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Ground Water Near Newton, Jasper County, Iowa

Water-Resources Investigations Report 01-4148

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

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By ROBERT C. BUCHMILLER

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Iowa City, Iowa
2001

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
cubic foot (ft^3)	28.32	liter
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot per second (ft/s)	0.3048	meter per second
gallon per minute (gal/min)	0.06308	liter per second
million gallons per day (Mgal/d)	3,785	cubic meter per day

Abbreviated water-quality units used in this report: Chemical concentrations are reported in milligrams per liter (mg/L) and micrograms per liter (µg/L). A milligram per liter expresses the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. A microgram per liter expresses the concentration of chemical constituents in solution as weight (micrograms) of solute per unit volume (liter) of water. Microsiemens per centimeter (µS/cm) at 25 degrees Celsius (°C) expresses the capability of a unit volume of water to conduct an applied electrical current.

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 the "Sea Level Datum of 1929."

Altitude: As used in this report, "altitude" refers to distance above or below sea level.

Ground Water Near Newton, Jasper County, Iowa

By Robert C. Buchmiller

Abstract

The U.S. Geological Survey, in cooperation with the city of Newton, Iowa, conducted an investigation of the ground-water resources of Jasper County, Iowa, near Newton during 1999–2001. The purpose of the investigation was to provide additional information on the South Skunk River alluvial aquifer from which Newton obtains its present municipal supply and to summarize the available information on other ground-water resources in the county.

The South Skunk River alluvial aquifer consists of unconsolidated deposits of sand and gravel of glacial and fluvial origin. These deposits overlie bedrock composed primarily of shale and limestone of Pennsylvanian or Mississippian age. Information on the South Skunk River alluvial aquifer and other Jasper County alluvial aquifers is limited to a few test holes in a few locations. Additional thickness and lithologic information was collected using seismic refraction and test-hole drilling to increase the understanding of the South Skunk River alluvial aquifer near Newton. Water-level and water-quality information also was collected.

The alluvial deposits along the South Skunk River near Newton range from less than 30 to more than 60 feet thick. Three areas of deposits exceeding 60 feet thick occur near the present city of Newton well field—about 5,000 feet west of the present well field, at the present well field, and about 5,000 feet southeast of the present well field.

Ground water in the South Skunk River alluvial aquifer near the Newton well field flows toward the municipal well field. Ground-water levels on the well-field side of the South Skunk River were lower than water levels in the river, indicating flow from the river toward the well field.

The water quality in the South Skunk River and the alluvial aquifer was similar, except most ground-water samples contained low dissolved-oxygen concentrations. The low dissolved-oxygen concentrations in ground water resulted in high concentrations of iron and manganese in some locations and reduced forms of nitrogen.

INTRODUCTION

The city of Newton, Iowa, obtains its municipal water supply from the alluvial sand and gravel aquifer along the South Skunk River. Twenty-one wells ranging in depth from 44 to 57 ft are completed in the alluvial aquifer about 5 mi southwest of the city. Each well yields between 100 and 700 gal/min of water. During the summer of 2000, an additional well was drilled to underlying bedrock and completed in the Jordan aquifer for municipal water supply.

Additional water-supply wells in a new well field may be required by the city of Newton during the next 10 years to meet future demand from commercial, industrial, and domestic users. Average daily ground-water withdrawals for municipal needs are expected to increase from 4.5 Mgal/d in 1998 to 8 Mgal/d by 2007 (M. Hoffert, city of Newton, oral commun., May 1998).

To help address concerns about future sources of water supply, the U.S. Geological Survey (USGS), in cooperation with the city of Newton, conducted a study from 1999 to 2001 to provide information about the sources of ground water (unconsolidated and bedrock aquifers) in Jasper County, particularly in the Newton area. The objectives of the study were to: (1) describe the thickness, lithology, and water quality of the unconsolidated alluvial deposits in the South

Skunk River Valley in the Newton area, and (2) briefly summarize available information on ground-water resources in the Jasper County area.

Purpose and Scope

The purpose of this report is to describe results of the study on ground-water sources in the Newton and Jasper County area (fig. 1). Available hydrologic and geologic information was compiled from the scientific literature and previous studies. New thickness, lithologic, and water-quality data for unconsolidated alluvial deposits were collected for this study from October 1999 through October 2000 from a part of the South Skunk River Valley near Newton's present municipal supply (fig. 2) and are presented in this report.

Information from this study will contribute to understanding the characterization and flow-system definition of local and regionally important alluvial aquifers. Collection of hydrogeologic data from alluvial aquifers will enhance databases needed for understanding and constructing flow models for simulating interactions between ground and surface water, furnish results needed by managers for planning and operation of public-water supplies, and provide information that is transferable to present and (or) future public-water supplies utilizing alluvial aquifer sources.

Previous Investigations

Few studies have been conducted that are related to the water resources associated with the unconsolidated deposits in the study area . The geology, physiography, and drainage of Jasper County are described in Williams (1904). Norton and others (1912) describe the water resources of Jasper County, including the study area. Information on the occurrence, availability, quality, and utilization of water in central Iowa is presented in Twenter and Coble (1965). The bedrock topography of central Iowa is mapped by Hansen (1985). Bruner and Hallberg (1987) describe the ground-water quality of the entire Skunk River Basin, particularly with regard to the occurrence of nitrate. 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). 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 and hydrologic characteristics for the major aquifers in Iowa is presented by Olcott (1992).

A geological and geophysical study of a small area of the flood plain near the Newton well fields was conducted by Lyle Sendlein in 1969 (L. Sendlein, written commun., June 1969). The objective of the study was to determine the altitude of the bedrock surface beneath the flood plain. Areas that appeared to be deeper to bedrock were believed to contain greater thicknesses of sand and gravel. Fifteen depth-to-bedrock determinations were made at selected locations using seismic-refraction techniques. From these interpretations, well logs, and rock outcrops, the altitude of the bedrock surface in the flood plain was mapped. The study concluded that the thickness of the alluvium is relatively uniform and that 47 ft ($\pm$10 ft) of sand and gravel overlie the bedrock.

Areas of the South Skunk River alluvial aquifer near the present municipal supply wells have been investigated by the city of Newton to determine the occurrence of sand and gravel deposits of sufficient thickness to construct additional municipal wells. Sixteen test holes were drilled in 1980 at selected locations southwest and southeast of the present well fields (Layne-Western Company, Inc., written commun., 1980). Results from this drilling indicated a highly variable thickness of sand and gravel and varying types of materials underlying the alluvial aquifer. Six of the test holes indicated limestone as the uppermost bedrock underlying the aquifer. Seven test holes penetrated shale beneath the alluvial aquifer. The remaining three test holes indicated clay or glacial till underlying the aquifer. Depths to bedrock varied from 42 to 66 ft below land surface. Thicknesses of sand and gravel ranged from 25 to 49 ft. Some well logs reported encountering wood, coal, or other vegetative debris within the aquifer.

Two additional test holes were drilled in 1998 southeast of the well fields (Northway Well and Pump Co., written commun., 1998). One test hole reported shale underlying the alluvial aquifer, whereas the second reported limestone. Depths to bedrock were 53 and 44 ft, respectively. Sand and gravel thicknesses were 27 and 32 ft, respectively.

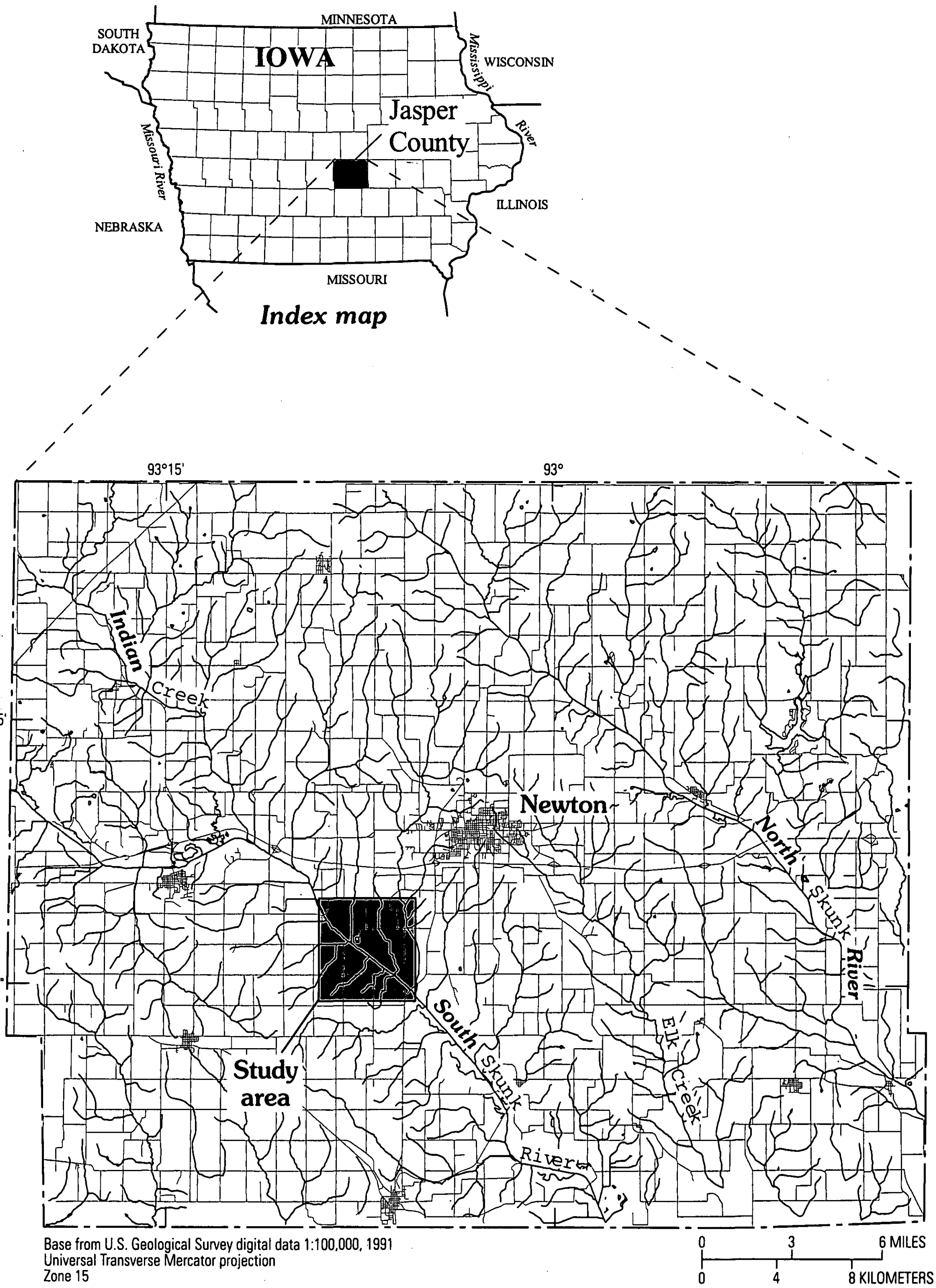
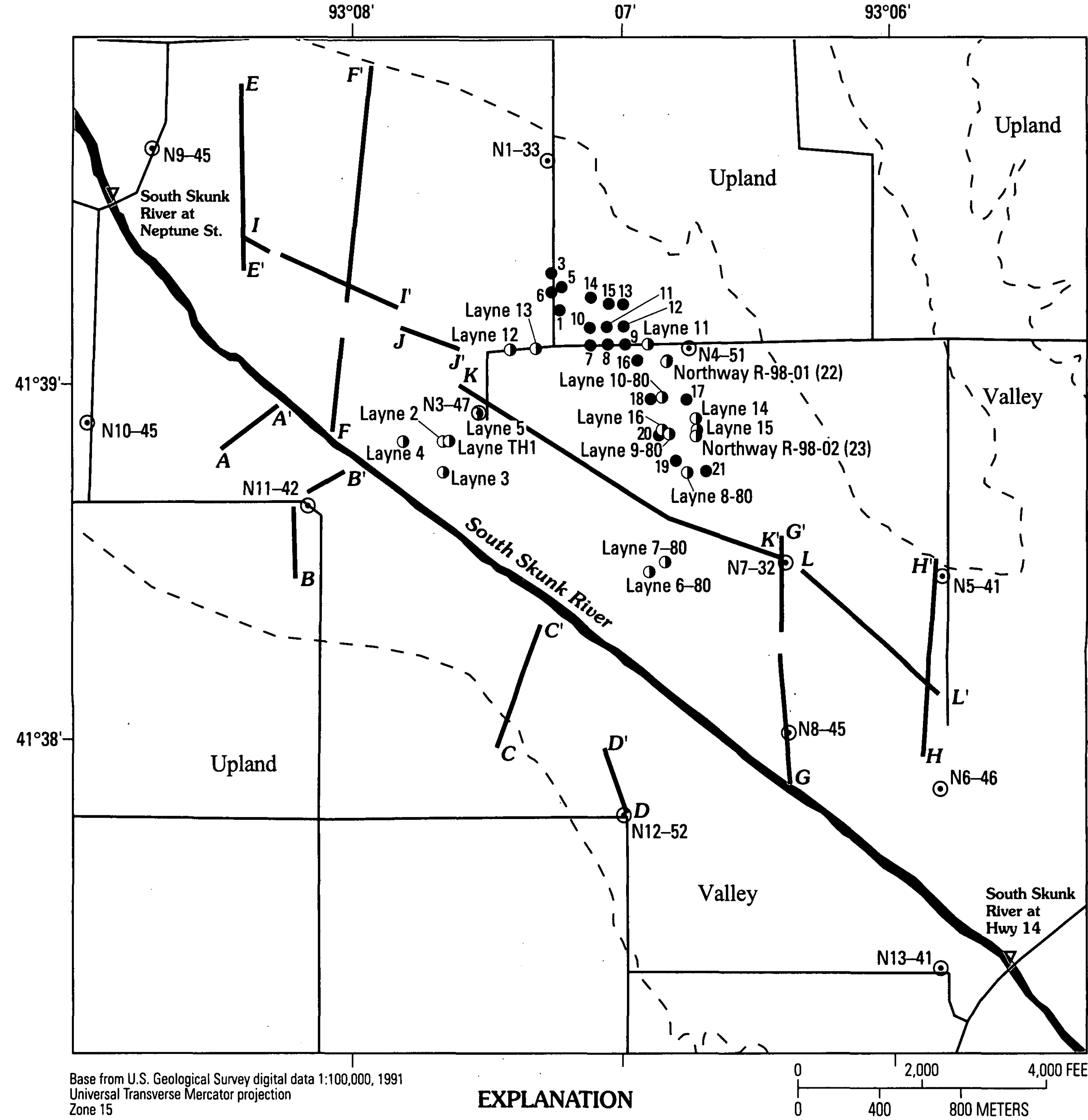


Figure 1. Location of Jasper County and Newton study area in Iowa.



EXPLANATION

Data-collection sites

Layne 13 ◑	Test hole and identifier
19 ●	Municipal well and identifier
N12–52 ⊙	USGS test hole/observation well and identifier
South Skunk River at Hwy 14 ▽	Surface-water measurement site and identifier
A—*A*'	**Trace of seismic geophysical section *A–A*' through *L–L*'**
— — —	**Boundary between upland area and river valley**

Figure 2. Location of data-collection sites in South Skunk Valley near Newton, Iowa.

Description of Study Area

Newton, Iowa, is located on the rolling, dissected uplands of the Southern Iowa Drift Plain in Jasper County (Prior, 1991). The city is located in the approximate center of the county and lies about 5 mi northeast of the South Skunk River Valley. The South Skunk River, one of two major drainage systems that receive runoff from Jasper County, drains about one-half of the county and originates in north-central Iowa. The other major drainage system, north and east of Newton, is the North Skunk River, which receives runoff from about one-third of the county. The two rivers join about 45 mi southeast of Jasper County before continuing on to the southeast to join the Mississippi River. Small areas in the southwest and northeast corners of the county drain to the Des Moines and Iowa Rivers, respectively.

The topography of Jasper County is dominated by steeply rolling hills eroded into glacial drift. Valleys of large rivers contain significant deposits of alluvial material. The thickness of the unconsolidated surficial deposits ranges from zero in small areas in the deeper river valleys where bedrock is exposed to about 200 ft beneath upland areas. The underlying bedrock consists of a thick sequence of sedimentary rocks. This geologic framework contains the hydrogeologic units described in table 1.

An area of about 9.6 mi^2 along the South Skunk River Valley southwest of Newton was selected for additional data collection during this study (fig. 1). The South Skunk River Valley is about 1.5 to 2 mi wide in the study area. The land-surface altitude of the river valley in this area varies from about 765 to 775 ft above sea level, and adjacent upland areas rise to about 900 ft. The South Skunk River in this area was channelized and straightened during the first quarter of the 20th century.

Streamflow in the South Skunk River is measured about 6 mi upstream from the study area at the USGS streamflow-gaging station South Skunk River at Colfax (station 05471050)[1]. Annual mean daily streamflow at this site is about 622 ft^3/s (October 1985 through September 2000). However, during October 1999 through September 2000, mean daily streamflow averaged 96.3 ft^3/s due to less-than-normal precipitation in central Iowa (Nalley and others, 2001).

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

Acknowledgments

The author thanks the city of Newton Waterworks staff for their assistance in gathering technical information and assisting in data collection. The author also thanks Peter Schulmeyer, Aimee Donnelly, and Dan Christiansen, USGS, for assisting with data collection and compilation. The author is grateful to landowners in the Newton area who granted access to their property for collection of data.

DESCRIPTION OF SOUTH SKUNK RIVER ALLUVIAL DEPOSITS NEAR NEWTON

The alluvial deposits associated with the South Skunk River Valley near Newton consist of stratified sand and gravel deposits of glacial and fluvial origin. The upper 20 ft of the alluvial deposits are interbedded with clay and silt lenses and overlain by a developed soil horizon. Alluvial deposits below a depth of about 20 ft typically become coarser with depth. Although all the unconsolidated materials described in available geologic logs could be expected to yield water, only those materials that are described as having a "medium" sand or larger-grained material are considered to be the alluvial aquifer for the purposes of this report. Therefore, the thickness of the alluvial aquifer, in general, is considered to be the amount of sand and gravel between about 20 ft below land surface and the top of the bedrock surface.

Collection of Seismic-Refraction and Observation-Well Data

Seismic refraction and observation-well drilling were used by the USGS to collect new geologic information for the unconsolidated deposits in the study area. Seismic refraction was used to determine the depth to bedrock below land surface and to estimate the thickness of unconsolidated deposits. Observation wells and test holes that penetrated the alluvium were used to provide additional geologic information and to provide verification of the seismic interpretations at selected locations. Observation wells also were

Table 1. Description of hydrogeologic units in central Iowa

Hydrogeologic unit[1]	Approximate thickness in central Jasper County (feet)[1]	Age of rock unit[2]	Potential well yield (gallons per minute)	Lithology[1]
Alluvial, glacial-drift, and buried-channel aquifers	0–100	Quaternary	Less than 20 to more than 500	Sand, gravel, silt, clay, and boulders.
Confining unit	50–100	Pennsylvanian	Very small	Shale, sandstone, thin limestone, and coal.
Mississippian aquifer	250–300	Mississippian	Less than 20 to 50	Limestone, dolomite, and shale (gypsum and anhydrite occur locally).
Confining unit	200–250	Mississippian and Devonian	Very small	Shale, siltstone, limestone, and dolomite.
Devonian aquifer	500–550	Devonian	Less than 20	Limestone, dolomite, and shale.
Confining unit	500–550	Silurian and Ordovician	Very small	Dolomite, shale, chert, limestone, and sandstone.
Cambrian-Ordovician System St. Peter aquifer Jordan aquifer	500–550 30–40 40–50	Ordovician and Cambrian	More than 1,000	Sandstone and dolomite.
Confining unit	350–550	Cambrian	Very small	Sandstone, shale, siltstone, and dolomite.

[1]Modified from Twenter and Coble (1965).

[2]Age classification of rock units are those of the Iowa Department of Natural Resources, Geological Survey Bureau.

constructed to provide for collection of water-level measurements and water-quality samples.

Using the seismic-refraction method, the contact between alluvium and bedrock is determined from a contrast in seismic acoustic velocity. Seismic-refraction velocities ranged from less than 1,000 ft/s in unsaturated unconsolidated materials to about 12,000 ft/s in the bedrock. The refraction system consisted of a 12-channel seismograph, geophones (receivers), an energy source, and related equipment. Geophones were placed in lines as much as 1,100 ft long in the areas of interest, and seismic energy was supplied by detonating an explosive mixture of ammonium nitrate and nitromethane. 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. Final processing of the data was done using a modeling program, SIPT2V4.1 (Rimrock Geophysics, Inc., 1995) assuming a three-layer system—unsaturated unconsolidated materials, saturated unconsolidated materials, and bedrock. An assumption of the modeling program is that refraction acoustic velocities increase with depth. More than 35,000 linear ft of seismic-refraction data were collected during October–November 1999. Seismic-refraction data were collected at sections *A–A'* through *L–L'* shown in figure 3. The latitude and longitude of the seismic shot points along each seismic section were determined by a global positioning system (GPS).

A total of 12 test holes were drilled by the USGS during the study (fig. 2), with an average depth of 44 ft. All test holes were drilled with 3.25-in. inside-diameter (ID) hollow-stem augers. Test holes were drilled to bedrock or to the limits of the drill rig being used. Samples of auger cuttings were collected at major lithologic changes. Observation wells were constructed at the test-hole locations by lowering 2.5 ft of 0.020-in. slot-size, polyvinyl chloride (PVC) schedule 40, flush-threaded, 2-in. diameter well screens and riser pipe inside the auger flights. Wells were installed near the bottom of the sand and gravel deposits overlying the bedrock. The annular space around the screen and riser was filled with native materials to within about 8 ft of land surface. The upper 8 ft were filled with bentonite clay and cement to prevent surface runoff from entering the borehole. A lockable, protective casing was cemented in place over the protruding

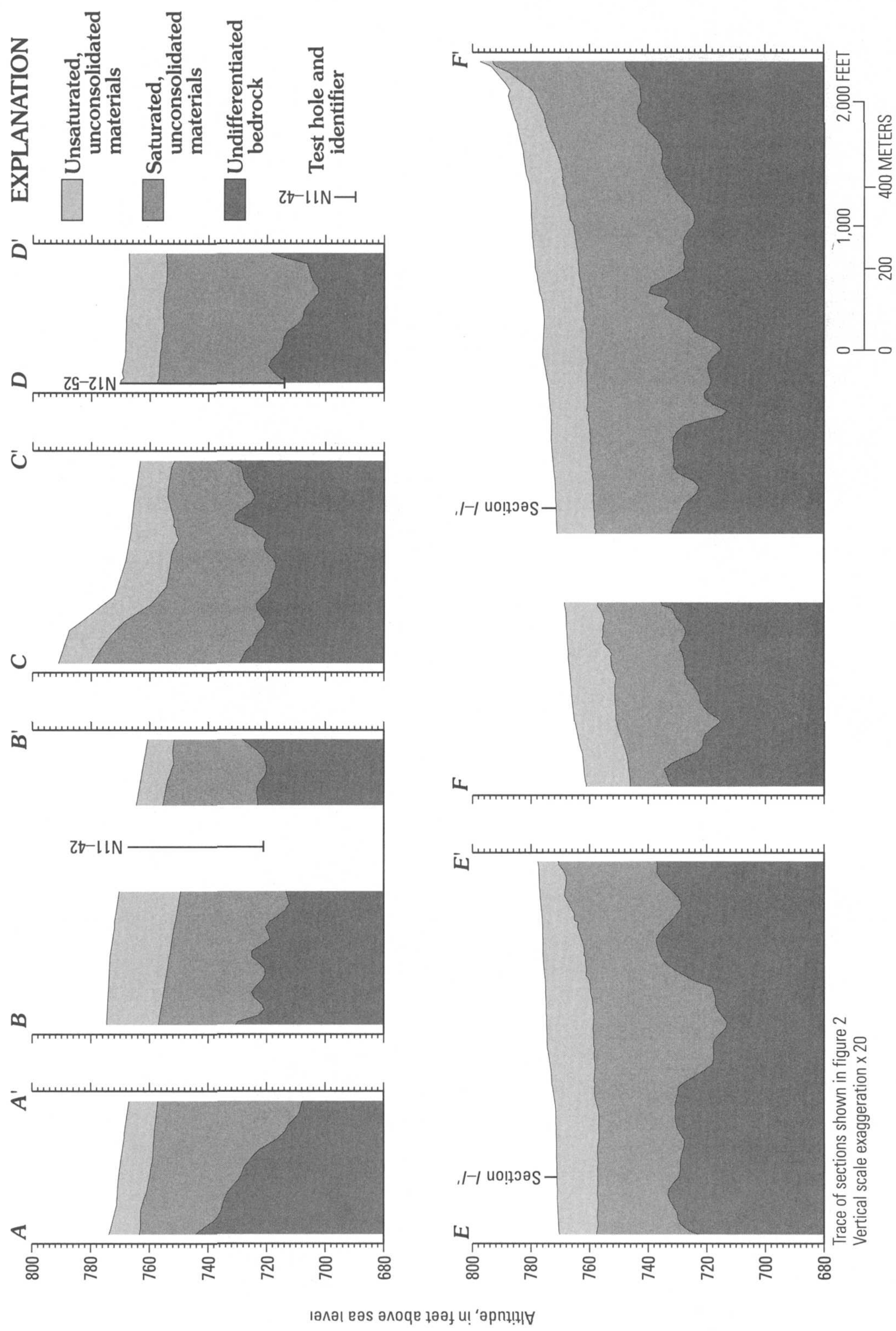
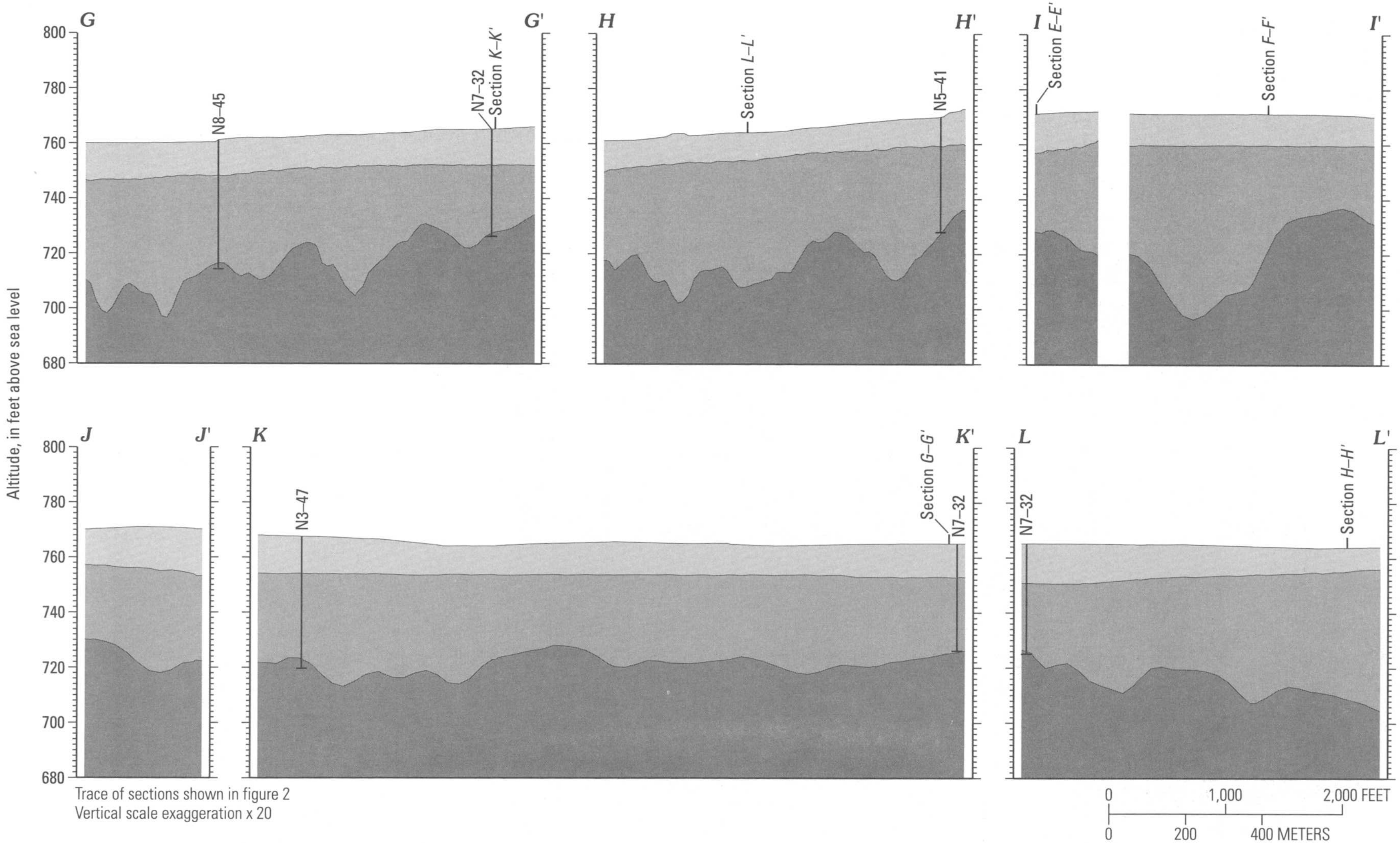


Figure 3. Geologic sections based on seismic-refraction and test-hole data.



Trace of sections shown in figure 2
Vertical scale exaggeration x 20

Figure 3. Geologic sections based on seismic-refraction and test-hole data—Continued

portion of the riser pipe. Wells were pumped after construction to develop the sand pack surrounding the screen.

Table 2 lists observation-well locations and associated geologic information. The prefix 'N' designates observation wells drilled by USGS personnel in 1999. Information about unconsolidated materials, including depth to bedrock and sand and gravel thickness, for test holes designated 'Layne' were obtained from Layne-Western Company, Inc. (written commun. to Newton Waterworks, 1980). Additional test-hole data were obtained from Northway Well and Pump Company (written commun. to Newton Waterworks, 1998) and are designated 'Northway'.

Thickness and Lithology

Descriptive logs of USGS, Layne-Western, and Northway test holes drilled in the study area (table 2) indicate shale, clay, glacial till, or limestone underlie the sand and gravel of the alluvial aquifer. Gray clay or glacial till can have the same appearance and drilling characteristics in the study area as a soft gray shale, and additional analysis would be required to determine the exact lithology of these deposits. For the purposes of this report, wells or test holes penetrating gray clay or glacial till beneath the sand and gravel are assumed to be shale and the top of the bedrock surface. On the basis of a limited number of wells and test holes that penetrate deeper into the bedrock, this gray shale or clay layer is from 0 to about 15 ft thick and overlies a hard white limestone. Depths to bedrock in wells and test holes ranged from 34 to more than 60 ft. The greatest depths to bedrock occurred in the southeastern part of the well field area where a thicker layer of sand and gravel may be a terrace or dune deposit.

Seismic-refraction data can be used to identify boundaries between unsaturated and saturated unconsolidated materials and saturated unconsolidated materials and bedrock. Seismic-refraction data do not differentiate between the types of material comprising the unconsolidated material. Therefore, thicknesses of aquifer material are inferred from the total thickness of unconsolidated deposits within the South Skunk River Valley. Additional test drilling is needed to confirm the interpreted depth to bedrock in areas where test-hole data are not available and to determine the type of material composing the unconsolidated deposits.

Seismic-refraction data show variations in the depth to the bedrock surface in places in the study area (fig. 3). The removal of bedrock materials through erosion and weathering may explain local differences in depth to bedrock and type of material composing the bedrock surface seen in the descriptive logs of wells and test holes fully penetrating the alluvium. For example, the two Northway test holes listed in table 2 are about 1,300 ft apart, yet the depth-to-bedrock varies by 9 ft. The type of material composing the bedrock surface in the two test holes also is dissimilar.

Figure 4 shows the altitude of the bedrock surface in feet above sea level in the study area. This map was prepared from depth-to-bedrock data from wells, test holes, and seismic-refraction shot-point locations. Figure 4 shows three areas in the study area where the bedrock surface is lower than 720 ft above sea level—an area about 5,000 ft west of the present well field area, the present well field area, and an area about 5,000 ft southeast of the present well field area.

The thickness of unconsolidated alluvial deposits is shown in figure 5. This map was created by a geographic information system (GIS) process. A grid of the altitude of the interpreted bedrock surface was created and subtracted from a grid of the land-surface altitude in the study area to provide a gridded estimate of the thickness of unconsolidated deposits.The greatest thicknesses of unconsolidated alluvial deposits, in excess of 60 ft, coincide with the areas of lowest bedrock-surface altitude. The altitude of the flood-plain land surface is relatively uniform, and the deeper bedrock-surface areas appear to be erosional channels in the bedrock that have been subsequently filled by unconsolidated deposits.

Ground-Water Flow

Water levels were measured in observation and municipal water-supply wells during February, June, and October 2000 with calibrated steel tapes or electric line. Altitudes of measuring points on the wells were surveyed to sea-level datum, and all water-level measurements were converted to altitudes above sea level. In addition, reference points surveyed to sea level were established on bridge crossings over the South Skunk River near the upstream and downstream extremes of the study area. River stages of the South Skunk River were measured to determine altitude and gradient of surface water in the study area at the time of ground-water-level measurements. Static (nonpumping) water levels were measured in municipal wells. There was less than 10-ft difference between water levels at different well locations. Water levels measured during this study are given in table 3.

River stages in the South Skunk River were similar for each measurement date, and the gradient

Table 2. Description of drilled test holes and geologic information

Test-hole identifier[1] (fig. 2)	Location land net[2] (latitude, longitude)	Geologic unit	Drillers log/cuttings description (feet below land surface)
N1–33	T20N–R79W–12DCDA (41° 39' 38.29", 93° 07' 16.47")	Quaternary-age alluvium	0–6, Dark-brown silt, clayey 6–12, Light-brown silt 12–15, Light-brown sand, silty, fine 15–23, Sand, fine 23–32, Medium-brown sand, fine to medium, well rounded 32–33, Gray-brown sand, with large gravel 33–34, Clay, glacial till, stiff
		Undifferentiated Paleozoic	34, Bedrock
N3–47	T79N–R20W–13DBCC (41° 38' 55.69", 93° 07' 32.01")	Quaternary-age alluvium	0–1, Lime, fill 1–2, Dark-brown soil, silty, small pebbles 2–3, Medium-brown soil, silty, fine sand 3–9, Medium-brown silt, soft 9–11, Gray silt, sandy, soft, damp 11–12, Fine sand, oxidized 12–18, Dark-brown sand, fine, wet at 17 feet 18–20, Medium-brown sand, fine to medium, some silt 20–24, Gray sand, fine to coarse 24–44, Gray sand, fine to coarse, pea gravel 44–47, Gravel 47–48, Clay, glacial till, hard
N4–51	T79N–R19W–18CBAB (41° 39' 06.57", 93° 06' 44.28")	Quaternary-age alluvium	0–3, Dark-brown soil, silty 3–4, Dark-brown silt, clayey 4–5, Black silt, clayey 5–9, Dark-brown silt, clayey 9–10, Dark-brown sand, silty 10–14, Brown sand, fine, some silt lenses 14–22, Light-brown sand, fine 22–51, Medium-brown sand, fine to medium, gravel at 45 feet 51, Clay, glacial till, hard
N5–41	T79N–R19W–19ADAA (41° 38' 28.28", 93° 05' 46.83")	Quaternary-age alluvium	0–4, Medium-brown sand, fine 4–5, Dark-brown sand, silty, fine 5–10, Dark-brown silt, sandy, stiff 10–17, Medium-brown sand, silty, fine, dark brown at 12–14 feet, wet at 17–18 feet 17–25, Dark-brown sand, fine 25–42, Medium-brown sand, fine to coarse 42, Clay, glacial till
N6–46	T79N–R19W–19DDDA (41° 37' 53.00", 93° 05' 47.06")	Quaternary-age alluvium	0–4, Black soil, silty 4–8, Dark-brown silt, clayey, stiff 8–10, Medium-brown silt, clayey, some sand, damp at 10 feet 10–12, Gray sand, clayey, silty 12–20, No returns, soft at 15 feet 20–40, Gray sand, fine, soupy 40–45, Same as above only coarser, cleaner, fine to pea–size gravel 45–46, Gravel, large 46–47, Clay, glacial till, stiff

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

Test-hole identifier[1] (fig. 2)	Location land net[2] (latitude, longitude)	Geologic unit	Drillers log/cuttings description (feet below land surface)
N7–32	T79N–R19W–19BADD (41° 38' 30.53", 93° 06' 22.26")	Quaternary-age alluvium	0–1, Dark-brown soil, silty 1–4, Dark-brown clay, silty 4–6, Medium-brown silt, clayey, stiff from 5–6 feet 6–7, Gray-brown silt, sandy 7–8, Brown sand, fine 8–12, Gray sand, silty 12–20, No returns, very soft 20–38, Gray sand, coarse 38–39, Gravely 39, Clay, glacial till, very hard
N8–45	T79N–R19W–19CADD (41° 38' 02.34", 93° 06' 21.55")	Quaternary-age alluvium	0–2, Dark-brown soil, silty 2–4, Dark-brown silt 4–5, Medium-brown silt, sandy 5–6, Medium-brown sand, silty, fine 6–12, Dark-brown sand, silty, fine 12–30, Gray sand, fine to medium, small gravel at 22 feet, wet 30–46, Same as above, gravel lense at 43 feet, large gravel lense at 45 feet 46–47, Clay, glacial till, coal, very hard
N9–45	T79N–R20W–11CDAD (41° 39' 40.24", 93° 08' 46.28")	Quaternary-age alluvium	0–3, Soil and road fill 3–6, Dark-brown silt, very stiff 6–8, Medium-brown clay, silty, softer than above 8–12, Medium-brown sand, silty, fine 12–18, Medium-brown sand, fine, wet at 15 feet 18–25, As above, coarser 25–44, Gray-brown sand, fine to very coarse, soupy, some pea gravel 44–45, Gravel 45–46, Clay, glacial till, very stiff
N10–45	T79N–R20W–14CBDD (41° 38' 53.92", 93° 09' 00.87")	Quaternary-age alluvium	0–2, Dark-brown soil, silty 2–4, Medium-brown silt, clayey 4–9, Medium-brown clay, silty, stiff 9–15, Medium-brown silt, sandy, soft, no returns 10–18 feet 15–25, Medium-brown sand, fine 25–35, Medium-brown sand, fine to coarse 35–47, Medium-brown to gray sand, fine to very coarse 47–48, Clay, glacial till, very hard
N11–42	T79N–R20W–23AAAA (41° 38' 40.02", 93° 08' 10.74")	Quaternary-age alluvium	0–3, Dark-brown soil, silty 3–5, Dark-brown silt 5–7, Dark-brown silt, clayey, very stiff 7–14, No returns, soft 14–25, Gray-brown sand, silty, fine, wet 25–30, Gray-brown sand, some silt, fine to coarse 30–42, Gray-brown sand, fine to coarse 42–43, Gravel, very large 43, Could not penetrate large gravel

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

Test-hole identifier[1] (fig. 2)	Location land net[2] (latitude, longitude)	Geologic unit	Drillers log/cuttings description (feet below land surface)
N12–52	T79N–R20W–25AAAA (41° 37' 48.54", 93° 06' 58.84")	Quaternary-age alluvium	0–2, Medium-brown silt 2–4, Dark-brown silt 4–5, Dark-brown silt, clayey, stiff 5–7, Medium-brown silt, clayey, stiff 7–8, Medium-brown clay, silty, softer 8–9, No returns 9–10, Sand and clay, oxidized 10–11, Medium-brown silt, sandy 11–13, No returns 13–14, Sand, fine, oxidized, wet 14–20, Medium-brown sand, silty, fine 20–25, As above, fine to medium 25–48, As above, fine to very coarse, little silt, some pea gravel 48–51, Gravel 51–55, Gray sand, coarse 55–56, Gravel, very coarse 56, Clay, glacial till, stiff
N13–41	T79N–R19W–30ADDD (41° 37' 22.91", 93° 05' 47.02")	Quaternary-age alluvium	0–1, Dark-brown soil, silty 1–2, Dark-brown silt, stiff 2–4, Medium-brown silt, stiff 4–6, Medium-brown silt, clayey 6–9, Medium-brown clay, silty, very soft 9–14, No returns, soft 14–20, Medium-brown sand, silty, fine to medium 20–25, Gray-brown sand, fine to medium 25–30, Gray sand, fine to medium 30–40, Gray-brown sand, fine to mostly coarse 40–44, As above, fine sand to pea gravel, mostly very coarse sand 44–45, Gravel, very large, unable to penetrate gravel
Northway R–98–01	T79N–R19W–18CBAB (41° 39' 04.50", 93° 06' 49.27")	Quaternary-age alluvium	0–26, Clay, sandy 26–42, Sand, fine to medium, and gravel 42–53, Sand, fine to coarse, and gravel
		Undifferentiated Paleozoic	53–60, Shale, gray
Northway R–98–02	T79N–R19W–18CDBB (41° 38' 51.98", 93° 06' 42.59")	Quaternary-age alluvium	0–4, Top soil 4–12, Sand, fine 12–44, Sand, fine to coarse, and gravel
		Undifferentiated Paleozoic	44–50, Limestone, with gray shale streaks
Layne TH1	T79N–R20W–13CDAB	Quaternary-age alluvium	0–4, Top soil, black 4–9, Clay, dark brown, gumbo 9–10, Sand, brown, silty 10–16.5, Sand, dark grayish white, black river mud and some wood cuttings 16.5–20, Sand and gravel, fine to medium, grayish white 20–25, Sand and gravel, test holes to coarse dark grayish white 25–30, Sand and gravel, fine to medium, grayish white 30–35, Sand and gravel, fine to medium, grayish white, cobble at 34 feet 35–40, Sand and gravel, medium to coarse, grayish white, with cobbles
		Undifferentiated Paleozoic	40–42, Sand and gravel, grayish white, with cobbles 42, Limestone, soft

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

Test-hole identifier[1] (fig. 2)	Location land net[2] (latitude, longitude)	Geologic unit	Drillers log/cuttings description (feet below land surface)
Layne 2	T79N–R20W–13CDAB	Quaternary-age alluvium	0–3, Top soil, black
			3–9.5, Clay, brownish yellow, silty
			9.5–10, Sand, brown, silty
			10–14.5, Clay, dark gray, with coal and lenses of fine, dark-gray sand
			14.5–30, Sand and gravel, fine to medium, gray
			30–35, Sand and gravel, fine to medium, with some coarse pea-size gravel in sand
			35–40, Sand and gravel, fine to medium, gray, with coarse sand and cobbles from 35–37 feet
			40–43.6, Sand and gravel, medium to fine, with some coarse sand and cobbles
		Undifferentiated Paleozoic	43.6, Limestone, soft
Layne 3	T79N–R20W–13CDDB	Quaternary-age alluvium	0–3, Top soil, black
			3–12.5, Clay, dark brownish yellow, gumbo
			12.5–15, Sand and gravel, with lenses of dark brownish-black gumbo clay with some wood and coal cuttings
			15–18, Clay, dark-black gumbo, with fine sand lenses
			18–20, Sand and gravel, fine to medium
			20–40, Sand and gravel, fine to medium, dark gray, with a large amount of dead vegetation and wood cuttings
			40–46, Sand and gravel, fine to medium, with some coarse, no dead vegetation
			46–50, Till, dark gray, layered with black gumbo
			50–62, Clay, grayish white, with vegetation and coal
		Undifferentiated Paleozoic	62–71.5, Limestone, soft and gritty, clay like, not in chip form
			71.5, Limestone, white, very hard, chip form
Layne 4	T79N–R20W–13CDBC	Quaternary-age alluvium	0–2, Top soil, black
			2–7, Clay, dark brown, yellow
			7–8, Sand, fine, brownish yellow
			8–10, Clay, brown, yellow
			10–15, Sand, fine, brown yellow, with layers of brown-yellow clay with fine sand and gravel that have wood and coal cuttings on top of dark-gray clay
			15–17.5, Dark-gray coal at 17.5 feet
			17.5–20, Sand and gravel, fine to medium
			20–25, Sand and gravel, fine to medium, with some coarse, gray
			25–30, Sand and gravel, fine to medium, with wood and dead vegetation
			30–46, Sand and gravel, fine to medium, with some coarse
		Undifferentiated Paleozoic	46–50, Shale, dark gray
			50, Limestone, hard

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

Test-hole identifier[1] (fig. 2)	Location land net[2] (latitude, longitude)	Geologic unit	Drillers log/cuttings description (feet below land surface)
Layne 5	T79N–R20W–13DBCC	Quaternary-age alluvium	0–2, Top soil, black 2–5, Black river gumbo 5–9, Black river gumbo 9–10, Clay, yellow, brown 10–15, Sand and gravel, fine to medium 15–20, Sand and gravel, fine to medium, with some coarse grayish dark sand 20–25, Sand and gravel, fine to medium, gray 25–30, Sand and gravel, fine to medium, gray, with good size pea gravel within 30–35, Sand and gravel, fine to medium, with some coarse, cobbles at 33 feet 35–40, Sand and gravel, fine to medium, very clean 40–43, Sand, medium to coarse, brownish white
		Undifferentiated Paleozoic	43–58, Shale, gray, with grayish-brown till on top of shale, shale turns to light gray to white 58–69, Shale, white, with particles of grit that turns to chips of limestone 69, Limestone, hard
Layne 10–80	T79N–R19W–18CBDB	Quaternary-age alluvium	0–5, Sand, fine 5–12, Sand, fine, clay 12–17, Clay, brown 17–25, Sand, fine to coarse, buff color 25–66, Sand and gravel, coarse
		Undifferentiated Paleozoic	66–73, Shale, blue 73–75, Limestone, shaly
Layne 11	T79N–R19W–18BCCD	Quaternary-age alluvium	0–13, Sand, very fine, yellowish brown 13–15, Clay, yellow 15–20, Sand, very fine, yellow brown, with lenses of yellow clay 20–23, Sand, very fine, yellow brown 23–25, Sand, fine, brown 25–30, Sand and gravel, fine to medium, with some coarse 30–35, Sand and gravel, medium to coarse, turns to fine sand at 31.5 feet 35–40, Sand and gravel, fine to medium, brown 40–45, Sand and gravel, fine, with some medium, brown 45–55, Sand and gravel, fine, with some medium, brownish white 55–59, Sand and gravel, fine to medium, with some coarse, brown
		Undifferentiated Paleozoic	59, Limestone, grayish white, hard

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

Test-hole identifier[1] (fig. 2)	Location land net[2] (latitude, longitude)	Geologic unit	Drillers log/cuttings description (feet below land surface)
Layne 12	T79N–R20W–13DBBA	Quaternary-age alluvium	0–5, Gumbo, black 5–8, Gumbo, yellowish black 8–10, Clay, yellow 10–11.5, Clay, yellow, with lenses of fine sand 11.5–15, Sand and gravel, fine to medium, brown 15–20, Sand and gravel, fine to medium, brown 20–25, Sand and gravel, fine to medium, with wood and dead vegetation from 23–25 feet 25–30, Sand and gravel, mostly fine to medium, gray, wood stops at 26 feet 7 inches 30–35, Sand and gravel, medium to coarse, with some fine cobbles at 32–35 feet 35–37, Sand and gravel, mostly fine to medium 37–43, Sand and gravel, fine, with some medium, grayish white 43–45.5, Sand and small cobbles, fine, grayish white 45.5–55, Till, blue gray
Layne 13	T79N–R20W–13DBAA	Quaternary-age alluvium	0–2, Top soil, black 2–4, Gumbo, black 4–7, Gumbo, yellow 7–9, Clay, yellow 9–10, Sand, rusty brown 10–15, Sand and gravel, fine, gray 15–20, Sand and gravel, fine to medium, gray 20–25, Sand and gravel, fine, with some medium, dead vegetation from 23–24.5 feet 25–30, Sand and gravel, fine to medium, with some coarse, gray 30–35, Sand and gravel, fine to medium, with some coarse cobbles from 32–34.5 feet 35–40, Sand and gravel, medium to coarse, with some fine cobbles from 36–40 feet, mixed 40–43.75, Sand and gravel, medium to coarse, with cobbles, gray
		Undifferentiated Paleozoic	43.75–44, Limestone, light yellow, very hard
Layne 14	T79N–R19W–18CDBB	Quaternary-age alluvium	0–5, Sand, very fine, brown 5–8, Till, brown 8–10, Till, brownish gray 10–13.4, Clay, brownish gray, silty 13.4–16, Sand, very fine, brownish gray 16–20, Sand and gravel, fine to medium, brownish gray 20–30, Sand and gravel, fine to medium, brown 30–35, Sand and gravel, medium to coarse, with some fine cobbles at 32–34 feet 35–38, Sand and gravel, fine, white 38–40, Sand and gravel, fine to medium, brown 40–45, Sand and gravel, fine to medium, with some coarse 45–49, Sand and gravel, medium to coarse, with small boulders and large cobbles 49–55, Clay, blue

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

Test-hole identifier[1] (fig. 2)	Location land net[2] (latitude, longitude)	Geologic unit	Drillers log/cuttings description (feet below land surface)
Layne 15	T79N–R19W–18CDBB	Quaternary-age alluvium	0–2.5, Sand, very fine, brown
			2.5–5, Clay, brown
			5–8.7, Clay, brownish gray
			8.7–11, Clay, brown, silty
			11–14, Clay, rusty brownish yellow, turning into very fine brownish-yellow sand
			14–15, Sand, fine, grayish yellow
			15–20, Sand and gravel, fine to medium, gray
			20–25, Sand and gravel, fine, with some medium, grayish white
			25–30, Sand and gravel, fine, with some medium, grayish white
			30–35, Sand and gravel, fine to medium, gravel becoming coarser
			35–40, Sand and gravel, medium to coarse, with pea gravel and cobbles at 36–40 feet
			40–45, Sand and gravel, medium to coarse, without pea gravel
			45–50, Sand and gravel, medium to coarse, with pea gravel and cobbles within
			50–53.3, Sand and gravel, medium to coarse, with some fine
		Undifferentiated Paleozoic	53.3, Limestone, white, very hard
Layne 16	T79N–R19W–18CCAB	Quaternary-age alluvium	0–2.5, Top soil, black, sandy
			2.5–5, Gumbo, black
			5–10, Clay, blackish gray yellow
			10–13, Clay, yellowish gray, silty
			13–15, Sand and gravel, fine, brown
			15–20, Sand and gravel, fine to medium, with some coarse
			20–25, Sand and gravel, fine to medium, brown
			25–30, Sand and gravel, fine to medium, with some coarse, brown
			30–35, Sand and gravel, medium to coarse, with some fine, brown
			35–40, Sand and gravel, fine, brownish white
			40–45, Sand and gravel, very fine, white
			45–50, Sand and gravel, fine, with some medium, brownish white
			50–54, Sand and gravel, fine to medium, brown
		Undifferentiated Paleozoic	54, Limestone, very hard
Layne 6–80	T79N–R19W–19BBCD	Quaternary-age alluvium	0–5, Soil, black
			5–7, Clay, sandy
			7–12, Sand, fine to coarse
			12–13, Wood log
			13–32, Sand and gravel, coarse, blue and white
			32–44, Gravel and coarse sand, some fine
			44–45, Boulders and gravel
			45–46, Gravel and clay
			46–59.5, Shale, gray
		Undifferentiated Paleozoic	59.5–60, Limestone, shaley

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

Test-hole identifier[1] (fig. 2)	Location land net[2] (latitude, longitude)	Geologic unit	Drillers log/cuttings description (feet below land surface)
Layne 7–80	T79N–R19W–19BBDC	Quaternary-age alluvium	0–7, Soil, black
			7–8, Sand, fine
			8–12, Clay, brown
			12–16, Sand, coarse, blue and white
			16–17, Clay, blue
			17–37, Sand and gravel, coarse, blue and white
			37–44, Sand, fine to coarse
			44–47, Gravel and boulders
		Undifferentiated Paleozoic	47–55, Shale, gray
			55–62, Limestone, gray, shaley
Layne 8–80	T79N–R19W–18CCDA	Quaternary-age alluvium	0–5, Soil, black
			5–15, Clay, blue gray
			15–27, Sand and gravel, coarse, blue and white
			27–44, Sand, fine to coarse
			44–46, Gravel and boulders
			46–47, Shale, gray
			47–54, Sandstone
		Undifferentiated Paleozoic	54–57, Shale, gray
			57, Limestone
Layne 9–80	T79N–R19W–18CCAB	Quaternary-age alluvium	0–12, Sand, fine to coarse
			12–14, Clay, brown, sandy
			14–28, Sand and gravel, coarse
			28–40, Sand and gravel, coarse, some fine
			40–58.5, Sand and gravel, coarse, some pebbles
		Undifferentiated Paleozoic	58.5–62, Shale, blue black and gray

[1]Sites N1–33 to N13–41 drilled by U.S. Geological Survey, November 3–11, 1999.

[2]Location indicated by township (north), range (west), and section. The letters after the section number represent successiveness 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.

between bridge measuring points was consistently 0.44 ft per 1,000 ft of river channel.

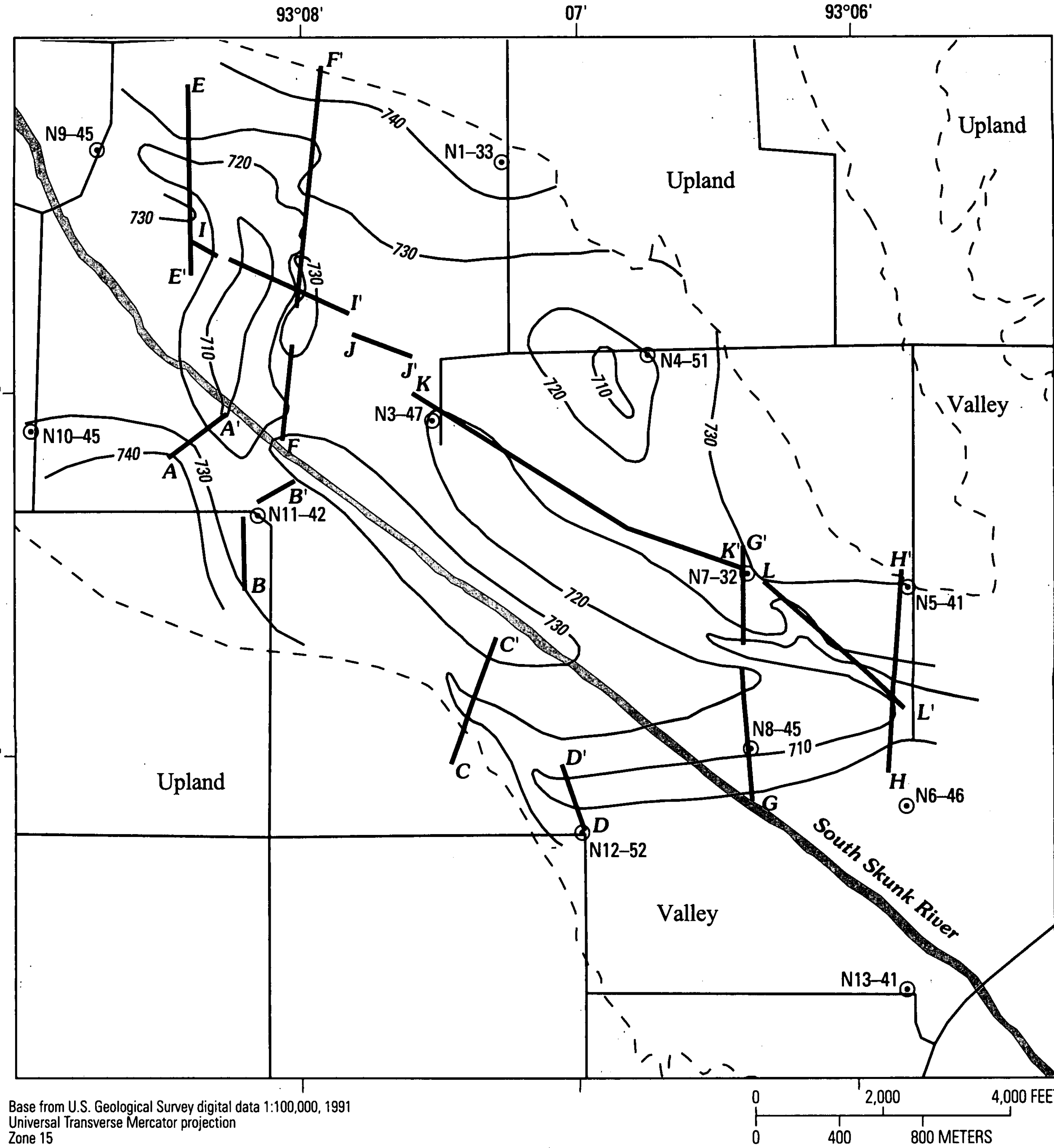
Ground-water levels were higher during the June 2000 measurement than either the February or October 2000 measurements at all observation wells except wells N1–33 and N4–51 (fig. 2), which are closest to the municipal well field. The highest water-level altitude occurred at well N10–45 in the west, upgradient part of the study area. The lowest water-level altitudes were measured at observation well N4–51, which is east and downgradient from the well field (fig. 2).

A potentiometric-surface map of water levels in the alluvial aquifer for the June 2000 measurements is shown in figure 6. Water levels are lowest in the well field area. Ground water flows radially towards the well field from adjacent areas of the alluvial aquifer. On the well-field side of the South Skunk River, water levels in the river are higher than adjacent ground-water levels except in the southeast corner of the study area, indicating flow from the river toward the well field. Gradients between the river and the well field were similar on the other measurement dates as well.

Water Quality

Samples were collected from the observation wells and the South Skunk River at Highway 14 on June 6–8, 2000 (table 4). Samples were analyzed for dissolved oxygen, pH, specific conductance, temperature, and alkalinity onsite at the time of sample collection. Laboratory analyses consisted of common ions, nutrients, dissolved solids, bromide, iron, and manganese. Analyses were performed at the USGS National Water Quality Laboratory in Denver, Colorado.

Concentrations of specific conductance, alkalinity, calcium, magnesium, sodium, bicarbonate, fluoride, silica, dissolved solids, and bromide were similar for



EXPLANATION

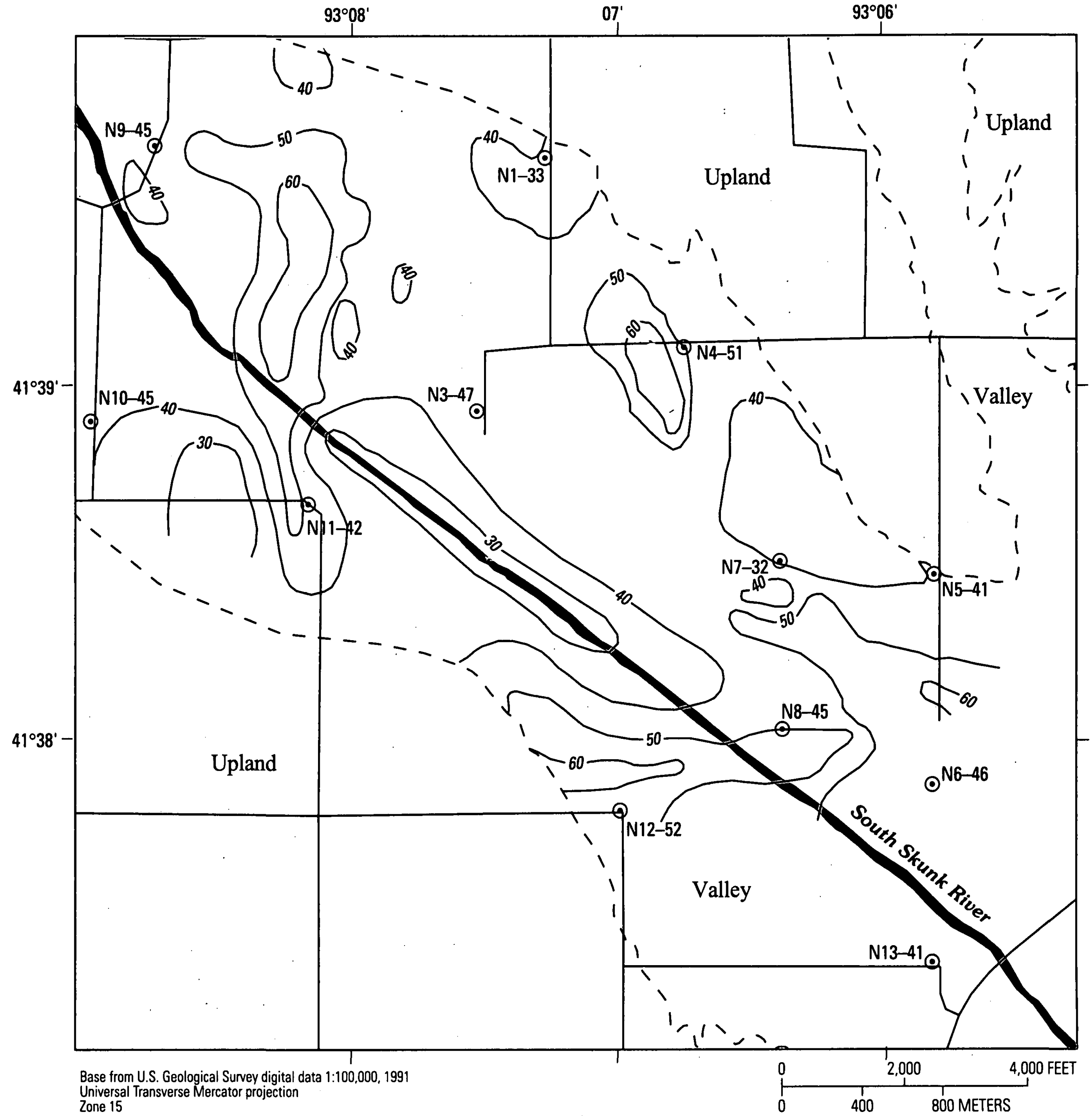
—710— **Bedrock contour**—Shows altitude of bedrock surface. Contour interval 10 feet. Datum is sea level

A—*A'* **Trace of seismic geophysical section *A–A'* through *L–L'***

— — — **Boundary between upland area and river valley**

N7–32⊙ **Observation well and identifier**

Figure 4. Altitude and configuration of bedrock surface based on seismic-refraction and test-hole data, South Skunk River Valley near Newton, Iowa.



EXPLANATION

—*50*— **Line of equal thickness of unconsolidated deposits**—Interval 10 feet

– – – **Boundary between upland area and river valley**

N7-32⊙ **Observation well and identifier**

Figure 5. Thickness of unconsolidated deposits based on seismic-refraction and test-hole data, South Skunk River Valley near Newton, Iowa.

Table 3. Static water-level measurements from observation wells, municipal wells, and surface-water sites in the South Skunk River alluvium near Newton, Iowa, February, June, and October 2000

[Water levels in feet above sea level; observation wells measured February 29, June 7, and October 15; municipal wells measured February 27, June 7, and October 15; South Skunk River measured March 1, June 8, and October 17]

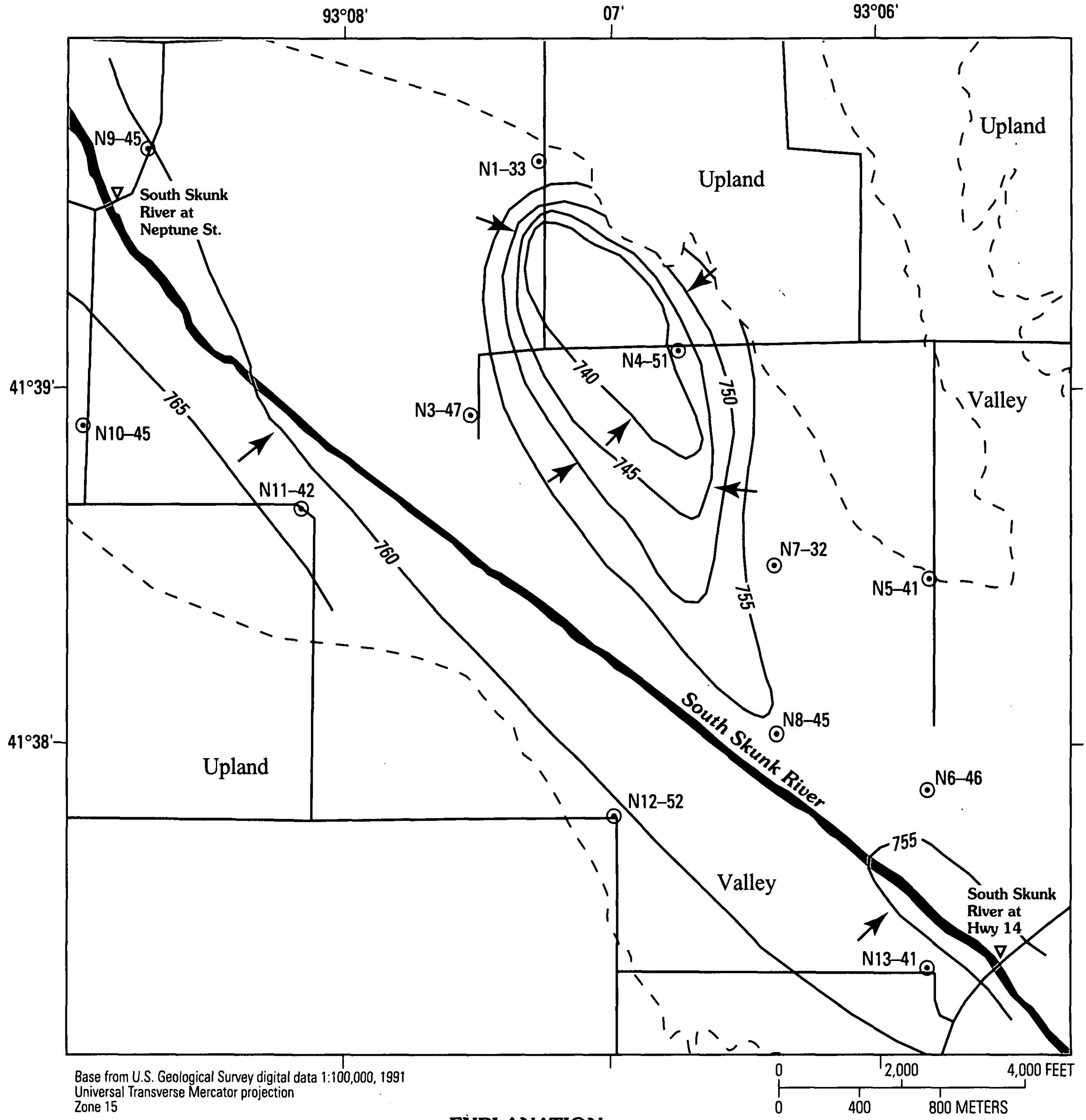
Data-collection site (fig. 2)	February	June	October
	Observation wells		
N1–33	757.02	756.34	754.57
N3–47	755.58	756.35	752.55
N4–51	741.41	740.60	736.66
N5–41	753.50	757.74	750.56
N6–46	756.47	759.48	752.33
N7–32	754.79	757.25	752.13
N8–45	753.70	755.09	751.23
N9–45	758.67	760.21	755.25
N10–45	764.21	769.91	761.41
N11–42	760.59	763.78	757.02
N12–52	757.85	760.03	754.96
N13–41	757.83	758.96	753.71
	Municipal wells		
Well 1	742.46	741.21	741.71
Well 3	745.04	742.13	743.04
Well 5	742.96	743.13	741.88
Well 6	743.91	742.16	741.49
Well 7	742.05	746.55	745.38
Well 8	742.02	739.77	739.02
Well 9	741.13	740.13	739.55
Well 10	742.35	740.35	739.43
Well 11	741.38	740.38	739.38
Well 12	739.12	737.79	738.20
Well 13	738.74	737.74	737.99
Well 14	741.89	743.39	743.72
Well 15	739.95	738.79	739.04
Well 16	739.85	738.43	738.85
Well 17	741.21	739.46	740.71
Well 18	740.44	737.61	738.77
Well 19	742.06	741.06	741.31
Well 20	741.35	739.60	740.18
Well 21	745.20	738.70	742.62
Well 22	740.21	738.71	739.96
Well 23	741.32	739.32	740.15
	South Skunk River		
Neptune Street bridge	762.22	762.44	761.33
Highway 14 bridge	753.74	754.00	752.84

all samples. Samples from all observation wells except well N1–33 had low concentrations of dissolved oxygen.

Measured values of pH, temperature, potassium, chloride, nitrite nitrogen, total phosphorus, and orthophosphorus were similar for all ground-water samples but higher for the river sample. River water was substantially more alkaline than ground-water samples. River water contained about twice as much potassium and chloride as ground-water samples. Ground-water samples typically contained ammonia plus organic nitrogen near or less than the method detection limit (0.10 mg/L), whereas the river-water sample was substantially higher (0.30 mg/L). River water also contained detectable concentrations of nitrite nitrogen, total phosphorus, and orthophosphorus, whereas ground-water samples were near or less than method detection limits.

Sulfate, ammonia nitrogen, nitrite plus nitrate, iron, and managanese concentrations varied. Sulfate was present in all samples, ranging from 34 to 112 mg/L. River water contained sulfate concentrations similar to ground water in some observation wells. Ammonia nitrogen was detected in all samples, including the river-water sample, with the exception of two ground-water samples. Nitrite plus nitrate nitrogen was detected only in three ground-water samples and one river-water sample. Considering that ground-water samples contained no detectable nitrite concentrations, nitrite plus nitrate concentrations are composed primarily of nitrate nitrogen. One sample (well N1–33) exceeded the U.S. Environmental Protection Agency Maximum Contaminant Level for nitrate (10 mg/L as N) (U.S. Environmental Protection Agency, 1996). Iron concentrations ranged from less than 10 to 2,350 µg/L. Samples that were high in iron also were high in manganese. Samples that had iron concentrations less than the method detection limit were the same samples that had detectable nitrate nitrogen concentrations, indicating oxygenated conditions.

Results of the water-quality sampling indicate that reducing conditions are present at most of the alluvial ground-water sampling sites in the study area. Conditions that are indicative of a reducing environment are low dissolved oxygen, large concentrations of iron and managanese, nitrogen in the reduced forms of nitrite or ammonia, and potentially high sulfate concentrations. Samples that contained substantial amounts of dissolved oxygen contained low concentrations of iron



EXPLANATION

—*755*— **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells. Contour interval 5 feet. Datum is sea level

Approximate direction of ground-water flow

Boundary between upland area and river valley

N7–32 ⊙ **Observation well and identifier**

South Skunk River at Hwy 14 ▽ **Surface-water measurement site and identifier**

Figure 6. Potentiometric surface of alluvial aquifer, South Skunk River Valley near Newton, Iowa, June 6, 2000.

Table 4. Selected water-quality characteristics and constituents in water from selected wells in the South Skunk River alluvial aquifer and South Skunk River near Newton, Iowa, 2000

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; µg/L, micrograms per liter; --, no data available; <, less than; E, estimated value]

Data-collection site (fig. 2)	Site identification	Date (month/day/ year)	Time (24 hour)	Oxygen, dissolved (mg/L)	pH, water, whole, onsite (standard units)	Specific conductance (µS/cm)	Temperature water (°C)	Alkalinity, onsite (mg/L as $CaCo_3$)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)
N1–33	413938093071601	6/7/2000	1330	8.0	6.7	750	13.0	254	93	32
N3–47	413856093073201	6/6/2000	1400	.1	6.7	593	12.0	200	71	24
N4–51	413907093064401	6/6/2000	1600	.1	6.7	884	13.2	415	112	40
N5–41	413828093054701	6/8/2000	1945	.3	6.8	819	16.0	330	107	40
N6–46	413753093054701	6/8/2000	2030	--	7.1	747	16.6	212	62	22
N7–32	413831093062201	6/8/2000	1445	.2	7.2	524	15.0	209	71	18
N8–45	413802093062201	6/8/2000	1700	.2	6.8	555	13.0	228	68	24
N9–45	413940093084601	6/7/2000	0845	.1	7.0	793	12.5	292	98	37
N10–45	413854093090101	6/7/2000	1030	.1	7.0	896	12.5	352	111	40
N11–42	413840093081101	6/7/2000	1715	.1	6.8	540	12.1	233	66	24
N12–52	413749093065901	6/7/2000	1515	.2	6.8	688	12.5	292	82	33
N13–41	413723093054701	6/7/2000	1330	.2	6.8	633	13.0	261	78	27
South Skunk River at Highway 14	05471380	6/8/2000	1230	9.3	8.2	640	23.5	242	80	26
Newton municipal well 13	413913093070001	7/19/2000	1400	--	6.9	673	12.2	280	95	35

Table 4. Selected water-quality characteristics and constituents in water from selected wells in the South Skunk River alluvial aquifer and South Skunk River near Newton, Iowa, 2000—Continued

Data-collection site (fig. 2)	Date (month/day/year)	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L as Na)	Bicarbonate (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Sulfate, dissolved (mg/L as SO_4)	Nitrogen, ammonia plus organic material, dissolved (mg/L as N)
N1–33	6/7/2000	0.9	8.3	310	0	12	0.4	20	34	<0.10
N3–47	6/6/2000	1.3	10	244	0	15	.3	20	53	.29
N4–51	6/6/2000	1.0	11	506	0	8.6	.3	21	56	E.10
N5–41	6/8/2000	.8	5.7	403	0	15	.2	24	102	<.10
N6–46	6/8/2000	1.0	7.5	259	0	13	.3	23	43	<.10
N7–32	6/8/2000	.9	7.0	255	0	8.4	.3	23	60	<.10
N8–45	6/8/2000	.9	6.9	278	0	8.3	.3	24	60	.13
N9–45	6/7/2000	1.4	7.5	356	0	17	.2	22	105	<.10
N10–45	6/7/2000	.9	14	430	0	17	.2	23	112	E.10
N11–42	6/7/2000	.9	6.3	284	0	6.2	.3	21	51	E.10
N12–52	6/7/2000	1.1	7.3	356	0	12	.2	19	70	<.10
N13–41	6/7/2000	1.2	9.0	318	0	8.9	.3	26	69	.15
South Skunk River at Highway 14	6/8/2000	2.5	13	295	0	24	.3	20	42	.30
Newton municipal well 13	7/19/2000	1.1	7.6	--	--	17	.3	23	39	.20

Table 4. Selected water-quality characteristics and constituents in water from selected wells in the South Skunk River alluvial aquifer and South Skunk River near Newton, Iowa, 2000—Continued

Data-collection site (fig. 2)	Date (month/day/year)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Solids, residue at 180 °C, dissolved (mg/L)	Bromide, dissolved (mg/L as Br)	Iron, dissolved (μg/L as Fe)	Manganese, dissolved (μg/L as Mn)
N1–33	6/7/2000	<0.02	12	<0.01	<0.05	<0.01	454	0.04	<10	22
N3–47	6/6/2000	.23	<.05	<.01	<.05	.02	364	.04	2,170	282
N4–51	6/6/2000	.03	<.05	<.01	<.05	<.01	543	.08	1,110	347
N5–41	6/8/2000	.03	.11	<.01	E.04	.04	521	.12	<10	18
N6–46	6/8/2000	<.02	.20	<.01	<.05	<.01	309	.03	<10	125
N7–32	6/8/2000	.04	<.05	<.01	<.05	.01	334	.04	940	286
N8–45	6/8/2000	.10	<.05	<.01	<.05	.05	350	.04	2,350	278
N9–45	6/7/2000	.02	<.05	<.01	<.05	<.01	507	.10	840	368
N10–45	6/7/2000	.07	<.05	<.01	<.05	<.01	577	.16	2,220	395
N11–42	6/7/2000	.06	<.05	<.01	<.05	<.01	333	.03	1,930	415
N12–52	6/7/2000	.02	<.05	<.01	<.05	<.01	419	.06	820	310
N13–41	6/7/2000	.12	<.05	<.01	<.05	.06	402	.07	2,210	386
South Skunk River at Highway 14	6/8/2000	.04	6.6	.03	.21	.19	418	.01	<10	66
Newton municipal well 13	7/19/2000	<.10	7.8	--	--	.10	410	--	<20	<20

and manganese and large amounts of nitrate nitrogen. Water quality for city of Newton municipal well 13, sampled as part of a separate program, is also listed in table 4 for comparison purposes.

The cause of low dissolved-oxygen concentrations and the reducing conditions in the aquifer is not known. One explanation would be that the alluvial valley could be a regional discharge area for ground-water flow that upwells from bedrock into the alluvial materials. This discharge of deep, regional ground water would be expected to contain "old" water with little to no remaining dissolved oxygen. Norton and others (1912) report that wells drilled into the Mississippian aquifer beneath the South Skunk River Valley are artesian, with hydraulic heads from 10 to 20 ft above the valley land surface. Wells drilled to the bedrock beneath the alluvial aquifer or additional alluvial wells at various depths would need to be installed to verify upward ground-water gradients beneath the valley and to confirm a discharge area of bedrock water.

A second explanation of the reducing conditions could be a biochemically driven reaction that is causing the denitrification of nitrate nitrogen with depth in the aquifer. The land use throughout and upgradient of the study area is mainly row-crop agriculture that utilizes substantial inputs of nitrogen fertilizer. As this nitrogen, predominately in the form of nitrate, infiltrates deeper in the aquifer, micro-organisms utilize the nitrate as part of their metabolism. These metabolic reactions result in reduced forms of nitrogen and low concentrations of dissolved oxygen. The low dissolved oxygen then causes oxidized forms of iron and manganese naturally present in the geologic materials to become reduced and mobilize into the dissolved phase. A source of organic carbon is needed to support these types of biochemical reactions. Well logs that describe coal, wood, and other buried vegetation indicate the presence of carbon in the aquifer to support these types of reactions.

GROUND-WATER SOURCES IN THE JASPER COUNTY AREA

Hydrogeologic units underlying the Jasper County area (table 1) vary considerably in lithology, thickness, extent, and water-yielding capability. The primary ground-water sources are alluvial aquifers, glacial-drift aquifers, buried-channel aquifers, and bedrock aquifers.

The rate at which ground water can be withdrawn from wells in Jasper County is not only different for each aquifer but also can be different within each aquifer depending on location and local aquifer characteristics. Generally, the thicker the aquifer, the more water it will yield to a well. Alluvial aquifers will yield more water to wells on a sustained basis 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) bedrock is near the land surface and is not covered by confining units, the rock may be highly fractured due to weathering and erosion prior to burial by younger-aged materials. Fractures in bedrock aquifers improve water-transmitting characteristics to wells.

In addition to well yield, water quality also affects whether ground water is used for human consumption. Naturally occurring minerals, such as dissolved solids and sulfate, limit the use of ground water in some areas either because of drinking-water regulations or for aesthetic reasons.

The aquifers that can consistently produce yields of sufficient quantity and that have acceptable water quality for municipal water supply in Jasper County include alluvial aquifers, the Mississippian aquifer, and the St. Peter and Jordan aquifers of the Cambrian-Ordovician aquifer system. Water from glacial-drift and buried-channel aquifers is used mainly by private, rural wells.

Alluvial Aquifers

Alluvial aquifers are the shallowest, and therefore most readily available, source of potential ground-water supply. Alluvial aquifers in Jasper County are composed of stream-deposited unconsolidated materials (mostly sand, gravel, silt, and clay) that occur in river valleys. Sand and gravel are the most permeable of the alluvial materials.

Two principal alluvial aquifers occur in Jasper County—one along the South Skunk River and the other along the North Skunk River (Bruner and Hallberg, 1987). The lithology and thickness of the South Skunk River alluvial deposits near Newton are described in the previous section of this report. Other smaller alluvial aquifers occur along Indian Creek and Elk Creek (Twenter and Coble, 1965).

Lithology and thickness of the alluvial aquifer in the South Skunk River Valley upstream and downstream from the study area is mostly unknown except from drillers' logs at a few well locations. That limited information does not indicate the presence of thicker alluvial deposits than those near the Newton well field. Information on alluvial materials along the North Skunk River, Indian Creek, and other streams in Jasper County is also limited. Alluvial materials along these smaller streams are probably thinner than those in the South Skunk River Valley and would have smaller water-yielding capabilities, except in locations where the alluvial aquifer might overlie a buried-channel aquifer.

Twenter and Coble (1965) report yields from the South Skunk River alluvium to be greater than 500 gal/min. A well in the Newton well field was pumped at a rate of 950 gal/min as part of an aquifer test ((Layne-Western Company, Inc., written commun., 1970). The greatest saturated thickness of sand and gravel in other alluvial aquifers (possibly as much as about 50 ft, locally) could produce yields of a few hundred gallons per minute to individual large-diameter wells.

The water quality of the alluvial aquifers reflect 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 250 mg/L ($CaCO_3$). Concentrations of dissolved solids averaging about 500 mg/L are characteristic of water from alluvial aquifers in the South Skunk River Valley (Twenter and Coble, 1965).

Glacial-Drift and Buried-Channel Aquifers

Glacial-drift aquifers are composed 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 produce variable yields to wells. Glacial-drift and the possibility of aquifer material can be found over much of the upland area. Norton and others (1912) report that wells completed in loess and glacial drift in upland areas of Jasper County produce acceptable quantities and quality for private wells. These wells range from 25 to 300 ft deep.

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. Major ions are calcium and bicarbonate, but like the alluvial aquifers, sodium and sulfate are also common ions. Hardness averages about 375 mg/L ($CaCO_3$), and dissolved solids average about 450 mg/L (Twenter and Coble, 1965).

Buried-channel aquifers are composed of alluvial materials deposited 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 because indications at the land surface normally are lacking (Olcott, 1992). Two major bedrock valleys were mapped by Hansen (1985) in Jasper County. One bedrock valley extends from east to west across the northern one-half of the county, whereas the other bedrock valley extends from east to west across the southern part of the county before turning northwesterly in the western part of the county. The thickness and type of materials filling these bedrock valleys and their water-yielding characteristics are not well known.

Ground water from buried-channel aquifers in central Iowa is generally more highly mineralized than water from the alluvial or glacial-drift aquifers. Major ions are calcium and bicarbonate, hardness averages about 1,200 mg/L ($CaCO_3$), and dissolved solids average about 2,000 mg/L ($CaCO_3$) (Twenter and Coble, 1965).

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.

Bedrock of Pennsylvanian age discontinuously underlies surficial unconsolidated materials and consists primarily of shale, thin layers of sandstone, siltstone, coal, and possibly limestone. These rocks form a regional confining unit that in some areas separate overlying unconsolidated materials from the Mississippian aquifer. In some localized areas, a limited water supply can be developed in bedrock of Pennsylvanian age.

The natural chemical quality of water from the principal bedrock aquifers in Jasper County is highly variable. The chemical quality of 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 is composed primarily of limestone and dolomite but can contain shale or evaporite deposits. The thickness of the Mississippian aquifer ranges from about 100 to more than 300 ft in Jasper County, and well yields typically range from 20 to 50 gal/min (Twenter and Coble, 1965).

The quality of water from the Mississippian aquifer is highly variable, but the water generally is quite mineralized. Water from the Mississippian aquifer tends to be of the calcium bicarbonate type. The dissolved-solids concentrations can range from 2,000 to 3,000 mg/L (Olcott, 1992).

The Silurian-Devonian aquifer is separated from the overlying Mississippian aquifer by a thick, usually shale, confining unit. Although composed primarily of carbonate rocks (limestone and dolomite), the Silurian-Devonian aquifer may contain evaporite minerals, such as gypsum and anhydrite. Typical thickness of the Silurian- Devonian aquifer in Jasper County is about 600 ft (Twenter and Coble, 1965). Well yields of less than 20 gal/min are estimated for most of Jasper County except near the western boundary of the county where yields increase to 20-50 gal/min (Twenter and Coble, 1965).

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, potassium, and chloride. Dissolved-solids concentrations in the Silurian-Devonian aquifer are in excess of 5,000 mg/L throughout most of Jasper County (Olcott, 1992). This naturally occurring poor water quality limits the use of water from the Silurian-Devonian aquifer.

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 Jasper County (Olcott, 1992). Sandstone in the upper part occurs from about 700 to 900 ft below land surface (Twenter and Coble, 1965). 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 central 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, and is about 550 ft thick in Jasper County (Twenter and Coble, 1965). In some parts of Iowa, the three units generally are hydraulically connected due to fracturing in the dolomite and function as one aquifer. The Jordan aquifer, ranging in thickness from 40 to 60 ft, yields more than 1,000 gal/min throughout Jasper County (Twenter and Coble, 1965). Ground-water flow in the Cambrian-Ordovician aquifer is generally southeasterly (Olcott, 1992). Primary recharge to the Cambrian-Ordovician aquifer is from vertical leakage (Burkart and Buchmiller, 1990). Declining water levels 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 and has hardness of about 300 mg/L ($CaCO_3$), and dissolved-solids concentrations range from 500 to 1,000 mg/L (Twenter and Coble, 1965). Large concentrations of iron, fluoride, and radium (Ra-266) (Horick and Steinhilber, 1978) are possible in water from this aquifer at some locations.

SUMMARY

The city of Newton obtains its municipal water supply from the South Skunk River alluvial aquifer.

Withdrawals averaged 4.5 Mgal/d in 1998, and additional sources of water may be needed by the city to meet an expected demand of 8 Mgal/d by 2007.

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

Available hydrologic and geologic information was compiled from the scientific literature and previous studies in the Newton area. Additional thickness and lithologic data for the unconsolidated materials in the South Skunk River Valley were collected for this study at selected sites from October 1999 through October 2000. Information on river stage and water quality in the South Skunk River alluvial aquifer near Newton also was collected.

The alluvial deposits along the South Skunk River Valley near Newton consist of sand and gravel deposits of glacial and fluvial origin. The sand and gravel are commonly interbedded with clay and silt lenses in the upper 20 ft of the deposits. Deeper materials appear to be primarily sand and gravel. The upper bedrock beneath the alluvial aquifer consists of shale or limestone.

Seismic refraction and test-hole drilling were used to collect geologic information for the unconsolidated material in the South Skunk River Valley. Seismic refraction was used to determine the depth to bedrock below land surface and to estimate the thickness of unconsolidated materials. Test holes were drilled to determine the thickness and lithology of the unconsolidated material and to construct observation wells for measuring water levels and collecting water-quality samples.

Thicknesses of the unconsolidated materials in the South Skunk River Valley in the study area range from less than 30 to more than 60 ft. Unconsolidated materials in three areas appear to exceed 50 ft in thickness—an area about 5,000 ft west of the present well field, the present well field area, and an area about 5,000 ft southeast of the present well field.

Water levels measured during 2000 indicate ground-water movement towards the Newton well field from within the alluvial aquifer. Water levels in the alluvial aquifer on the well-field side of the South Skunk River were lower than water levels in the river, indicating flow from the river toward the well field.

Water quality in the aquifer was similar to water quality in the South Skunk River except that most ground-water samples were low in dissolved oxygen. The reducing conditions in the aquifer resulted in high concentrations of iron and manganese and reduced forms of nitrogen.

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