameter (OD) solid-stem augers with a variety of cutting heads. Penetration of the bedrock could not always be achieved with spoon-type bits that typically provide the best down-hole samples; therefore, hardened cutting bits, which tend to destroy the integrity of the sample, were used as needed. All test holes drilled during the study were drilled to bedrock or to the limits of the drill rig being used. Samples of auger cuttings were collected at major lithologic changes.

Table 2 lists test-hole locations and associated geologic information. The prefix 'OTH' designates the test hole as drilled by USGS personnel in 1998. Information about unconsolidated materials, including sand and gravel thickness, for test holes designated 'RTH' were obtained from Hydro Group, Inc., Ranney Division (written commun. to Ottumwa Water and Hydro, 1984).

Test-hole results compared to the interpreted seismic data indicate differences of as much as 10 percent between drilled and estimated depth to bedrock. Seismic-refraction interpretation can give nonuniform solutions, and it may not be possible to identify the most accurate solution. The varying thickness of unconsolidated materials interpreted on the basis of seismic data may be caused by the weak energy source and equipment limitations mentioned earlier.

Geologic sections in figures 4 and 5 were constructed from seismic data collected along sections *A–A'* through *H–H'* and from test-hole results. The estimated thickness of unconsolidated material overlying bedrock shown in figures 4 and 5 may include the weathered part of Pennsylvanian-age rocks because acoustic properties of weathered shale, siltstone, and sandstone could be similar to that of unconsolidated materials. Thin intermediate layers of shale, siltstone, or sandstone could be hidden in the return data due to insufficient seismic-velocity contrasts. Geologic sections in figures 4 and 5 reflect the assumed level land-surface elevation of 640 ft above sea level for the river valley used by the seismic-refraction modeling program.

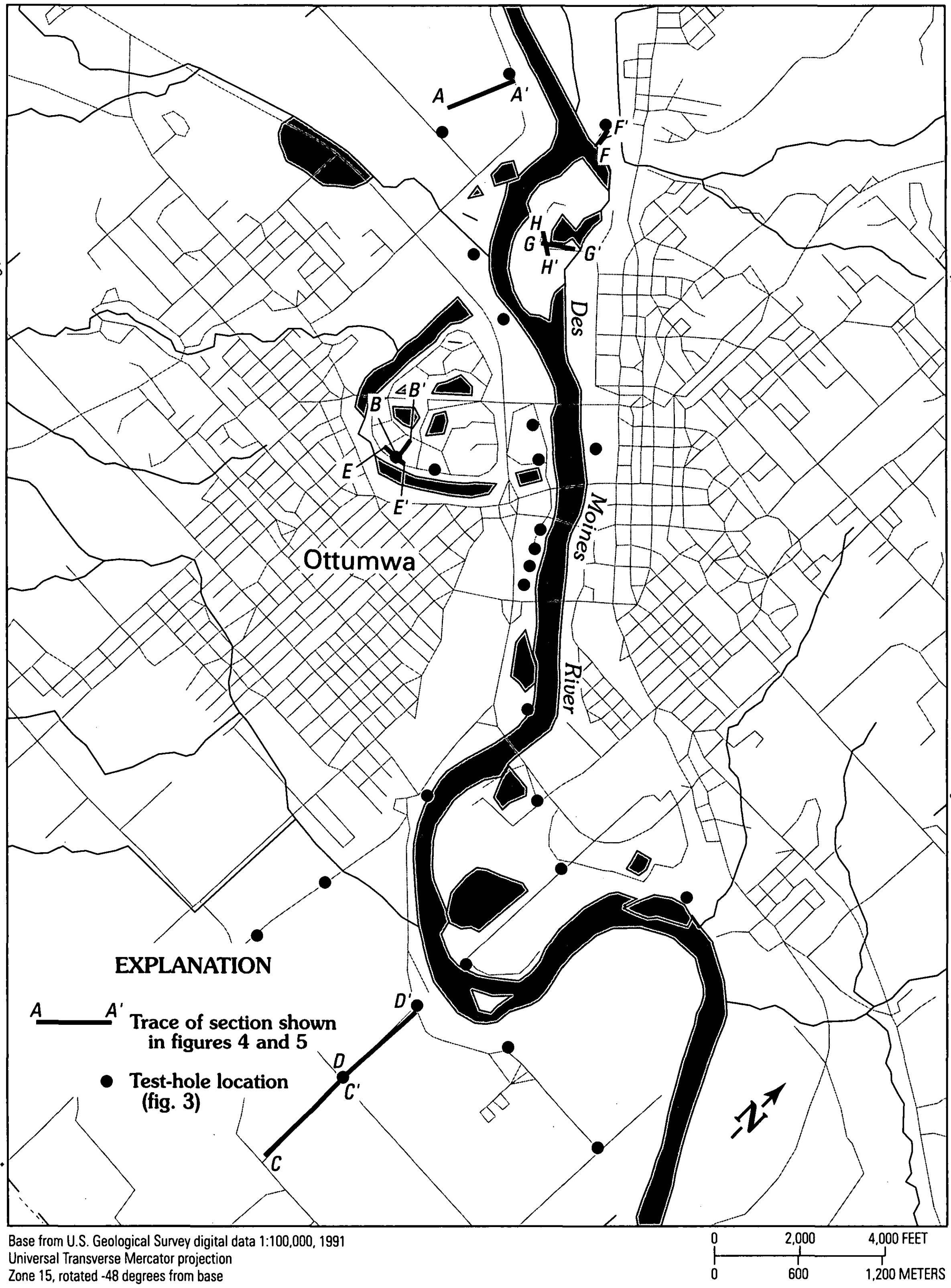


Figure 2. Location of sections *A–A'* through *H–H'*.

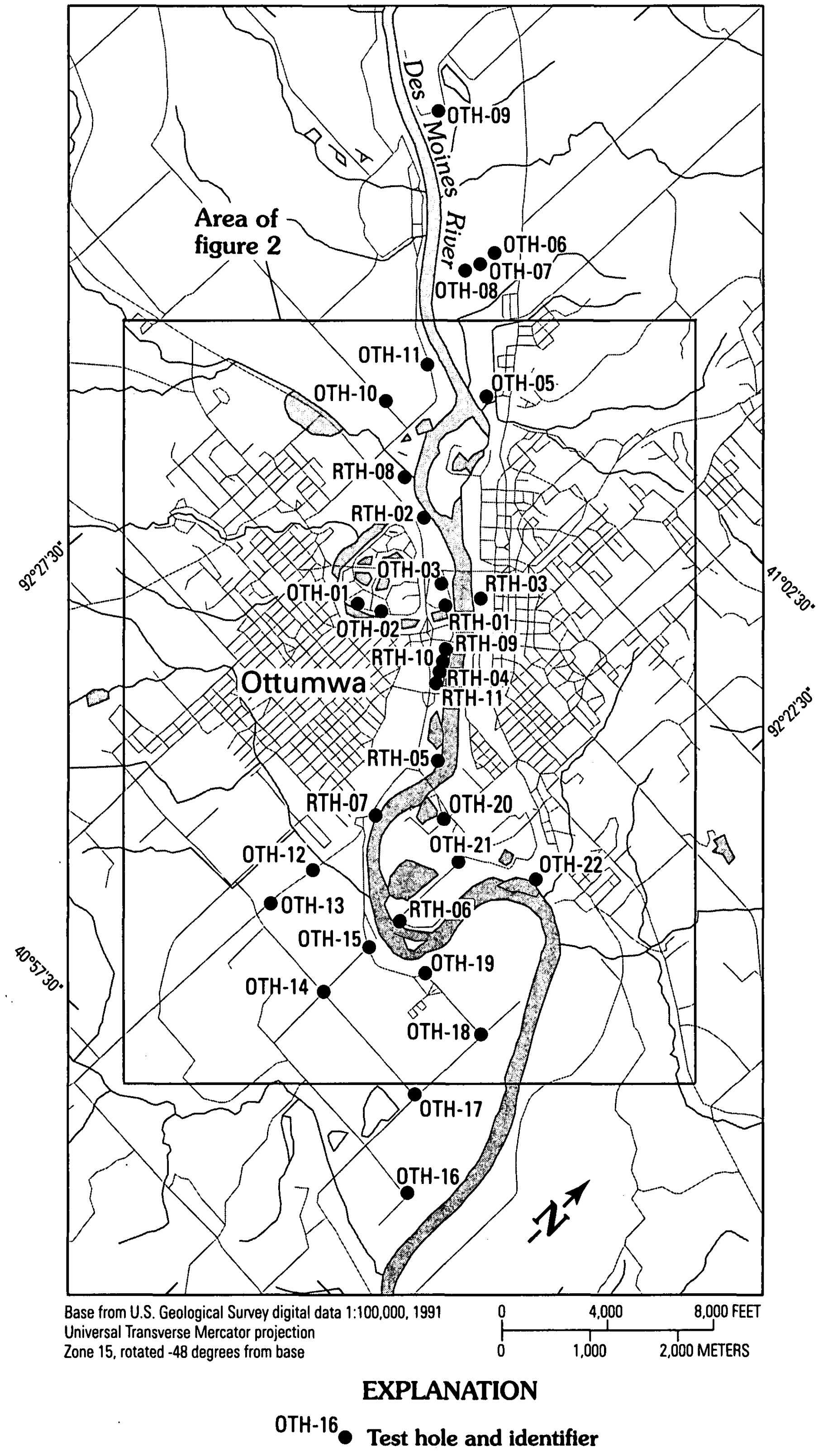


Figure 3. Location of test holes along the Des Moines River, Ottumwa, Iowa.

Table 2. Description of test holes and geologic information

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
OTH-01	T72N-R14W-25CAD	Quaternary-age alluvium		
	(41° 00' 28.04" 92° 25' 32.92")		0–1	Medium-brown, silty soil
			1–5	Medium-brown, silty fine sand
			5–6	Medium-brown, sandy silt
			6–13	Light-brown sand, fine
			13–15	Medium-brown, silty fine sand, wet (occasional methane gas pockets)
			15–21	Light-brown sand, medium
			21–22	Gravelly sand
		Pennsylvanian-age shale		
			22–24	Hard to very hard shale, poor return
			24–33	Very hard, no return
			33–35	Soft clay
		Mississippian-age limestone (?)	35	Very hard rock, no penetration, no sample
OTH-02	T72N-R14W-25CAA	Quaternary-age alluvium		
	(41° 00' 32.74" 92° 25'22.19")		0–2	Medium-brown, sandy silt
			2–4	Medium-brown, clayey silt
			4–5	Medium-brown, silty sand
			5–18	Medium-brown, sandy silt, wet at 15 feet
		Pennsylvanian-age shale		
			18–25	Shale, black, dry
			25	Very hard, no penetration
OTH-03	T72N-R14W-25ABB	Quaternary-age alluvium		
	(41° 00' 56.25" 92° 25' 12.07")		0–1	Medium-brown, sandy soil
			1–4	Medium-brown sand, fine to medium
			4–12	Dark-brown-gray silt, wet at 12 feet
			12–15	No returns
			15–25	Dark-brown, sandy silt
			25–27	Dark-gray clay, stiff
			27–32	Dark-gray sand, fine to coarse
			32–33	Stiff gray clay
			33–35	Dark-brown sand, fine to coarse
			35–36	Gray clay, stiff
			36–40	Gray to brown, silty sand, fine to medium
			40–41	Clay, stiff
			41–43	Gray to brown, silty fine sand
			43–47	Gray sandy silt
			47–48	Brown clay layered with black shale
		Pennsylvanian-age shale		
			48–58	Black to dark-gray shale
		Mississippian-age limestone	58	Limestone, very hard

Table 2. Description of test holes and geologic information—Continued

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
OTH-04	T72N-R14W-25ADB			Hole abandoned, fill area with concrete, not shown in figure 3
OTH-05	T72N-R14W-14DCD	Quaternary-age alluvium		
	(41° 01' 55.03" 92° 26' 04.22")		0–3	Dark-brown, sandy soil, road fill
			3–5	Dark-brown, silty sand, wet
			5–21	Medium-brown, sandy silt
			21–24	Medium-brown sandy, silt with gravel
		Pennsylvanian-age shale		
			24–29	Shale, very hard
			29–37	Clay, occasional sandy, gravelly lenses
		Mississippian-age limestone	37	Limestone
OTH-06	T72N-R14W-15AAA	Quaternary-age alluvium		
	(41° 02' 32.88" 92° 26' 53.40")		0–4	Medium-brown silt
			4–6	Medium-brown clay
			6–15	Medium-brown to gray, sandy clay
			15–24	Medium-brown sand, fine to medium, gravelly at 23 feet
		Pennsylvanian-age sandstone	24	Sandstone, very hard
OTH-07	T72N-R14W-15ACC	Quaternary-age alluvium		
	(41° 02' 26.09" 92° 26' 53.99")		0–2	Dark-brown silt
			2–4	Dark-brown, silty clay
			4–9	Medium-brown, clayey silt, soft
			9–16	Medium-brown to tan, silty fine sand, wet
			16–18	Dark-brown clay, stiff
			18–28	Sand, fine to very coarse, gravel at 26 feet, mostly coarse sand at 24 to 28 feet
		Pennsylvanian-age shale		
			28	Shale, black, dry
OTH-08	T72N-R14W-15CAA	Quaternary-age alluvium		
	(41° 02' 20.38" 92° 26' 56.83")		0–2	Dark-brown, silty soil
			2–4	Dark-brown silt
			4–5	Medium-brown, clayey silt
			5–12	Medium-brown to tan clay, wet at 10 feet
			12–13	Medium-brown, sandy clay
			13–16	Gray, clayey sand
			16–18	Dark-brown clay, soft
			18–24	Light-brown, silty sand, fine to coarse
		Pennsylvanian-age sandstone	24–25	Sandstone
		Pennsylvanian-age shale		
			25–28	Shale, dark-gray, dry

Table 2. Description of test holes and geologic information—Continued

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
OTH-09	T72N-R14W-09DDD	Quaternary-age alluvium		
	(41° 02' 52.41" 92° 28' 02.68")		0–3	Medium-brown, sandy silt
			3–4	Oxidized brown silt, trace fine sand
			4–12	Oxidized brown sand, fine, wet at 6 feet
		Mississippian-age limestone	12	Limestone
OTH-10	T72N-R14W-23BDC	Quaternary-age alluvium		
	(41° 01' 26.06" 92° 26' 36.14")		0–1	Medium-brown, silty soil
			1–7	Medium-brown silt, soft, wet at 6 feet
			7–10	Medium-brown, sandy silt
			10–11	Medium-brown sand, fine
			11–23	Medium-brown sand, fine to coarse
		Pennsylvanian-age sandstone	23	Sandstone, soft
OTH-11	T72N-R14W-23BAC	Quaternary-age alluvium		
	(41° 01' 46.60" 92° 26' 35.35")		0–3	Medium-brown sand, fine with pebbles
			3–5	Medium-brown, silty sand, fine
			5–13	Medium-brown, sandy silt
			13–22	Medium-brown, silty sand, fine to coarse, gravelly at 22 feet
		Mississippian-age limestone	23	Limestone
OTH-12	T71N-R13W-06BAB	Quaternary-age alluvium		
	(40° 59' 10.19" 92° 24' 12.64")		0–2	Dark-brown, pebbly silt
			2–4	Medium-brown, pebbly silt
			4–5	Dark-brown, silty sand
			5–7	Medium-brown, silty sand
			7–28	Medium-brown sand, fine to very coarse lignite chips below 20 feet, occasional gravel below 24 feet
			28–29	Dark-gray clay
			29–33	Medium-brown sand, fine to medium, with occasional gravel
			33–36	Dark-gray clay
		Pennsylvanian-age shale	36–48	Shale, black to dark gray
		Pennsylvanian-age sandstone	48	Sandstone

Table 2. Description of test holes and geologic information—Continued

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
OTH-13	T71N-R13W-06BDC	Quaternary-age alluvium		
	(40° 58' 50.26" 92° 24' 14.79")		0–2	Medium-brown silt
			2–4	Light-brown silt with pebbles
			4–5	Dark-brown silt with pebbles
			5–20	Dark-brown, silty sand, fine to coarse
			20–25	Medium-brown sand, fine to coarse, with lignite
			25–27	Medium-brown, clayey sand
			27–43	Dark- to medium-brown, silty sand, occasional gravel at 30 to 40 feet
			43–48	Light-gray clay with sand stringers
		Pennsylvanian-age shale		
			48	Shale, dark gray, very hard
OTH-14	T71N-R13W-05BCC	Quaternary-age alluvium		
	(40° 58' 43.20" 92° 23' 25.68")		0–3	Dark-brown, clayey silt
			3–7	Medium-brown, clayey silt, soft
			7–24	Medium-brown, silty sand, fine to coarse
			24–26	Dark-gray, sandy clay, occasional gravel
			26–33	Gray clay, sand and gravel lenses
		Mississippian-age limestone	33	Limestone
OTH-15	T71N-R13W-06AAD	Quaternary-age alluvium		
	(40° 59' 06.83" 92° 23' 26.31")		0–3	Road fill
			3–13	Medium-brown, clayey silt
			13–15	Medium-brown silt
			15–17	Medium-brown, silty sand
			17–26	Medium-brown sand, fine to very coarse
			16–29	Light-gray, sandy clay with gravel
			29–32	Medium-brown sand, fine to medium
			32–39	Hard and soft, gray clay lenses
			39–48	Medium-gray, sandy clay, occasional gravel
			48–53	Medium-gray clay
		Pennsylvanian-age shale		
			53	Dark-gray shale, dry

Table 2. Description of test holes and geologic information—Continued

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
OTH-16	T71N-R13W-04CDD	Quaternary-age alluvium		
	(40° 58' 16.26" 92° 21' 45.32")		0–3	Medium-brown, silty soil, limestone chips
			3–8	Medium-brown silt, stiff
			8–9	Medium-brown, clayey silt
			9–13	Medium-gray, silty clay, wet
			13–21	Gray clay
			21–33	Gray, sandy clay, poor returns
			33–38	Gray clay, stiff
			38–74	Gray clay, alternating stiff and soft layers
		Mississippian-age limestone (?)		
			74	Limestone, poor sample on bit
OTH-17	T71N-R13W-05DAA	Quaternary-age alluvium		
	(40° 58' 42.86" 92° 22' 18.33)		0–3	Medium-brown, silty sand
			3–5	Light-brown, sandy silt, limestone chips
			5–9	Medium-brown, sandy silt, limestone chips, wet
			9–23	Medium-brown, silty sand, fine to coarse
			23–25	Medium-brown, silty sand, gravel, and oxidized zone at 23 to 25 feet
			25–27	Medium-brown sand, fine to medium
			27–32	Light-gray clay, stiff
			32–33	Light-gray clay, soft, gravelly
			33–40	Light-gray clay, stiff
		Pennsylvanian-age shale		
			41	Shale, dark gray
OTH-18	T72N-R13W-32DDD	Quaternary-age alluvium		
	(40° 59' 15.99" 92° 22 18.11")		0–1	Road fill
			1–3	Dark-gray, silty soil
			3–7	Medium-brown, clayey silt
			7–17	Medium-brown silt, wet
			17–21	Dark-gray, sandy clay, gravelly at 21 feet
			21–23	Gray clay, soft
			23–28	Dark-brown clay, stiff
			28–36	Medium-gray, silty, sandy clay
			36–45	Dark-gray clay, stiff
		Pennsylvanian-age shale		
			45	Shale, hard

Table 2. Description of test holes and geologic information—Continued

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
OTH-19	T72N-R13W-05BAA	Quaternary-age alluvium		
	(40° 59' 15.84" 92° 22'58.30")		0–3	Dark-gray, silty soil
			3–6	Medium-brown silt, pebbly
			6–9	Light-brown silt
			9–10	Medium-brown silt, dry
			10–12	Medium-brown, sandy silt, fine
			12–20	Medium-brown, silty sand, fine
			20–31	Medium-brown sand, fine to coarse
			31–33	Light-gray clay
			33–38	Medium-gray, silty, clayey sand
			38–43	Gray clay, very hard
		Pennsylvanian-age sandstone	43–48	Medium-brown sand, slightly consolidated
			48–58	Medium-brown clay, occasional sand lens
		Pennsylvanian-age shale		
			58	Dark-gray shale, very hard
OTH-20	T72N-R13W-31ABD	Quaternary-age alluvium		
	(40° 59' 59.01" 92°23'47.45")		0–6	Medium-brown silt, pebbley
			6–9	Light-brown silt, wet at 7 feet
			9–17	Medium-brown, silty sand, fine to medium
			17–27	Medium-brown, sandy, pebbly clay
		Pennsylvanian-age shale		
			27–40	Shale, soft, reworked
			40–53	Dark-gray clay, thin sand stringers and pebbles
OTH-21	T72N-R13W-31AAD	Quaternary-age alluvium		
	(40°59' 52.45" 92°23' 27.30")		0–1	Road fill
			1–3	Medium-brown, sandy silt
			3–5	Dark-brown silt, powdery
			5–7	Dark-brown, clayey silt
			7–8	Medium-brown, sandy silt
			8–10	Medium-brown, sandy clay
			10–15	Medium-brown sand, fine to medium
			15–17	Medium-gray clay, stiff
			17–19	Gray, sandy clay
		Pennsylvanian-age shale		
			19	Shale, dark gray, dry

Table 2. Description of test holes and geologic information—Continued

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
OTH-22	T72N-R13W-32BAA	Quaternary-age alluvium		
	(41° 00 09.38" 92° 22' 55.26")		0–3	Medium-brown, clayey silt
			3–12	Light-brown silt, wet at 7 feet
			12–14	Light-gray, sandy silt
			14–20	Medium-gray clay with sand stringers
		Pennsylvanian-age sandstone		
			20–21	Sandstone, gritty, hard
		Mississippian-age limestone (?)	21	Limestone, poor sample on bit
RTH-01	T72N-R14W-25ACA	Quaternary-age alluvium		
			0–4	Medium-brown, sandy silt
			4–5	Medium-brown, silty, fine sand
			5–7	Medium-brown, silty sand
			7–9	Brown sand, fine
			9–11	Gray, silty sand
			11–15	Gray-black silt, trace fine sand
			15–17	Gray sand, fine to medium
		Pennsylvanian-age shale		
			17	Shale, black
RTH-02	T72N-R14W-24CBC	Quaternary-age alluvium		
			0–5	Medium-brown sand
			5–11	Medium-brown to black, clayey silt
			11–13	Medium-gray sand
			13–20	Brown-black sand, fine to coarse
			20–30	Medium-gray sand, fine to medium
		Pennsylvanian-age shale		
			30	Shale and coal
RTH-03	T72N-R14W-24DCC	Quaternary-age alluvium		
			0–4	Brown-black, clayey silt
			4–8	Black, clayey silt
			8–18	Brown-black, clayey silt
			18–24	Silty, clayey sand, fine
		Pennsylvanian-age siltstone	24	Siltstone
RTH-04	T72N-R14W-25ADD	Quaternary-age alluvium		
			0–7	Silt, organic, fill materials
			7–13	Brown sand, fine to coarse, trace gravel
			13–20	Light-brown sand, medium to coarse
		Pennsylvanian-age shale		
			20	Shale, black

Table 2. Description of test holes and geologic information—Continued

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
RTH-05	T72N-R13W-30CDD	Quaternary-age alluvium		
			0–2	Brown, clayey silt, fill
			2–6	Brown silt
			6–10	Brown sand, fine to coarse, trace gravel
			10–17	Light-brown sand, fine to coarse, trace gravel
		Pennsylvanian-age siltstone, limestone	17	Siltstone, limestone
RTH-06	T72N-R13W-32CCC	Quaternary-age alluvium		
			0–1	Soil
			1–2	Light-brown sand
			2–6	Silty, fine sand
			6–9	Black-brown silt
			9–13	Black, sandy silt
			13–18	Dark-gray to white sand, fine to coarse
		Pennsylvanian-age shale		
			18	Shale, black
RTH-07	T72N-R14W-15CAA	Quaternary-age alluvium		
			0–2	Dark-brown, silty soil
			2–6	Black, clayey silt
			6–11	Brown silt
			11–14	Brown, silty sand, fine
			14–17	Sand, fine to medium, trace gravel
		Pennsylvanian-age siltstone	17	Siltstone
RTH-08	T72N-R14W-23DBD	Quaternary-age alluvium		
			0–4	Brown-orange, clayey silt
			4–10	Gray, silty sand, fine
			10–11	Brown, silty sand, fine
			11–12	Gray silt
			12–15	Sand, fine to coarse, trace gravel
			15–27	Sand, fine to coarse, pea to large gravel
		Mississippian-age limestone	27	Limestone

Table 2. Description of test holes and geologic information—Continued

Test-hole identifier[1] (fig. 3)	Location land net[2] (degrees, minutes, seconds)	Geologic unit	Feet below land surface	Drillers' log/cuttings description[3]
RTH-09	T72N-R14W-25ADB	Quaternary-age alluvium		
			0–1	Black soil
			1–2	Brown silt
			2–4	Dark-brown silt
			4–6	Brown-orange sand, medium to coarse
			6–9	Gray-brown silt
			9–12	Gray silt
			12–17	Gray sand, fine to medium
		Pennsylvanian-age siltstone	17	Siltstone
RTH-10	T72N-R14W-25ADB	Quaternary-age alluvium		
			0–2	Silty sand, fill
			2–4	Clayey silt, fill
			4–8	Silt, fill
			8–9	Black soil
			9–13	Orange-brown sand, fine to coarse, trace gravel
			13–18	Sand, fine to coarse, trace gravel
		Pennsylvanian-age siltstone	18	Gray siltstone
RTH-11	T72N-R14W-25DAA	Quaternary-age alluvium		
			0–2	Black, clayey silt
			2–4	Brown, sandy silt, fine
			4–6	Brown, silty sand
			6–10	Brown sand, fine to medium
			10–17	Orange-brown sand, fine to coarse
		Pennsylvanian-age siltstone	17	Gray siltstone

[1]Test-hole sites OTH drilled by U.S. Geological Survey, June 2–July 16, 1998; test-hole sites RTH drilled by Hydro Group, Inc., April 16–18, 1984.

[2] Location indicated by township, range and section. The letters after the section number represent successive subdivisions of the section assigned in a counterclockwise direction beginning with 'A' in the northeast quarter. The first letter indicates a 160-acre area. Each successive letter indicates an area one-fourth the size of the area represented by the previous letter.

[3]Cuttings descriptions for RTH test-hole logs supplied in written communication from Hydro Group, Inc., Ranney Division, to Ottumwa Water and Hydro (1984).

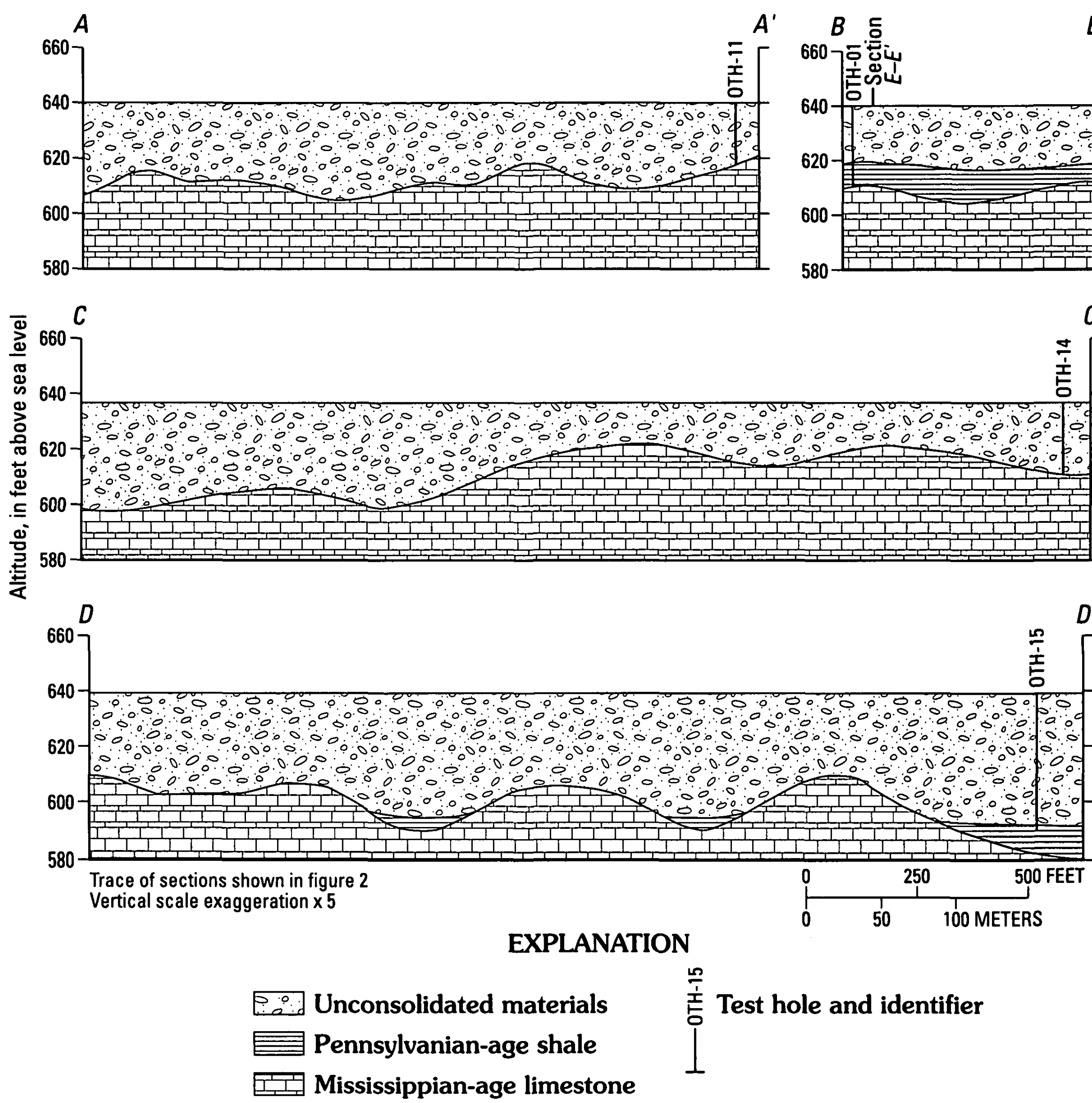


Figure 4. Geologic sections *A–A'* through *D–D'* based on seismic-refraction and test-hole data.

Thickness and Lithology

Test-hole results generally indicate that the thickness of unconsolidated materials in the river valley in the study area ranged from slightly more than 10 ft in the northern part to more than 70 ft in the southern part (fig. 6). Cumulative sand and gravel thickness in individual test holes ranged from 0 to 38 ft (table 2, fig. 7). Sand and gravel thickness varies greatly within the unconsolidated material in most areas. The vertical continuity of sand and gravel is interrupted by intermittent layers of silt and clay at most test-hole locations within the study area. Saturated thickness of sand and gravel ranged from 0 to about 30 ft.

Test-hole results at sites OTH–12 and OTH–13 on the south side of the Des Moines River represent the area having the greatest thickness of sand and gravel in the study area. Cumulative sand and gravel thicknesses at these sites are 28 and 38 ft, respectively (table 2, fig. 7). The water table averaged about 8 ft below land surface at these sites.

GROUND-WATER SOURCES IN THE WAPELLO COUNTY AREA

Hydrogeologic units underlying the Wapello County area (table 1) vary considerably in lithology, thickness, extent, and water-yielding capability. The

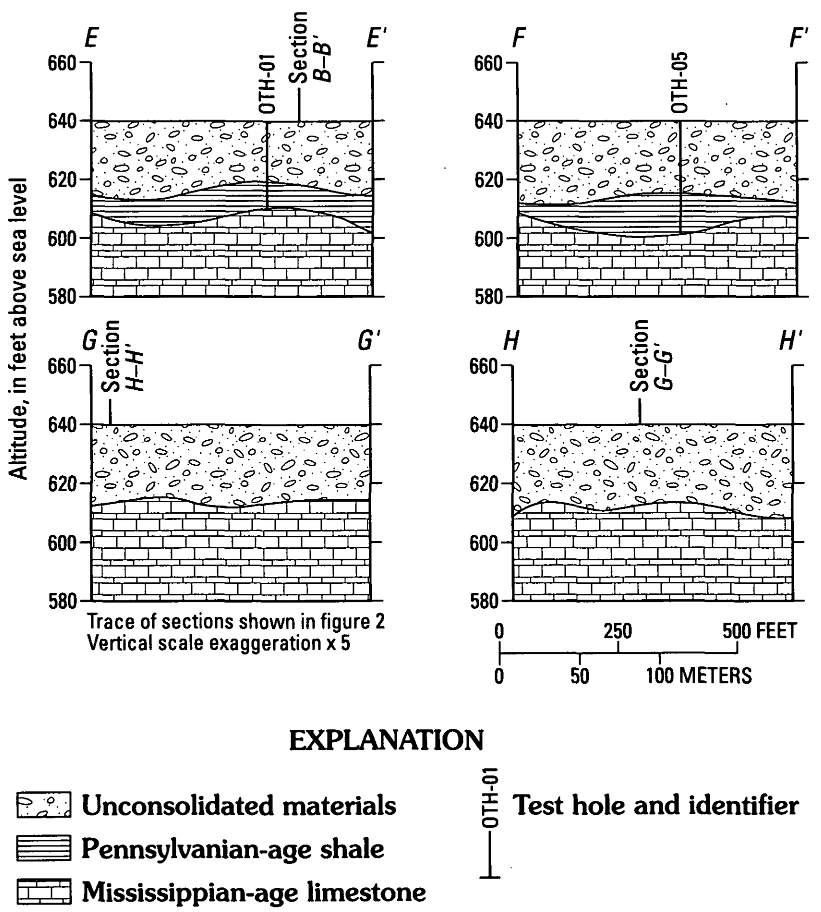


Figure 5. Geologic sections *E–E'* through *H–H'* based on seismic-refraction and test-hole data.

major ground-water sources are alluvial aquifers, glacial-drift aquifers, buried-channel aquifers, and bedrock aquifers.

Aquifers were divided into two categories on the basis of yield—major aquifers capable of sustaining individual-well pumping rates greater than 300 gal/min and minor aquifers generally capable of sustaining rates of less than 300 gal/min. Both major and minor aquifers are important in Wapello County for different reasons (Trombley and others, 1996).

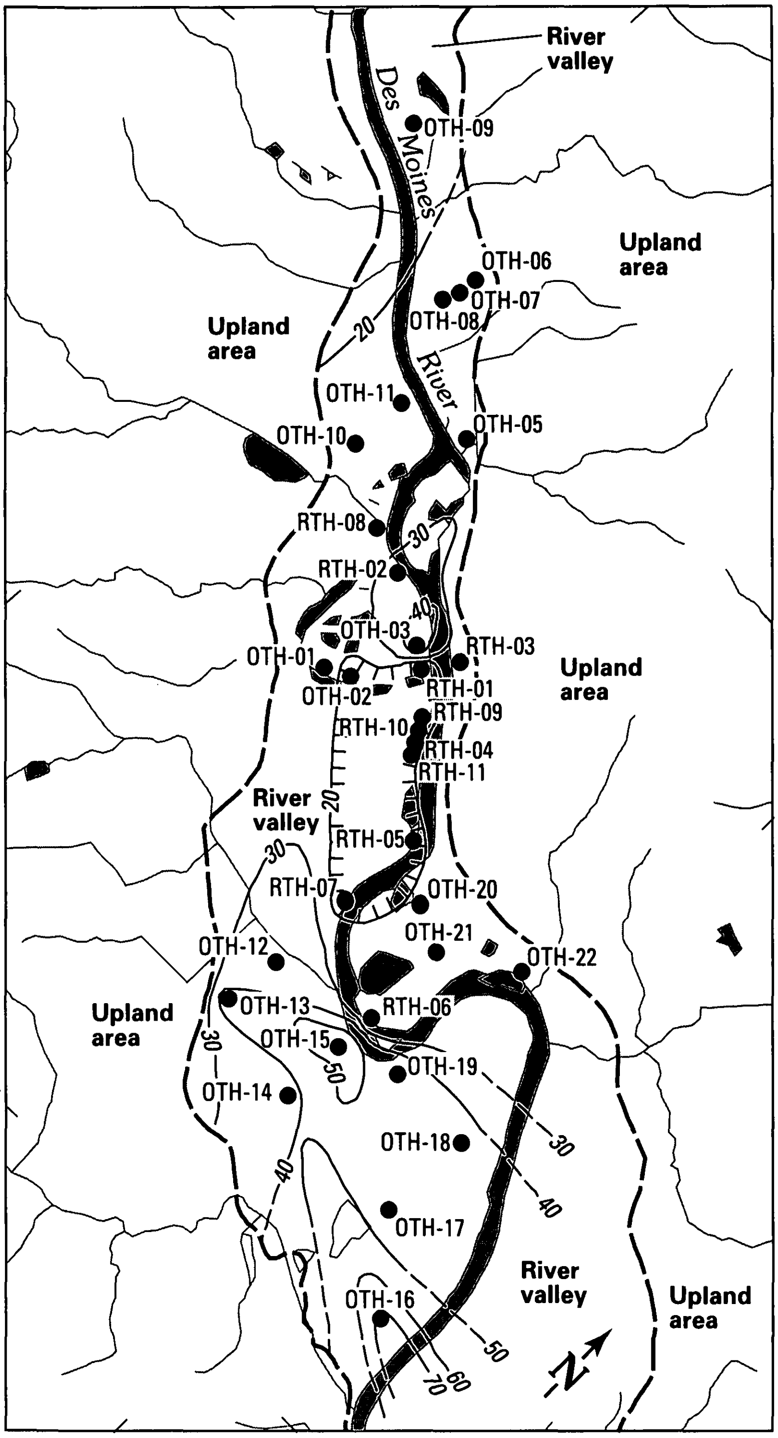
The rate at which ground water can be withdrawn from wells in Wapello County is not only different for each aquifer but also can be different within each aquifer depending on location. Generally, the thicker the aquifer, the more water it will yield to a well. Alluvial aquifers will yield more water to wells where the deposits are exposed at or near the surface and can be recharged by infiltrating precipitation or by surface water. Glacial-drift and buried-channel aquifers can have moderately high yields but usually cannot sustain high pumping rates (greater than 300 gal/min) because recharge to these deeper aquifers is limited by the water-transmitting characteristics of the overlying materials.

In areas where carbonate (limestone and dolomite) rocks are near the land surface and are not covered by confining units, the rock may be highly fractured. Fractures in bedrock aquifers improve water-transmitting characteristics to wells.

The major aquifers that can consistently sustain large yields are parts of the Cambrian-Ordovician aquifer system and occur throughout the study area and Wapello County. The minor aquifers generally are available throughout most of Wapello County.

Alluvial Aquifers

Alluvial aquifers are the shallowest, and therefore most readily available, source of potential water supply. Alluvial aquifers in Wapello County consist of stream-deposited unconsolidated materials (mostly



Base from U.S. Geological Survey digital data 1:100,000, 1991
Universal Transverse Mercator projection
Zone 15, rotated -48 degrees from base

0 4,000 8,000 FEET
0 1,000 2,000 METERS

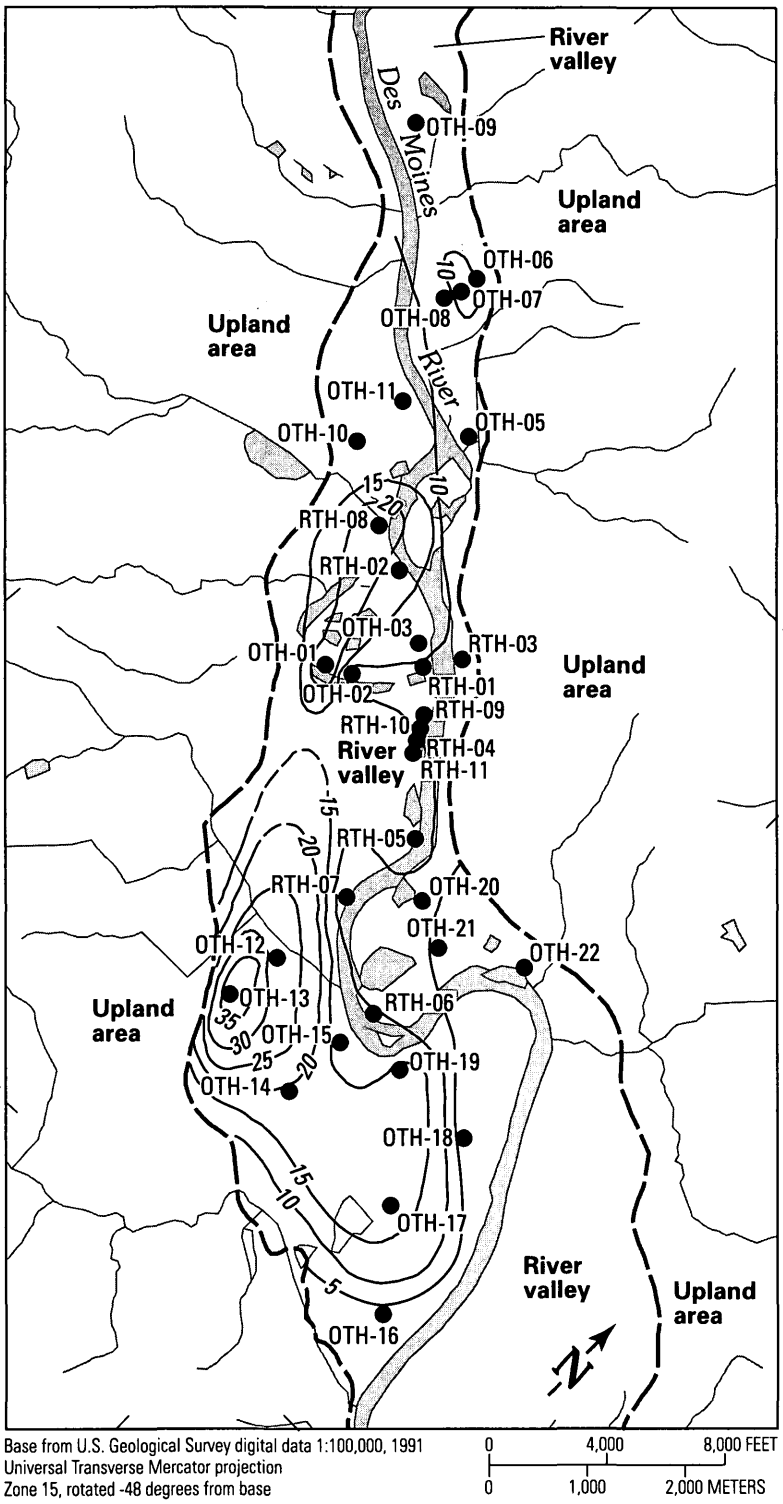
EXPLANATION

—20— — Line of equal thickness of unconsolidated material. Dashed where approximately located. Interval 10 feet

— — Boundary between upland area and river valley

OTH-16 ● Test hole and identifier

Figure 6. Thickness of unconsolidated materials along the Des Moines River, Ottumwa, Iowa.



EXPLANATION

——*10*—— Line of equal thickness of sand and gravel deposits. Dashed where approximately located. Interval 5 feet

—— —— Boundary between upland area and river valley

OTH-16 ● Test hole and identifier

Figure 7. Thickness of sand and gravel deposits along the Des Moines River, Ottumwa, Iowa.

sand, gravel, silt, and clay) that occur in river valleys. Sand and gravel are the most permeable of the alluvial materials. The sand and gravel in an alluvial aquifer potentially can yield large amounts of water if they are recharged by adequate precipitation or infiltration from rivers and streams (Coble and Roberts, 1971).

The largest alluvial aquifer in Wapello County occurs in the Des Moines River Valley. The valley is generally 0.75 to 2 mi wide. Lithology and thickness of the alluvial deposits at Ottumwa were described in the previous section of this report.

Lithology and thickness of the alluvial aquifer in the Des Moines River Valley upstream and downstream from Ottumwa are mostly unknown except from drillers' logs at a few well locations. That limited information does not indicate the presence of alluvial materials any thicker than those at Ottumwa. Information on alluvial materials along Cedar Creek and other streams in Wapello County is also limited. Alluvial materials along these smaller streams probably are thinner than those in the Des Moines River Valley and would have smaller water-yielding capabilities.

The greatest saturated thickness of sand and gravel in the alluvial aquifers (possibly as much as about 30 ft, locally) could yield a few hundred gallons per minute to individual large-diameter wells. The largest current (1999) well yields from the alluvial aquifer are from two supply wells operated by the city of Eddyville (fig. 1) that each yield about 350 gal/min from the alluvial aquifer along the Des Moines River (R. Lewman, city of Eddyville, oral commun., November 1998). Long-term sustainability of yields depends on factors such as the rate of recharge to the aquifer and the intensity of development (possible increased water-table declines caused by pumping of closely spaced wells), in addition to the permeability and saturated thickness of the materials.

The water quality of the alluvial aquifers reflects the characteristics of water from wells that are completed in sand and gravel consisting mostly of siliceous materials of low solubility. Majors ions are calcium and bicarbonate, but sulfate and sodium are also important constituents. Hardness averages about 400 mg/L ($CaCO_3$), and alkalinity averages about 230 mg/L ($CaCO_3$). Concentrations of dissolved solids averaging about 500 mg/L are characteristic of water from alluvial aquifers in the Des Moines River Valley (Witinok, 1979). Water from alluvial aquifers generally is less mineralized than water from bedrock aquifers in southeast Iowa (Coble and Roberts, 1971).

Seismic-refraction data and test-hole results indicate little potential for development of large ground-water supplies from the unconsolidated materials of the Des Moines River Valley in the study area because of the limited vertical and areal distribution of sand and gravel.

Glacial-Drift and Buried-Channel Aquifers

Glacial-drift aquifers consist of materials very similar to alluvial aquifer materials. The glacial-drift aquifers contain thin to moderately thick lenses of aquifer material that tend to be discontinuous and yield variable quantities of water to wells. Glacial-drift aquifers and the possibility of such aquifer material can be found over much of the upland area. Wells completed in glacial-drift aquifer wells range from 30 to 150 ft deep in Wapello County (Norton and others, 1912).

Ground water from the glacial-drift aquifers is of generally acceptable quality, but wells seldom yield large quantities of water except locally from thick layers of sand and gravel that may be present above the contact between the glacial drift and bedrock. Adequate information is not available to define the specific characteristics of these sources; however, general summaries of water-quality data for glacial-drift aquifers in the area are available in Detroy and Skelton (1983). Major ions are calcium and bicarbonate, but like the alluvial aquifers, sodium and sulfate are also common ions. Hardness averages about 400 mg/L ($CaCO_3$), alkalinity averages about 250 mg/L ($CaCO_3$), and dissolved solids average about 800 mg/L.

Buried-channel aquifers consist of alluvial materials in bedrock valleys that have been covered by glacial deposits. Buried-channel aquifers can, but do not always, coincide with present stream valleys. Buried-channel deposits are difficult to locate as they normally have no surface expression (Olcott, 1992). Sand and gravel deposits in buried-channel aquifers in Wapello County can be as thick as 50 ft (Witinok, 1979).

Ground water from buried-channel aquifers is generally more highly mineralized than water from the alluvial or glacial-drift aquifers. It is possible, however, that the dissolved-solids concentration can be less in the buried-channel aquifer than in the alluvial aquifers (Witinok, 1979). Major ions are calcium and bicarbonate, hardness averages about 375 mg/L

($CaCO_3$), and dissolved solids average about 500 mg/L ($CaCO_3$) (Witinok, 1979).

Bedrock Aquifers

Some bedrock units are sources of water, and some yield very little water. The bedrock units that yield water to wells are, in order of increasing depth below land surface, the Mississippian aquifer, the Silurian-Devonian aquifer, and the Cambrian-Ordovician aquifer system.

Nonaquifer bedrock of Pennsylvanian age discontinuously underlies the unconsolidated materials and consists primarily of shale, thin layers of sandstone, siltstone, coal, and possibly limestone. These rocks form a confining unit that in some areas separates overlying unconsolidated materials from the Mississippian aquifer (figs. 4 and 5).

The natural chemical quality of water from the principal bedrock aquifers in Wapello County is quite variable. The chemical quality of natural ground water is affected primarily by the mineralogy of aquifer materials and the length of time that the water is in contact with these minerals (Olcott, 1992). Because concentrations increase along flow paths, ground water in outcrop and recharge areas is the least mineralized. Ground water in deep, confined aquifers where the water movement is slow tends to be the most mineralized.

The Mississippian aquifer consists primarily of limestone and dolomite but can contain shale or evaporite deposits. The thickness of the Mississippian aquifer ranges from 30 to 500 ft in Wapello County. Well yields in the Mississippian aquifer are typically less than 50 gal/min. Generally, yields of 5 to 15 gal/min to domestic wells can be obtained from either the upper or lower part of the Mississippian aquifer (Olcott, 1992).

The quality of water from the Mississippian aquifer is quite variable, but the water generally is not potable (Detroy and Skelton, 1982). Where present, a confining unit (corresponding to the Warsaw Formation) separates the Mississippian aquifer into upper and lower parts and can affect the water quality in the lower unit with increased dissolved solids and mineralization. Water from the Mississippian aquifer tends to be a calcium bicarbonate type. The hardness is approximately 1,000 mg/L ($CaCO_3$), and dissolved-solids concentrations can range from 1,000 to 3,000 mg/L (Coble and Roberts, 1971).

The Silurian-Devonian aquifer is separated from the overlying Mississippian aquifer by a thick, usually shale, confining unit. Although composed primarily of carbonates (limestone and dolomite), the Silurian-Devonian aquifer may contain evaporite minerals, such as gypsum and anhydrite. Typical thickness of the Silurian-Devonian aquifer in Wapello County is about 400 ft. Insufficient data are available to determine potential well yields from the Silurian-Devonian aquifer in Wapello County, but approximate well yields of 20 to 50 gal/min are estimated for areas such as this where the Silurian-Devonian aquifer probably has limited secondary porosity (Olcott, 1992).

Evaporite deposits that occur locally in the Silurian-Devonian aquifer have a major effect on water quality. In areas where these minerals occur, degradation of water quality can be caused by high concentrations of sulfate, sodium, and chloride. Dissolved-solids concentrations in the Silurian-Devonian aquifer can range from 3,000 to 11,000 mg/L (Coble and Roberts, 1971).

The Cambrian-Ordovician aquifer system is a complex multi-aquifer system with individual aquifers separated by leaky confining units. In Iowa, the system is separated by a thick confining unit into an upper part, the Cambrian-Ordovician aquifer, and a lower part, the Dresbach aquifer (Olcott, 1992). The Cambrian-Ordovician aquifer system contains the deepest water-bearing units in Wapello County (Witinock, 1979). Sandstone in the upper part occurs about 1,800 ft below land surface. The Dresbach aquifer contains saline water throughout most of Iowa and is not used extensively. Rocks in the lower part of the Cambrian-Ordovician aquifer system are not considered aquifers in southeast Iowa, so only aquifers in the upper part of the Cambrian-Ordovician aquifer system will be discussed.

The Cambrian-Ordovician aquifer, also referred to as the St. Peter-Prairie du Chien-Jordan aquifer, contains two sandstone aquifers, the St. Peter aquifer and the Jordan aquifer, separated by a unit composed predominately of dolomite. In some parts of Iowa, the three units generally are connected hydraulically due to fracturing in the dolomite and function as one aquifer. The St. Peter aquifer, as much as 50 ft thick, can yield 50 to 300 gal/min. The Jordan aquifer, with an average thickness of 60 to 100 ft, can yield more than 1,000 gal/min (Coble and Roberts, 1971). Ground-water flow in the Cambrian-Ordovician aquifer is generally west to east (Olcott, 1992). Primary recharge to the Cambrian-Ordovician aquifer is from vertical leakage (Burkart and Buchmiller, 1990). Declining water levels (hydraulic head) in this aquifer in some parts of Iowa are attributed to regional pumping rates exceeding recharge (Burkart and Buchmiller, 1990).

The water from the Cambrian-Ordovician aquifer is not as highly mineralized as that from parts of the Mississippian and Silurian-Devonian aquifers. Water from this aquifer generally is a calcium bicarbonate type, has a hardness of about 350 mg/L ($CaCO_3$), and dissolved-solids concentrations of about 1,100 mg/L (Witinok, 1979). Local occurrences of iron, fluoride, and radium (Ra-266) (Horick and Steinhilber, 1978) in objectionable concentrations are possible in water from this aquifer.

SUMMARY

Ottumwa obtains its municipal water supply from the Des Moines River and from pools excavated in alluvial material near the river. Withdrawals averaged 5.5 Mgal/d in 1997. Future demand from commercial, industrial, and domestic users requires a dependable source of good quality water. The river provides water of acceptable quality about 80 percent of the time, and the pools are relied upon for the other 20 percent. Seasonal patterns of water quality in the Des Moines River and the level of treatment required for surface water were concerns that led to further investigation of ground-water sources. Whereas river flows are sufficient to meet current (1999) water demands, an additional source of water is desirable to supplement withdrawals from the river and the pools, especially during periods of degraded water quality in the Des Moines River.

To help address concerns about future sources of water supply, the U.S. Geological Survey (USGS), in cooperation with Ottumwa Water and Hydro, conducted a study to provide information about the sources of ground water (unconsolidated and bedrock aquifers) in Wapello County, particularly the Ottumwa area.

Available hydrologic and geologic information was compiled from the scientific literature and previous studies. New thickness and lithology data for the unconsolidated materials in the Des Moines River Valley were collected for this study at selected sites from May 8, 1998, through July 16, 1998.

The alluvial deposits associated with the Des Moines River Valley at Ottumwa consist of stratified sand and gravel deposits of glacial and fluvial origin. The sand and gravel commonly are interbedded with clay and silt lenses.

Surface geophysics (seismic-refraction method) and test-hole drilling were used to collect geologic information for the unconsolidated material in the Des Moines River Valley. Seismic refraction was used to determine the depth to bedrock below land surface, to estimate thickness of unconsolidated materials, and to aid in selecting locations for some of the test holes drilled for this study. Test holes were drilled to determine thickness and lithology of the unconsolidated material.

Thicknesses of the unconsolidated materials in the Des Moines River Valley in the study area range from slightly more than 10 to more than 70 ft. Saturated thicknesses of alluvial sand and gravel range from 0 to about 30 ft. Test-hole results at sites OTH–12 and OTH–13 on the south side of the Des Moines River south of Ottumwa represent the area having the greatest thickness of alluvial deposits in the study area.

Seismic-refraction data and test-hole results indicate little potential for development of large ground-water supplies from the unconsolidated materials of the Des Moines River Valley in the study area because of the limited vertical and areal distribution sand and gravel.

Aquifers were divided into two categories on the basis of aquifer yield—major aquifers capable of sustaining individual-well pumping rates greater than 300 gal/min and minor aquifers generally capable of sustaining rates of less than 300 gal/min. The major aquifers that can consistently sustain large yields are parts of the Cambrian-Ordovician aquifer system and occur throughout the study area and Wapello County. The minor aquifers generally are available throughout most of Wapello County.

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