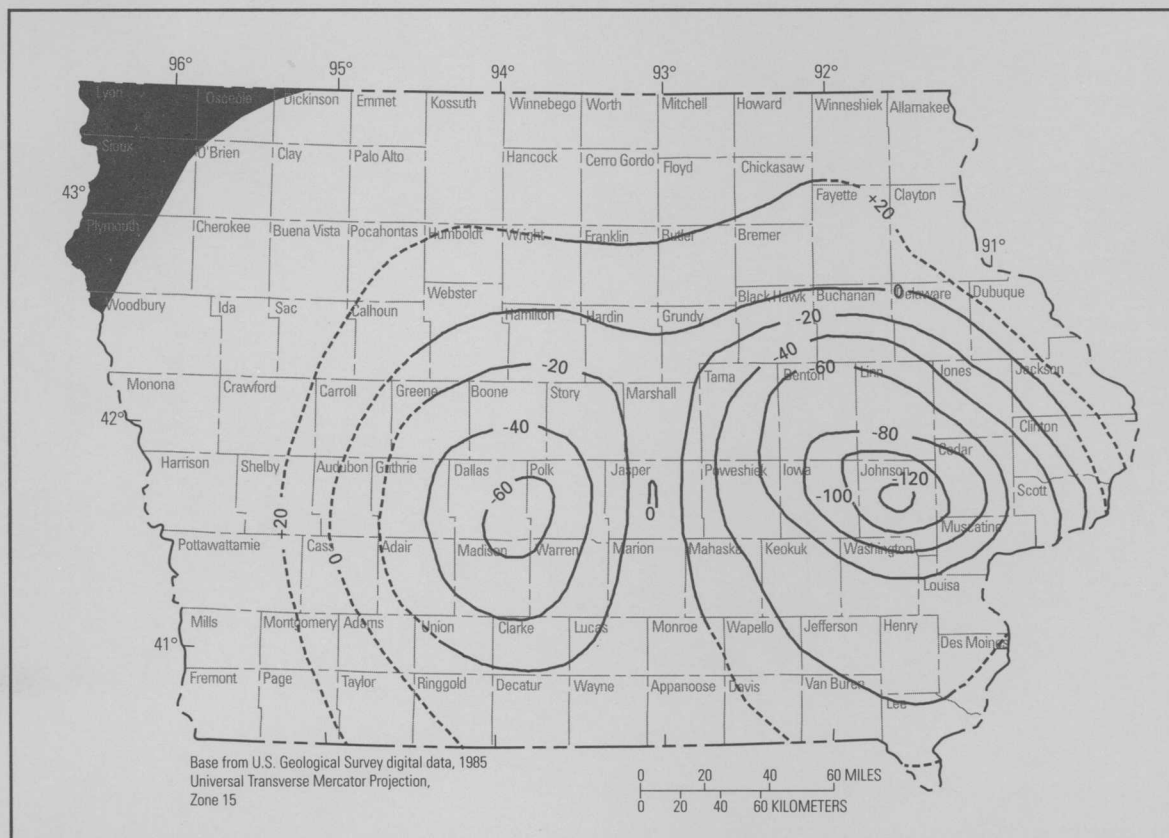


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IOWA DEPARTMENT OF NATURAL RESOURCES—
GEOLOGICAL SURVEY BUREAU

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Regional Water-Level Changes for the Cambrian-Ordovician Aquifer in Iowa, 1975 to 1997

Water-Resources Investigations Report 99-4134



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

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By MICHAEL J. TURCO

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Iowa City, Iowa
1999

U.S. Department of the Interior

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CONTENTS

Abstract.....	1
Introduction	1
Purpose and Scope.....	3
Acknowledgment.....	3
Hydrogeology	3
Comparison of 1975 and 1997 Potentiometric Surfaces	3
Comparison of Measured and Simulated 1997 Water Levels.....	7
Summary.....	9
References	11

FIGURES

1. Graph showing estimated pumpage from the Jordan aquifer during 1975 water year and from the Cambrian-Ordovician aquifer system during 1995 water year.	2
2. Chart showing stratigraphic and hydrogeologic units of the Cambrian-Ordovician aquifer system in Iowa	6
3-6. Maps showing:	
3. Potentiometric surface of the Jordan aquifer based on water levels measured during 1975 water year	7
4. Potentiometric surface of the Cambrian-Ordovician aquifer based on maximum measured water level during 1997 water year and location of wells in the Cambrian-Ordovician aquifer system monitoring network, 1997	8
5. Water-level change in the Cambrian-Ordovician aquifer, 1975 to 1997	9
6. Potentiometric surface of the Cambrian-Ordovician aquifer based on maximum water levels measured during 1997 water year with simulated water levels at major pumping centers	10

TABLES

1. Description of wells in the Cambrian-Ordovician aquifer system monitoring network during 1997 water year ...	4
2. Water levels in wells in the Cambrian-Ordovician aquifer system monitoring network during 1997 water year ..	5

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

	Multiply	By	To obtain
	foot (ft)	0.3048	meter
	foot per year (ft/yr)	0.3048	meter per year
	foot squared per day (ft ² /d)	0.0929	meter squared per day
	million gallons per year (Mgal/yr)	0.00012	cubic meter per second
	mile (mi)	1.609	kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1988 (NGVD of 1988)—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 1988.

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

Water Year: In this report, "water year" is the interval from October 1 to September 30. For example, the 1997 water year is October 1, 1996, to September 30, 1997.

Regional Water-Level Changes for the Cambrian-Ordovician Aquifer in Iowa, 1975 to 1997

By Michael J. Turco

Abstract

The Cambrian-Ordovician aquifer is one of the principal sources of ground water for industry and municipalities in Iowa. The 1998 Iowa Administrative Code Chapter 52.4(3) states that water levels in the Cambrian-Ordovician aquifer are not to decline more than 200 feet from the 1977 baseline. The potentiometric-surface map of the Cambrian-Ordovician aquifer, known locally as the Jordan aquifer, prepared by the Iowa Department of Natural Resources-Geological Survey Bureau and the U.S. Geological Survey in 1978 using water levels measured during the 1975 water year is considered the 1977 baseline.

For this study, water levels measured during the 1997 water year were used to construct a potentiometric-surface map that was compared to the 1977 baseline to describe water-level changes. Since 1975, water levels have declined in two areas of central and eastern Iowa. The maximum measured water-level decline is 133 feet in Johnson County in eastern Iowa. The estimated maximum rate of decline is 6 feet per year in Johnson County.

Results from a two-layer, ground-water flow model of the Cambrian-Ordovician aquifer constructed by the U.S. Geological Survey in 1990 were compared to selected measured 1997 water levels. The difference between the simulated water levels and the 1997 maximum measured water levels ranges from 0 to about 150 feet, but most differences are less than 25 feet. The com-

parison indicates that the model may help estimate future water levels in the Cambrian-Ordovician aquifer as an aid in managing the resource.

INTRODUCTION

The Cambrian-Ordovician aquifer system in Iowa includes the Galena aquifer, the Cambrian-Ordovician aquifer, and the Dresbach aquifer. The Cambrian-Ordovician aquifer is one of the principal sources of water for industry and municipalities in Iowa and contains two sandstone aquifers—the St. Peter aquifer and the Jordan aquifer. Some supply wells are open to both sandstone aquifers and the intervening part of the Prairie du Chien Group or to the Jordan aquifer and the overlying part of the Prairie du Chien Group, but most water comes from the Jordan aquifer.

Horick and Steinhilber (1978) used data from the late 1800's to construct a predevelopment potentiometric-surface map and compared that map to water levels measured during the 1975 water year. This comparison showed a regional decline of water levels in the Jordan aquifer. The decline of water levels extended from Iowa's eastern border west across the State into Shelby, Cherokee, and Ida Counties and from the northern border of Iowa south to northern Lucas County. The mean water-level decline across the State was about 100 ft; however, there were areas where water levels declined as much as 200 ft. Average rates of water-level declines at some pumping centers were about 1.8 to 2.4 ft/yr, whereas at the major pumping centers average rates of water-level decline were about 6 ft/yr (Horick and Steinhilber, 1978).

Pumpage from the Cambrian-Ordovician aquifer has increased since 1975. The total pumpage from the

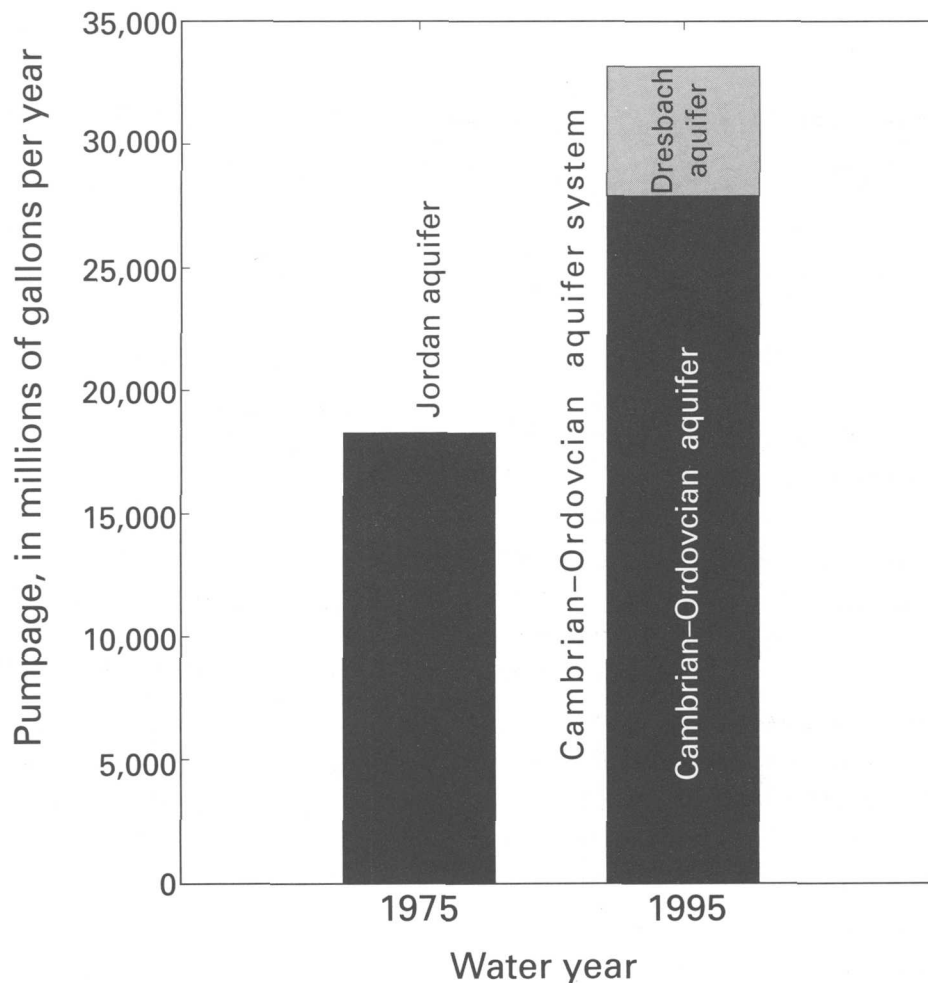


Figure 1. Estimated pumpage from the Jordan aquifer during 1975 water year (Horick and Steinhilber, 1978) and from the Cambrian-Ordovician aquifer system during 1995 water year (E. Fischer, U.S. Geological Survey, written commun., 1998).

Jordan aquifer in 1975 was about 18,000 Mgal/yr (Horick and Steinhilber, 1978). The total pumpage from the Cambrian-Ordovician aquifer in 1995 was almost 28,000 Mgal/yr (fig. 1). The total pumpage from the Cambrian-Ordovician aquifer system, which includes the Cambrian-Ordovician aquifer and the Dresbach aquifer, was more than 33,000 Mgal/yr in 1995. This increase in pumping has focused attention on the Cambrian-Ordovician aquifer and on the importance of documenting the water-level changes on a regional scale.

Iowa Administrative Code Chapter 52.4(3) states that water levels in the Cambrian-Ordovician aquifer

are not to decline more than 200 ft from the 1977 base-line in any high-use area (State of Iowa, 1998). The potentiometric-surface map prepared by Horick and Steinhilber (1978) is currently (1999) used as the base-line. To address these concerns, the U.S. Geological Survey (USGS), in cooperation with the Iowa Department of Natural Resources–Geological Survey Bureau (IDNR–GSB), conducted a review of water-level changes in the Cambrian-Ordovician aquifer from 1975 to 1997. Information from this review can be used by water-resource managers and planners as an aid in evaluating present and future ground-water availability.

In this report, the Cambrian-Ordovician aquifer includes the St. Peter Sandstone, Prairie du Chien Group, and Jordan Sandstone, after nomenclature described by Olcott (1992). Horick and Steinhilber (1978) define the Jordan aquifer to include the Jordan Sandstone and part of the overlying Prairie du Chien Group. Burkart and Buchmiller (1990) refer to the St. Peter-Jordan aquifer as including the St. Peter Sandstone, the Prairie du Chien Group, and the Jordan Sandstone. For convenience in this report, the term Cambrian-Ordovician aquifer will be used to refer to the hydrogeologic units studied by Horick and Steinhilber (1978) and Burkart and Buchmiller (1990).

Purpose and Scope

The primary purpose of this report is to present a comparison of the 1975 and 1997 potentiometric surfaces of the Cambrian-Ordovician aquifer and describe rates of water-level change. A secondary purpose is to present a comparison of actual and simulated water levels for 1997 to assess the predictive capability of a previously developed ground-water flow model of the Cambrian-Ordovician aquifer. This report uses data collected during the 1997 water year from the IDNR-GSB and USGS statewide ground-water-level monitoring network (Lambert, 1990) for 30 wells open to the hydrogeologic units of the Cambrian-Ordovician aquifer system (table 1). Seventeen wells in the ground-water-level monitoring network are open exclusively to the Jordan aquifer (table 2).

Acknowledgment

The author thanks Robert Libra, Iowa Department of Natural Resources-Geological Survey Bureau, for his critical review of the manuscript.

HYDROGEOLOGY

The Cambrian-Ordovician aquifer system in Iowa comprises three major aquifers in rocks of Cambrian and Ordovician age (fig. 2). These are, in descending order, the Galena, Cambrian-Ordovician, and Dresbach aquifers (Olcott, 1992). The Galena aquifer comprises dolomite and shale of Ordovician age (Horick and Steinhilber, 1978). The Cambrian-Ordovician aquifer comprises two permeable sandstone

units of Ordovician and Cambrian age. The Dresbach aquifer comprises sandstone of Cambrian age confined by overlying shale and underlying Precambrian crystalline rocks (Burkart and Buchmiller, 1990).

The principle source of ground water to wells within the Cambrian-Ordovician aquifer system is the Cambrian-Ordovician aquifer. The thickness of the Cambrian-Ordovician aquifer ranges from about 70 to 740 ft in Iowa and dips to the southwest (Olcott, 1992). Transmissivity of the Cambrian-Ordovician aquifer varies from 50 to more than 38,000 ft²/d (Burkart and Buchmiller, 1990). It is recharged principally by vertical leakage from overlying rocks (Burkart and Buchmiller, 1990) and by infiltration of precipitation in northern Iowa and farther north (Horick and Steinhilber, 1978). Ground water in the Cambrian-Ordovician aquifer moves generally from northwest to southeast across Iowa. Water discharges from the aquifer at pumping wells and into overlying aquifers east and south of Iowa (Horick and Steinhilber, 1978).

COMPARISON OF 1975 AND 1997 POTENTIOMETRIC SURFACES

A potentiometric-surface map for the Cambrian-Ordovician aquifer was constructed by Horick and Steinhilber in 1978 (fig. 3) using water levels measured at more than 100 wells. The map shows the altitude at which water levels would have stood in tightly cased wells in 1975. The potentiometric surface was not extended to the western edge of Iowa because of sparse data and was approximated in the northeastern corner of Iowa because of aquifer-unit outcrops in that area. A geographic information system (GIS) was used to construct a digitized version of the 1975 potentiometric-surface map.

A 1997 potentiometric-surface map (fig. 4) was constructed using water levels measured during the 1997 water year (May and others, 1998). Water levels generally were measured on a quarterly basis with a chalked, graduated steel tape or an electric line for the statewide ground-water-level monitoring network operated by the IDNR-GSB and the USGS. The maximum water-level altitude measured in each well was used in an attempt to reduce the effects of nearby pumping on the measurement. Dashed contours in eastern and northeastern Iowa indicate the uncertainties in representing the potentiometric surface of the Cambrian-Ordovician aquifer using water levels mea-

Table 1. Description of wells in the Cambrian-Ordovician aquifer system monitoring network during 1997 water year

[Data modified from May and others (1998). Highlighted wells are open exclusively to the Jordan aquifer. dms, degrees, minutes, seconds]

Map no. (fig. 4)	USGS site identification number	Latitude (dms)	Longitude (dms)	County	Well name
1	404103092404001	40°41'03"	92°40'40"	Appanoose	Moulton Town Well
2	422339094375101	42°23'47"	94°37'57"	Calhoun	Rockwell City Well No. 4
3	430757093131801	43°07'57"	93°13'18"	Cerro Gordo	St. Brand Creameries No.1
4	424348095231601	42°43'48"	95°23'16"	Cherokee	Well D-28
5	425433091285002	42°54'33"	91°28'50"	Clayton	Well BS1-B
6	430156091182901	43°01'56"	91°18'29"	Clayton	USGS 22E1
7	413613093530401	41°36'13"	93°53'04"	Dallas	Waukee No.2
8	404422093445602	40°44'22"	93°44'56"	Decatur	Leon City Well
9	422901090471901	42°29'01"	90°47'19"	Dubuque	Standard Oil No.2
10	430800092540301	43°07'45"	92°54'07"	Floyd	Rudd Town Well No.2
11	422611092552501	42°26'07"	92°55'27"	Grundy	Wellsburg Well No. 1
12	432158092065801	43°21'58"	92°06'58"	Howard	Cresco Well
13	420842090165701	42°08'42"	90°16'57"	Jackson	Green Island No. 1
14	420842090165702	42°08'42"	90°16'57"	Jackson	Green Island No. 2
15	420842090165703	42°08'42"	90°16'57"	Jackson	Green Island No. 3
16	420842090165704	42°08'42"	90°16'57"	Jackson	Green Island No. 4
17	414147093035401	41°41'50"	93°03'53"	Jasper	John Coppess Well
18	414145091350101	41°41'45"	91°35'01"	Johnson	Coralville Well No. 10
19	404306091270201	40°43'06"	91°27'02"	Lee	West Point No. 3
20	420200091363001	42°02'00"	91°36'36"	Linn	Marion No. 4
21	420219091344101	42°02'45"	91°34'43"	Linn	Marion No. 5
22	431620095250501	43°16'20"	95°25'05"	Osceola	Well D-38
23	424850096074801	42°48'50"	96°07'48"	Plymouth	Well D-21
24	412407095391201	41°24'01"	95°39'17"	Pottawattamie	Underwood Well
25	413544090212901	41°35'44"	90°21'29"	Scott	Le Claire Well No.3
26	420129093273701	42°01'30"	93°27'33"	Story	Nevada Well No. 4
27	420957092181801	42°09'57"	92°18'21"	Tama	Dysart Park Well
28	411813091411202	41°18'13"	91°41'14"	Washington	Washington No. 5
29	411822091411001	41°18'22"	91°41'13"	Washington	Washington No. 6
30	411812091412601	41°18'08"	91°41'49"	Washington	Washington No. 7

sured in wells open to the Dresbach and Galena aquifers.

A water-level change map (fig. 5) was developed using manual contouring methods. The potentiometric surface during the 1975 water year (Horick and Steinhilber, 1978) was combined with well locations and maximum water levels measured during the 1997 water year. The water-level change at each well location was calculated by subtracting the interpolated 1975 water level from the measured 1997 water level. The changes calculated for those wells screened in the Cambrian-Ordovician aquifer (table 2) are considered

good representations of the water-level change from 1975 to 1997. The water-level changes calculated for the remaining wells are considered approximations.

There are two areas of water-level decline in eastern and central Iowa (fig. 5). The area of decline in eastern Iowa is centered in Johnson County where a measured water-level decline of 133 ft has occurred since 1975. The area of decline in central Iowa is centered along the border of Dallas and Polk Counties where a measured water-level decline of about 77 ft has occurred.

Table 2. Water levels in wells in the Cambrian-Ordovician aquifer system monitoring network during 1997 water year

[Data modified from May and others, (1998). Highlighted wells are open exclusively to the Jordan aquifer]

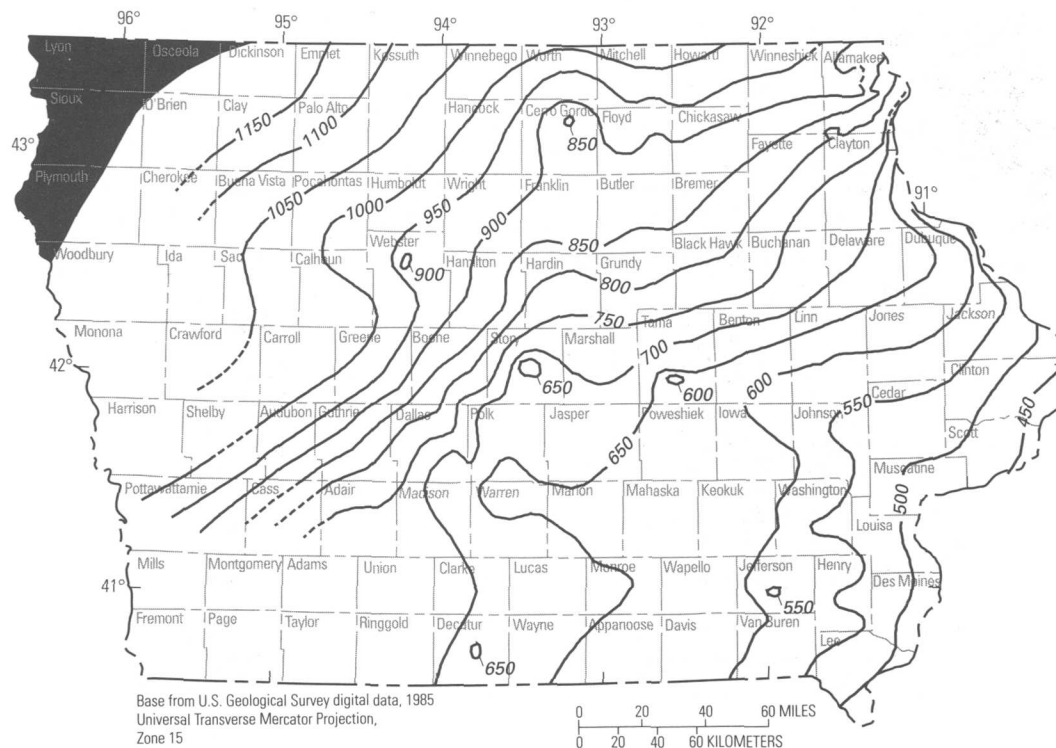
Map no. (fig. 4)	Altitude of land surface (feet above sea level)	Minimum depth of water level below land surface (feet)	Maximum altitude of water level (feet above sea level)	Hydrogeologic unit (fig. 2)	Depth of bottom of well (feet below land surface)
1	992	381.37	610.63	Cambrian-Ordovician aquifer	2,380
2	1,227	205	1,022	Cambrian-Ordovician aquifer	1,970
3	1,162	273.17	888	Jordan aquifer	1,340
4	1,370	193.94	1,176	Cambrian-Ordovician aquifer system	1,550
5	855	3.71	851	Galena aquifer	85
6	940	21.84	918	St. Peter aquifer	49
7	1,012	389	623	Jordan aquifer	2,730
8	1,105.6	440.27	665.33	Jordan aquifer	2,850
9	889	240.38	648.62	Dresbach aquifer	1,230
10	1,123	161	962	Jordan aquifer	1,290
11	1,094	275	819	Jordan aquifer	20,50
12	1,288	318	970	Jordan and Dresbach aquifers	1,120
13	610	-4.85	614.85	Dresbach aquifer	1,800
14	610	.73	609.27	Dresbach aquifer	1,280
15	610	7.19	602.81	St. Peter and Jordan aquifers	910
16	610	12.98	597.02	Galena aquifer	400
17	910	236.18	673.82	Jordan aquifer	2,570
18	740	318	422	Jordan aquifer	1,710
19	763	262.04	501	Jordan aquifer	1,910
20	800	283	517	Jordan aquifer	1,570
21	859	330	529	Jordan aquifer	1,660
22	1,402	197.83	1,204	St. Peter aquifer	662
23	1,245	56.99	1,88	Cambrian-Ordovician aquifer system	1,340
24	1,093	73.60	1,019	Jordan aquifer	2,520
25	703	262.00	441.00	Jordan aquifer	1,610
26	991	370	621	Jordan aquifer	2,630
27	961	334	627	Jordan aquifer	1,880
28	755	248	507	Jordan aquifer	1,900
29	757	304	453	Jordan aquifer	1,900
30	748	247	501	Jordan aquifer	1,830

Water levels throughout the remaining areas of Iowa show no change or an increase since 1975. Large increases can and do occur when wells stop being pumped. Areas showing water-level increases also can be explained by the uncertainty in comparing the 1975 potentiometric surface constructed using water levels measured in more than 100 wells to the 1997 potentiometric surface constructed using maximum water levels measured in 30 wells or in using water levels measured in wells open to aquifers above or below the Cambrian-Ordovician aquifer in both data sets. The annual rate of water-level change has varied little compared to rates reported by Horick and Steinhilber (1978). Maximum rates of water-level decline from

metric surface constructed using maximum water levels measured in 30 wells or in using water levels measured in wells open to aquifers above or below the Cambrian-Ordovician aquifer in both data sets. The annual rate of water-level change has varied little compared to rates reported by Horick and Steinhilber (1978). Maximum rates of water-level decline from

Era	System	Stratigraphic units		Hydrogeologic units		
PALEOZOIC	ORDOVICIAN	Maquoketa Formation		Confining unit		
		Galena Dolomite		Galena aquifer		
		Decorah Formation		Confining unit		
		Platteville Formation				
		St. Peter Sandstone		St. Peter aquifer	Cambrian-Ordovician aquifer	
		Prairie du Chien Group	Willow River Dolomite Member	Confining unit		
			Root Valley Sandstone Member	Jordan aquifer		
			Oneota Dolomite Member			
		CAMBRIAN	Trempealeau Group	Jordan Sandstone		Confining unit
	St. Lawrence Dolomite					
	Franconia Sandstone					
	Dresbach Group		Galesville Sandstone	Ironton-Galesville aquifer	Dresbach aquifer	
			Eau Claire Formation	Confining unit		
			Mount Simon Sandstone	Mount Simon aquifer		
	Cambrian-Ordovician aquifer system					

Figure 2. Stratigraphic and hydrogeologic units of the Cambrian-Ordovician aquifer system in Iowa (modified from Olcott, 1992, and Burkart and Buchmiller, 1990).



EXPLANATION

Jordan aquifer not present (Horick and Steinhilber, 1978)

—650— Potentiometric contour—Shows altitude at which water levels would have stood in tightly cased wells. Dashed where approximately located. Contour interval 50 feet. Datum is sea level

Figure 3. Potentiometric surface of the Cambrian-Ordovician aquifer based on water levels measured during 1975 water year (potentiometric surface of Jordan aquifer from Horick and Steinhilber, 1978).

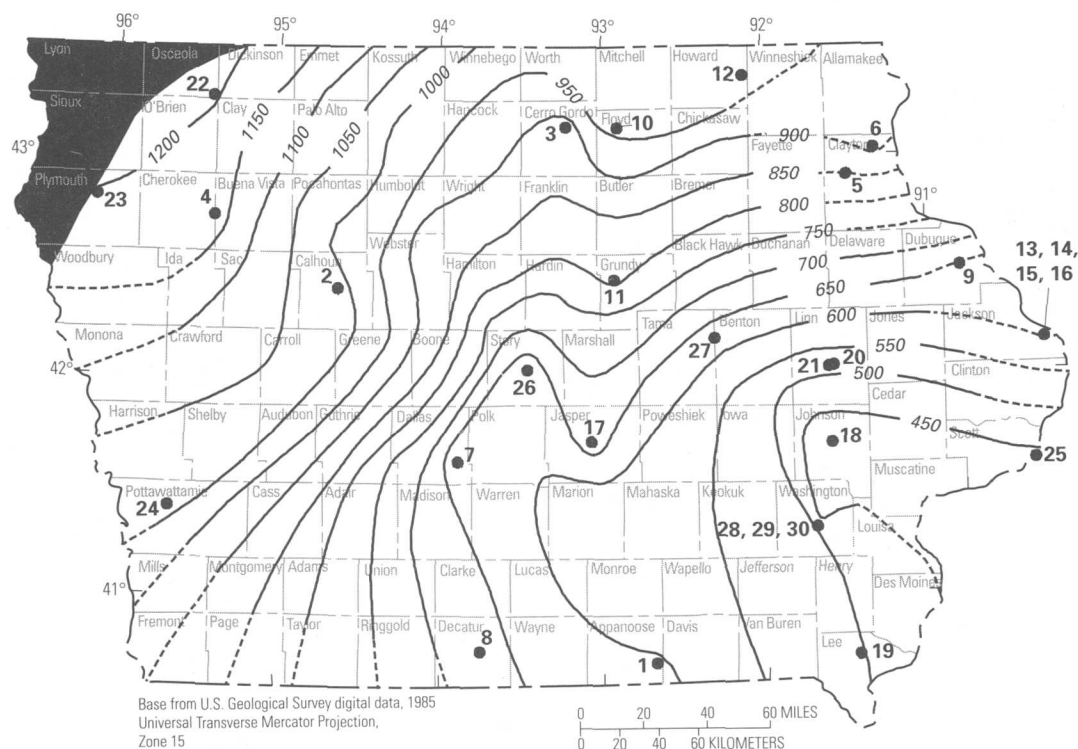
1975 to 1997 were about 3 ft/yr in central Iowa and about 6 ft/yr in eastern Iowa.

COMPARISON OF MEASURED AND SIMULATED 1997 WATER LEVELS

The Cambrian-Ordovician aquifer was simulated in the late 1980's using a two-layer, finite-difference, ground-water flow model (Burkart and Buchmiller, 1990). The upper layer simulated inflow from aquifers composed of Silurian-, Devonian-, and Cretaceous-age rocks, and the lower layer simulated flow in the Cambrian-Ordovician aquifer (Burkart and Buchmiller,

1990). Vertical leakage from overlying units was determined to be the principal source of recharge to the Cambrian-Ordovician aquifer. Discharge from the aquifer was assumed to occur mostly through lateral boundaries and overlying rocks (Burkart and Buchmiller, 1990).

Simulated 1997 water levels for six major pumping centers in Johnson, Henry, Polk (two pumping centers), Benton, and Cerro Gordo Counties in Iowa were compared to the 1997 potentiometric-surface map. To assess the predictive capability of the flow model, simulated 1997 water levels were estimated from hydrographs in Burkart and Buchmiller (1990) and compared to water levels measured during the



EXPLANATION



Jordan aquifer not present (Horick and Steinhilber, 1978)



650 --- Potentiometric contour—Shows altitude at which water levels would have stood in tightly cased wells. Dashed where approximately located. Contour interval 50 feet. Datum is sea level

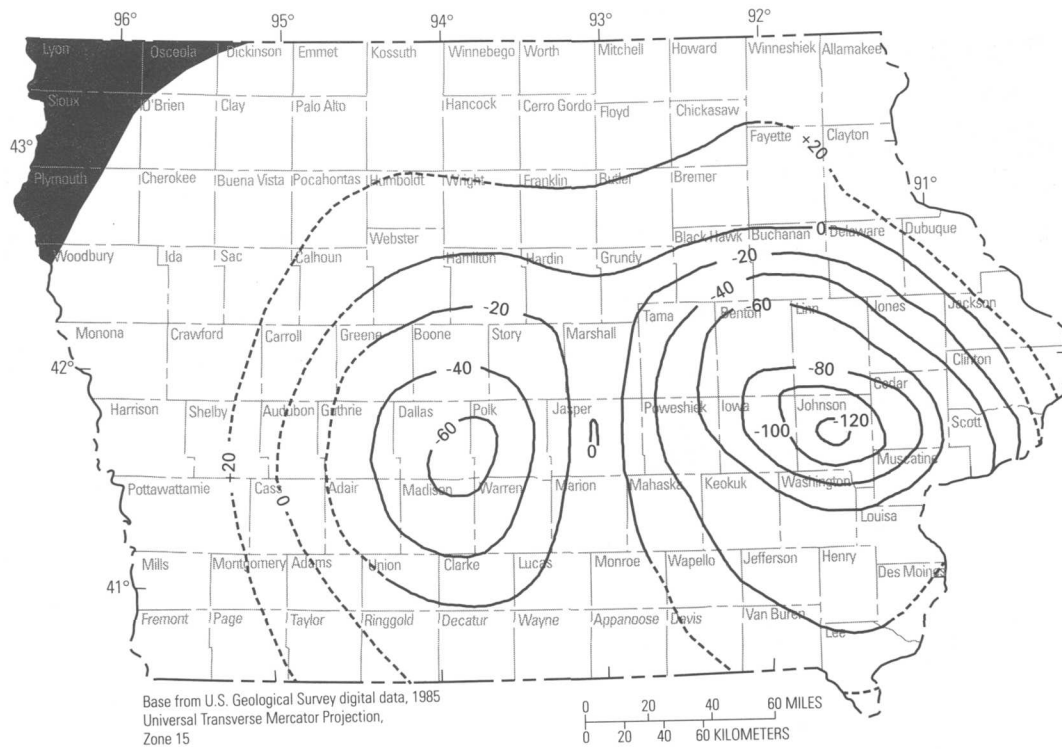


3 Location of well in the Cambrian-Ordovician aquifer system monitoring network and map number (May and others, 1998)

Figure 4. Potentiometric surface of the Cambrian-Ordovician aquifer based on maximum measured water level during 1997 water year and location of wells in the Cambrian-Ordovician aquifer system monitoring network, 1997.

1997 water year (fig. 6). The difference between the simulated water levels and the 1997 maximum measured water levels ranges from 0 to about 150 ft, but most differences were less than 25 ft. The simulated water level in Cerro Gordo County in north-central Iowa was 150 ft less than the measured 1997 water level. The well used for the comparison in that area is open to the Cambrian-Ordovician aquifer, and the model assumptions include pumping rates that continued at the 1975–80 rates from 1980 until the year 2020 (Burkart and Buchmiller, 1990). Error in model

assumptions could account for differences in measured and simulated water levels. Results indicate that this ground-water flow model may help estimate future water levels in the Cambrian-Ordovician aquifer as an aid in managing the resource. To improve the model's predictive capability, pumpage assumptions could be evaluated and adjusted to represent recent changes in water use.



EXPLANATION

■ Jordan aquifer not present (Horick and Steinhilber, 1978)

—60— Line of equal water-level change, 1975 to 1997—Dashed where approximately located. Interval 20 feet

Figure 5. Water-level change in the Cambrian-Ordovician aquifer, 1975 to 1997.

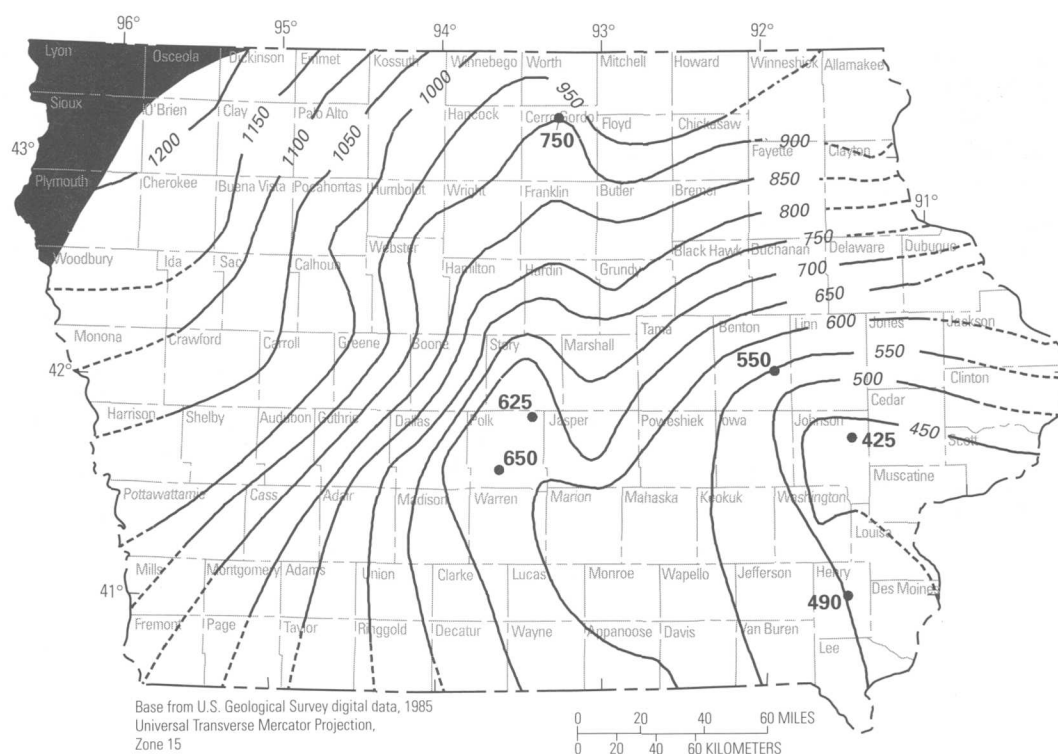
SUMMARY

The Cambrian-Ordovician aquifer is one of the principal sources of water for industry and municipalities in Iowa and contains two sandstone aquifers—the St. Peter aquifer and the Jordan aquifer. Previous studies of this aquifer include a 1977 potentiometric-surface map, prepared by Horick and Steinhilber (1978), showing the altitude at which water levels would have stood in tightly cased wells, and a two-layer, ground-water flow model constructed by Burkart and Buchmiller (1990) that simulated the effects of pumping on the aquifer.

Pumpage from the Cambrian-Ordovician aquifer has increased since 1975. The total pumpage from the

Cambrian-Ordovician aquifer during 1975 was about 18,000 Mgal/yr, whereas the total pumpage during 1995 was almost 28,000 Mgal/yr. The Cambrian-Ordovician aquifer is recharged predominantly by vertical leakage from overlying rocks and the infiltration of precipitation in northern Iowa and farther north. This increase in pumping has focused attention on the Cambrian-Ordovician aquifer and on the importance of documenting the water-level changes on a regional scale.

Iowa Administrative Code Chapter 52.4(3) states that water levels in the Cambrian-Ordovician aquifer are not to decline more than 200 ft from the 1977 baseline in any high-use area (State of Iowa, 1998). The potentiometric-surface map prepared by Horick and



EXPLANATION

- Jordan aquifer not present (Horick and Steinhilber, 1978)
- 650 --- Potentiometric contour—Shows altitude at which water levels would have stood in tightly cased wells. Dashed where approximately located. Contour interval 50 feet. Datum is sea level
- 490 Approximate location of pumping cell modeled by Burkhart and Buchmiller (1990)—Number is simulated water level for 1997 in feet above sea level

Figure 6. Potentiometric surface of the Cambrian-Ordovician aquifer based on maximum water levels measured during 1997 water year and simulated water levels at major pumping centers (from Burkhart and Buchmiller, 1990).

Steinhilber (1978) currently (1999) is used as the base-line. To address these concerns, this report, prepared by the U.S. Geological Survey (USGS), in cooperation with the Iowa Department of Natural Resources—Geological Survey Bureau (IDNR—GSB), presents a review of water-level changes in the Cambrian-Ordovician aquifer from 1975 to 1997. Information from this review can be used by water-resource managers and planners as an aid in evaluating present and future ground-water availability.

A 1997 potentiometric-surface map of the Cambrian-Ordovician aquifer was constructed using the maximum water levels measured in 30 wells during

the 1997 water year. Water levels were predominately measured on a quarterly basis with a chalked, graduated steel tape or an electric line for the statewide ground-water-level monitoring network operated by the IDNR—GSB and the USGS.

There are two areas of water-level decline in eastern and central Iowa. The area of decline in eastern Iowa is centered in Johnson County, with a measured water-level decline of 133 ft since 1975. The area of decline in central Iowa is centered along the border of Dallas and Polk Counties, with a measured water-level decline of about 77 ft. Annual rates of water-level

change have varied little compared to rates reported by Horick and Steinhilber (1978).

Results from the Burkhart and Buchmiller (1990) ground-water flow model were compared to water levels measured during 1997. Simulated 1997 water levels at six major pumping centers in Johnson, Henry, Polk (two pumping centers), Benton, and Cerro Gordo Counties in Iowa were compared to the 1997 potentiometric-surface map. The difference between the simulated water levels and the 1997 maximum measured water levels ranges from 0 to about 150 ft, but most differences were less than 25 ft. Results indicate that the ground-water flow model may help estimate future water levels in the Cambrian-Ordovician aquifer as an aid in managing the resource. To improve the model's predictive capability, pumpage assumptions could be evaluated and adjusted to represent recent changes in water use.

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