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Ground-Water Levels in Huron County, Michigan, 2004-05

Open-File Report 2005-1082

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

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By T.L. Weaver, S.L. Crowley, and S.P. Blumer

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

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)

Vertical Datum

In this report, vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29)--geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called sea level datum of 1929.

Altitude, as used in this report, refers to distance above the vertical datum.

Ground-Water Levels in Huron County, Michigan, 2004-05

Executive Summary

In 1990, the U.S. Geological Survey (USGS) completed a study of the hydrogeology of Huron County, Michigan (Sweat, 1991). In 1993, Huron County and the USGS entered into a continuing agreement to measure water levels at selected wells throughout Huron County. As part of the agreement, USGS has operated four continuous water-level recorders, installed from 1988 to 1991 on wells in Bingham, Fairhaven, Grant, and Lake Townships (fig. 1) and summarized the data collected in an annual or bi-annual report. The agreement was altered in 2003, and beginning January 1, 2004, only the wells in Fairhaven and Lake Townships retained continuous water-level recorders, while the wells in Grant and Bingham Townships reverted primarily to periodic or quarterly measurement status. USGS also has provided training for County or Huron Conservation District personnel to measure the water level, on a quarterly basis, in 25 wells. USGS personnel regularly accompany County or Huron Conservation District personnel to provide a quality assurance/quality control check of all measurements being made. Water-level data collected from the 25 periodically or quarterly-measured wells is summarized in an annual or bi-annual report. In 1998, the USGS also completed a temporal and spatial analysis of the monitoring well network in Huron County (Holtschlag and Sweat, 1998).

The altitude of Lake Huron and precipitation are good indicators of general climatic conditions and, therefore, provide an environmental context for ground-water levels in Huron County. Figure 2 shows the mean-monthly water-level altitude of Lake Huron, averaged from measurements made by the U.S. Army Corps of Engineers at sites near Essexville or Harbor Beach, or both (National Oceanic and Atmospheric Administration, 2003-05), and monthly precipitation measured in Bad Axe (National Oceanic and Atmospheric Administration, 2003-05). In March 2003, a new low-water level for the period from 1991 through 2005 was measured in Lake Huron. There was almost no net change in the water level of Lake Huron from January 2004 through December 2005. In 2004, annual precipitation measured in Port Hope was about 3.7 inches above normal, but precipitation measured in Bad Axe was about 1.4 inches below normal. About 14.5 inches of precipitation was measured in Bad Axe during the 2004 summer growing season (May through August), which is about the same as was measured in Port Hope during the same period. Provisional precipitation totals for 2005 were 30.7 inches for January through November in Port Hope, and about 31.7 inches for the year in Bad Axe. About 10.6 inches of precipitation was measured in Bad Axe during the 2005 summer growing season, which is about 0.2 inches more than was recorded at Port Hope during the same period.

Two wells equipped with continuous-data recorders are completed in the Saginaw and Marshall aquifers in Fairhaven and Lake Townships, respectively. From January 2004 through December 2005, the net rise in the water level in the Fairhaven Township well was 0.71 ft, and the net rise in the Lake Township well was 0.98 ft. The Fairhaven Township well is drilled adjacent to Saginaw Bay (Lake Huron), and, as previously noted, there was almost no net change in the water level in Saginaw Bay over the same period. Hydrographs showing water levels are presented for the two wells equipped with continuous-data recorders. Continuous-data recorders were discontinued in the Grant and Bingham Township wells at the end of 2003 due to budget constraints. The decision of which two wells to discontinue was based on an analysis of the intrinsic value to Huron County of data from each well. The Grant Township well was selected for periodic or quarterly measurement at that time because it is completed in the glacial aquifer, which is little used for drinking water purposes or absent in much of Huron County. The Bingham Township well, which is completed in the Marshall aquifer, was selected for periodic or quarterly measurement because water levels in the well are often perturbed as a result of pumpage from nearby production wells and do not reflect baseline conditions within the aquifer.

Twenty five wells were measured on a periodic or quarterly basis in 2004-05. These wells are completed in the glacial, Saginaw, and Marshall aquifers, and the Coldwater confining unit. Although each quarterly measurement only provides a “snapshot” water level (measured in feet below land surface), the data adequately define the generalized water-level trend in the aquifer near the well. Water levels in 15 quarterly-measured wells had a net rise ranging from 0.20 to 1.31 ft for the period from January 2004 to December 2005, while water levels in 10 of the wells had a net decline ranging from 0.07 to 0.99 ft over the same period (fig. 3; table 1). Period-of-record (the time period when water levels have been measured by U.S. Geological Survey or their cooperators) minimum depths to water (high-water levels) were measured in March 2004 in two quarterly-measured wells completed in the Marshall aquifer in Lake and Hume Townships. Period-of-record maximum depths to water were measured in September 2005 in three wells completed in the Marshall aquifer near Bad Axe. Water levels in those three wells recovered about 3 to 5 ft between September and December 2005. No period-of-record minimum or maximum depths to water were measured for the period from January 2004 through December 2005 in wells completed in either the glacial and Saginaw aquifers, or the

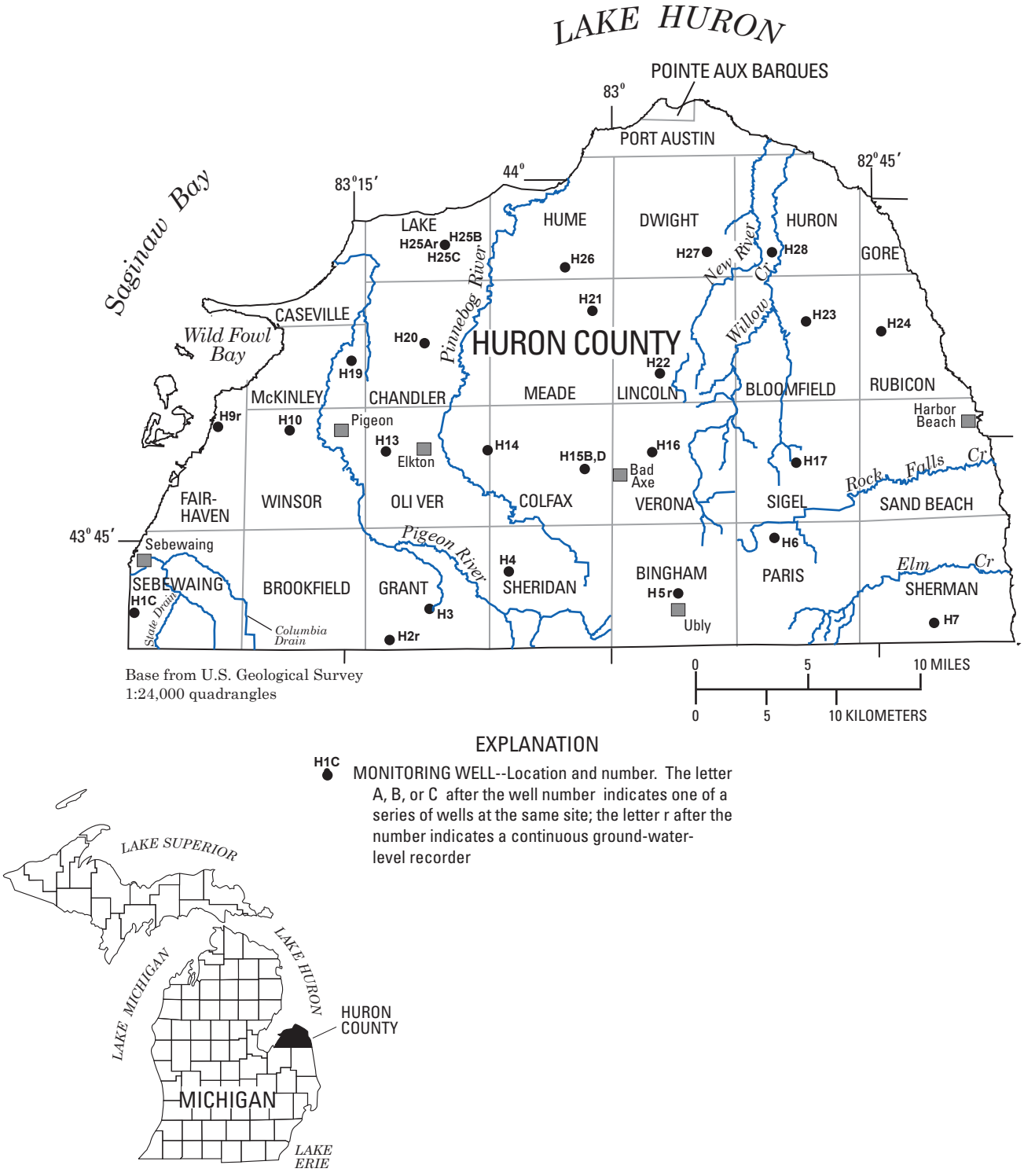

Figure 1. Location of monitoring wells in Huron County, Michigan.

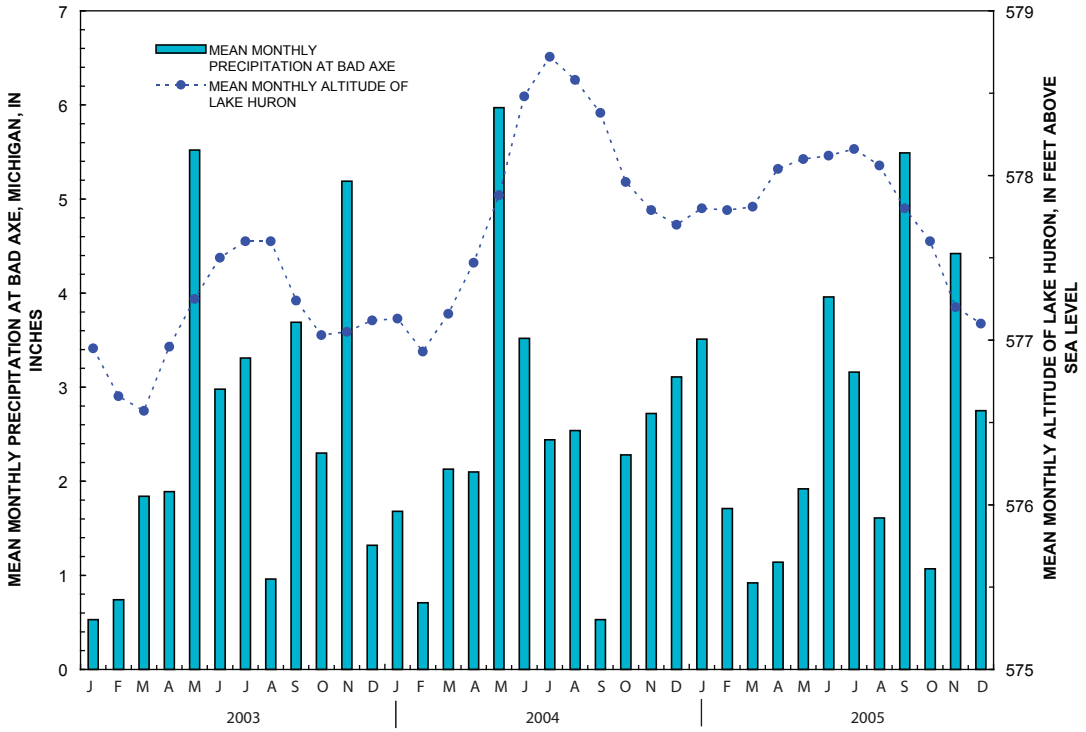

Figure 2. Monthly water-level altitude of Lake Huron averaged from measurements made at Essexville and or Harbor Beach, Michigan, and monthly precipitation measured at Bad Axe, Michigan, January 2003 through December 2005. (November and December 2005 lake levels are only from measurements made at Harbor Beach and December precipitation is only from measurements made at Bad Axe.)

Coldwater confining unit. Hydrographs showing water levels measured in each well are presented for the 25 wells measured on a quarterly basis.

Water-level trends measured for the period from January 2004 through December 2005 in other wells in Lower Michigan have similarities to those measured in Huron County wells. Several external factors influence water-level trends including proximity to nearby production wells, amount and timing of precipitation events, evapotranspiration and type of prevalent ground cover, proximity of aquifer to the surface, and hydraulic characteristics of overlying geologic materials.

Introduction

Ground water is used for drinking water in most parts of Huron County. The notable exceptions are communities adjacent to Lake Huron and the Village of Pigeon (fig. 1), which use Lake Huron water. In addition, most agricultural and dairy operations in the county depend on ground water for their needs. Productive aquifers in the unconsolidated sediments overlying bedrock are absent in much of Huron County and the bedrock Saginaw and Marshall aquifers are used in most locations. Huron County became concerned about declining ground-water levels in 1988, and USGS installed a number of observation wells in the county to establish a water-level database. Water levels in the network of observation wells have been measured since 1988, with the exception of 1990 through late 1992. USGS provides ground-water level data that enables resource planners to make informed decisions about the impact of water withdrawals within the county.

The purpose of this data report is to (1) summarize water-level measurements made during 2004-05 in 27 observation wells in Huron County, (2) compare those water-level measurements with measurements made in the same wells since 1988, Lake Huron levels measured by the Army Corps of Engineers at Essexville and Harbor Beach, Michigan and precipitation measured at Port Hope and or Bad Axe, Michigan during the same period, and (3) compare those water-level measurements with measurements made in observation wells elsewhere in Michigan. Data from previous study periods are analyzed to provide a historical context for ground-water level trends observed during 2004-05.

Figure 2 shows the mean-monthly water-level altitude of Lake Huron measured by the U.S. Army Corps of Engineers (January 2003 through October 2005 levels are averaged

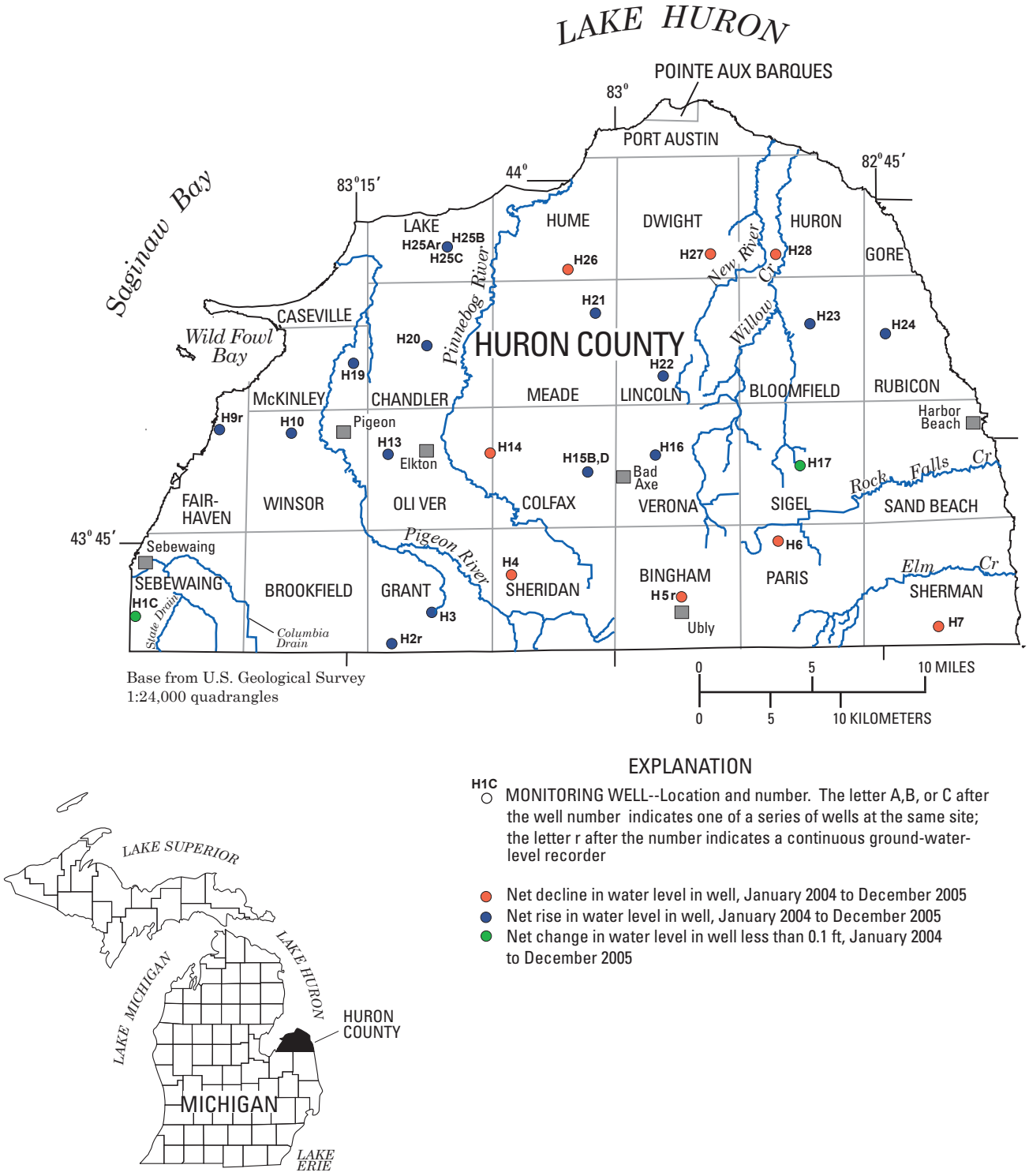

Figure 3. Net change in ground-water levels, Huron County, Michigan, January 2004 through December 2005.

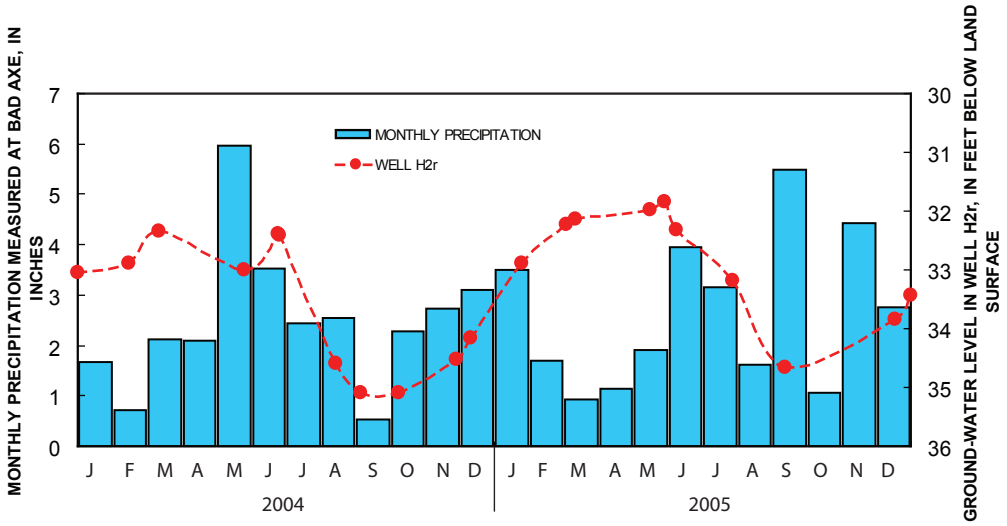

Figure 4. Depth below land surface of water in Grant Township well H2r and monthly precipitation at Bad Axe, January 2004 through December 2005. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

from sites near Essexville and Harbor Beach, and November and December 2005 levels are preliminary data from Harbor Beach only), and monthly precipitation measured in Bad Axe for the period from January 2003 to December 2005 (National Oceanic and Atmospheric Administration, 2003-05). In January 2004, the water level of Lake Huron was about 0.20 ft higher than January 2003. The lake level rose about 1.6 ft through July, but then declined about 1.0 ft from August through December. In January 2005, the water level was about 0.7 ft higher than January 2004, but rose less than 0.4 ft through July, and fell about 1.0 ft from August through December. Mean-monthly water levels in Lake Huron were nearly the same in January 2004 and December 2005.

All 2004-05 precipitation records for this study were provided by National Oceanic and Atmospheric Administration (NOAA) in 2005. Average annual precipitation measured at Bad Axe, Michigan is 31.1 inches. Precipitation measured in 2004 was about 29.7 inches, or about 1.4 inches below normal. Provisional precipitation (not quality assured by NOAA at the time of this study) measured in 2005 was about 31.7 inches, or about 0.6 inches above normal. Distribution of precipitation during the growing season is an important factor that influences how much, if any, aquifer recharge occurs during those months. Precipitation measured in Bad Axe from May through August 2004 was 14.47 inches, but only 10.65 inches fell during the same period in 2005. As a consequence, water levels in most of the wells in 2004 were higher than they were in 2005.

Ground-Water Levels

Glaciofluvial Aquifer Well

The Grant Township well (H2r) is completed in the glaciofluvial aquifer. The well, which is 91 ft deep, is cased to 87 ft and screened in unconsolidated sand from 87 to 91 ft. A continuous-data recorder was installed in February 1991 and operated continuously, with the exception of the period from October 1998 through February 1999, until it was discontinued on December 31, 2003. Periodic water-level measurements have been made at H2r since that time (11 in 2004 and 10 in 2005).

Figure 4 shows the generalized water-level trend in well H2r for the period from January 2004 through December 2005 compared with monthly precipitation measured at Bad Axe, Michigan. Unlike water levels in wells completed in deeper bedrock aquifers, levels in shallow wells completed in unconfined glaciofluvial aquifers like H2r typically respond rapidly to precipitation. The water level in shallow, unconfined aquifers is affected mostly by losses due to evapotranspiration and recharge from precipitation. In general, precipitation during the period from fall through early spring exceeds evapotranspiration, allowing infiltrated water to recharge the aquifer and causing the water level to rise relative to land surface. From late spring through summer, evapotranspiration typically exceeds precipitation and infiltration is minimized, causing the water level to drop relative to land surface. Previous studies illustrated both how rapidly the water level in well H2r can respond to precipitation events and how even large

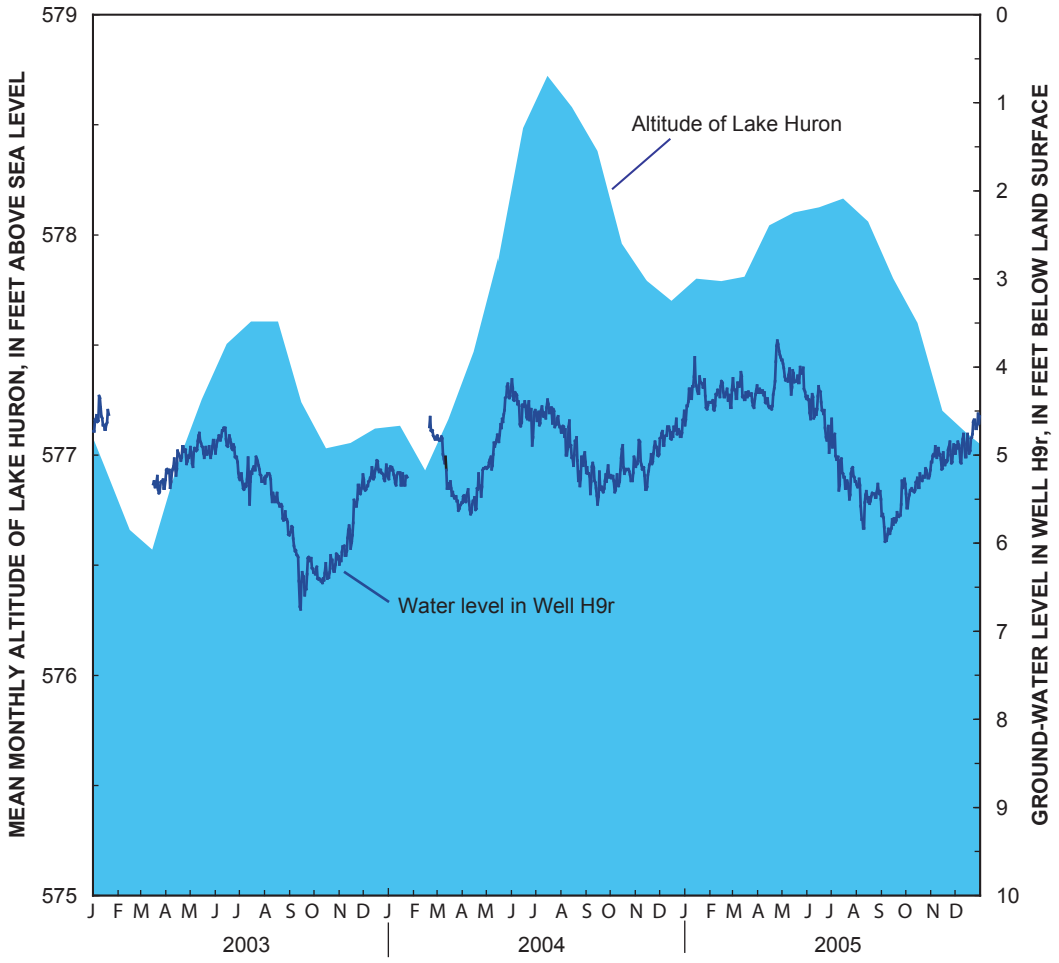

Figure 5. Depth below land surface of water in Fairhaven Township well H9r, and monthly water-level altitude of Lake Huron averaged from measurements made at Harbor Beach and Essexville, January 2003 through December 2005, Huron County, Michigan.

magnitude single precipitation events may have little or no long-term effect on the water-level trend, particularly when those precipitation events occur during the growing season when evapotranspiration is greatest (Sweat, 1999; Weaver and others, 2000; Weaver, 2001; Weaver and McGowan, 2002; Weaver and others, 2005).

The water level in well H2r (measured in feet below land surface) was 33.63 ft on Dec. 31, 2003, when continuous monitoring of water level in the well was discontinued. From Jan. 1, 2004 through December 15, 2005, when the most recent periodic measurement of water level in the well was made, the net rise in water level was 0.20 ft (tables 2 and 3). The greatest depth to water during the period (35.10 ft) was measured September 13 and October 15, 2004. Minimum depth to water for the period (31.83 ft) was measured May 24, 2005.

In 2003, Huron County personnel expressed interest in comparing localized-precipitation data and ground-water levels during the growing season in a near-surface aquifer (Greg Renn, Huron Conservation District, written commun., 2003). For that study, precipitation data measured by NOAA observers in Grant Township was compared with the water levels in well H2r. The same type of comparison could not be made in the current study because water levels in well H2r were only periodically measured in 2004-05.

Saginaw Aquifer Wells

The Fairhaven Township well (H9r) is completed in the Saginaw aquifer and is located on the western shore with Saginaw Bay, at the eastern edge of Wild Fowl Bay. The well is cased to 147 ft, and is open to limestone, shale, and sandstone of the Saginaw aquifer between 147 and 180 ft. A continuous-data recorder was installed in February 1991 and has operated since, except for short periods due to equipment malfunctions.

Sweat (1999) noted that the water level in well H9r shows normal seasonal fluctuations (fig. 5) that typically precede those of Lake Huron by 3 to 6 months. It appears that the cycle was tighter in 2004-05, with changes in water levels in H9r preceding changes in Lake Huron levels by as little as 6 weeks. In 2004, the highest water level in H9r occurred June 1 and the highest Lake Huron level occurred on July 14. In 2005, the highest water level in H9r occurred April 24-25 and the highest Lake Huron level occurred on July 26. Curiously, in 2004, the lowest water level in H9r occurred April 11, while the lowest Lake Huron level occurred about two months prior, on February 18. The period-of-record maximum depth to water in well H9r, of 12.30 ft, recorded on June 2, 1998, was not even approached in 2004-05. The net rise in water level in well H9r from January 1, 2004 through December 31, 2005 was 0.71 ft.

Water levels measured quarterly in four wells completed in the Saginaw aquifer are included in table 1. Wells are listed using the identifier shown in figure 1. The hydrographs in figure 6 illustrate water levels measured quarterly and a generalized water-level trend for the period from 1988 through 2005. Net change in water levels from December 2003 to December 2005 ranged from a 0.07 ft decline in well H1C (located near Saginaw Bay in Sebewaing Township) to 1.27 ft rise in well H13 (located in Oliver Township). No notable trends in water levels of all four wells were noted during 2004-05, although two of the wells had their minimum measured depth to water in June 2004; and two had their maximum measured depth to water in September 2005. No period-of-record minimum or maximum depths to water were measured in the wells completed in the Saginaw Aquifer in 2004-05.

The water-level trend measured in well H20, which is located in Chandler Township, has previously differed from what has been observed in the other wells completed in the Saginaw aquifer (Weaver and others, 2005). Huron County and other governmental agencies expressed interest in the water level in well H20 during the first half of 2003, as a large commercial agricultural operation was being developed in Chandler Township north of the well. This facility withdraws water from the Marshall aquifer and the effect of this water withdrawal on the water level in well H20 is unknown. A net rise in water level of 0.81 ft was measured in well H20 during 2004-05.

Water levels in well H9r and three of four quarterly-measured wells completed in the Saginaw aquifer experienced a net rise during the period from January 2004 to December 2005, while the level in well H1C declined less than 0.1 ft. Well H9r had near period-of-record minimum depth to water in June 2005. No wells completed in the Saginaw aquifer had period-of-record maximum depths to water measured in 2004-05.

Marshall Aquifer Wells

The Lake Township well (H25Ar) is 200 ft deep, cased to 179 ft, and open to sandstone of the Marshall aquifer from 179 to 200 ft. It is located on the southern shore of Rush Lake in northwestern Huron County, and is the deepest of three adjacent wells at the site. A continuous-data recorder was first installed in September 1988 and began collecting data in October 1988 and operated until September 1989. The recorder was re-activated in December 1992 and has operated continuously since. In addition to normal seasonal variation, the water level in H25Ar also is affected by withdrawals from nearby irrigation wells (fig. 7). On January 1, 2004, the water level in well H25Ar (measured in feet below land surface) was 8.50 ft. In 2004, the minimum depth to water (6.33 ft) was measured on June 1 and maximum depth to water (9.97 ft) was measured on Nov. 14. On January 1, 2005, the water level in well H25Ar was 8.93 ft. In 2005, the minimum depth to water (6.93 ft) was measured on April 25 and maximum depth to water (9.57 ft) was measured on September 24. The net rise in water level in well H25Ar from January 1, 2004 through December 31, 2005 was 0.98 ft.

The Bingham Township well (H5r) also was equipped with a continuous-data recorder until December 31, 2003, when it was discontinued. Six periodic measurements of the water level in well H5r were made in 2004 and quarterly measurements were made in 2005 (tables 2 and 3). A hydrograph in figure 8a illustrates periodically-measured water levels in well H5r (and others) and a generalized water-level trend for the period from 1988 through 2005. In addition to normal seasonal fluctuation, the water level in well H5r also is affected by withdrawal at a nearby public-water-supply well belonging to the Village of Ubly. The water level in well H5r (measured in feet below land surface) was 11.62 ft on Dec. 31, 2003, when continuous monitoring of water level in the well was discontinued. From Jan. 1, 2004 through December 2, 2005, when the last periodic measurement of water level in the well was made, the net change in water level was -0.62 ft (tables 2 and 3). The greatest depth to water during the period (12.68 ft) was measured September 2, 2005. Minimum depth to water for the period (10.16 ft) was measured June 8, 2004.

Water levels measured quarterly in 16 wells completed in the Marshall aquifer are included in table 1. Wells are listed by an identifier shown in figure 1. The hydrographs in figures 8a and 8b illustrate water levels measured quarterly and generalized water-level trends for the period from 1988 through 2005. In 2004, water levels in all of the wells ranged two or more feet throughout the year. In most of the wells, water-level trends were similar, rising in the first quarter in all 16 wells, rising in most wells in the second quarter, falling in most wells in the third quarter, and mixed in the last quarter. In 2005, water-level trends were also similar, rising in the first quarter in all 16 wells, stable or dropping in most wells in the second quarter, falling in the third quarter in most wells, and rising in all 16 wells in the fourth quarter. Well H19 was the exception again in 2004-05, as it has been in previous years,

Table 1. Depth to water in wells measured quarterly, Huron County, Michigan, 2004-05, and net change in depth to water from December 2003 to December 2005.

[S, indicates well in Saginaw aquifer; M, indicates well in Marshall aquifer; C, indicates well in Coldwater confining unit; BOLD type indicates a new maximum depth to water for period-of-record, BOLD italic type indicates a new minimum depth to water for period-of-record].

Well identifier	Aquifer code	Altitude of measuring point, in feet	Depth to water below land surface, in feet										
Date of measurement			Period of record maximum, in feet	12/03	3/04	6/04	9/04	12/04	3/05	6/05	9/05	12/05	Net change 12/03 to 12/05
H1C	S	600.00	26.67	15.74	17.47	14.96	14.88	14.41	15.13	14.08	15.62	15.81	-0.07
H3	M	731.70	34.80	29.59	28.54	27.42	30.37	29.80	28.33	28.29	30.68	28.97	.62
H4	M	751.60	14.98	13.16	11.87	11.55	13.86	14.12	12.31	12.26	14.24	13.49	-.33
H6	M	781.50	17.48	14.92	13.44	12.67	15.43	16.22	13.26	13.06	15.38	15.19	-.27
H7	C	726.80	16.94	15.92	15.59	15.34	15.78	15.96	15.35	15.43	15.96	16.16	-.24
H10[a]	S	617.07	27.50	23.23	21.74	21.38	22.03	22.24	21.29	21.62	22.37	22.16	1.07
H13	S	642.35	36.90	29.33	27.56	26.63	29.97	28.67	28.28	27.99	30.23	28.06	1.27
H14[b]	M	681.30	11.09	7.72	6.68	5.75	9.59	8.48	6.21	7.84	**11.09**	8.05	-.33
H15B	M	751.20	23.21	18.51	17.32	16.82	21.05	19.95	17.18	18.09	**23.21**	18.29	.22
H15D[c]	M	unknown	24.99	21.26	18.87	18.50	22.71	21.26	18.79	20.71	**24.99**	19.95	1.31
H16	M	771.50	34.15	32.23	30.47	28.52	31.16	32.31	30.41	29.11	31.17	31.05	1.18
H17	M	751.00	28.09	8.34	6.62	5.62	22.92	10.03	6.23	6.08	17.05	8.43	-.09
H19	M	611.90	6.13	4.88	4.53	4.61	4.20	4.01	4.10	4.62	4.41	3.82	1.06
H20	S	631.00	17.22	16.19	15.35	13.89	15.08	15.93	15.63	15.13	15.58	15.38	.81
H21	M	702.90	13.21	10.42	8.96	9.32	10.46	12.09	8.80	8.63	10.51	9.63	.79
H22	M	695.50	18.68	15.82	13.84	13.52	15.91	17.25	14.13	14.02	16.21	15.13	.69
H23	C	721.80	10.37	9.53	9.19	9.17	9.15	8.87	8.47	8.71	8.82	8.49	1.04
H24	C	691.50	29.04	26.05	25.36	25.18	25.78	26.26	25.47	25.41	26.01	25.70	0.35
H25B	M	601.00	5.70	3.76	2.45	1.13	4.13	4.72	2.41	2.51	4.28	2.55	1.21
H25C	M	602.20	5.28	3.06	***0.40***	1.65	4.42	4.01	2.26	2.58	4.21	2.14	.92
H26	M	662.70	16.10	3.43	***0.39***	1.87	5.57	8.38	2.32	2.04	6.92	4.27	-.84
H27	M	716.50	37.66	34.81	32.96	32.21	36.12	37.27	34.32	33.35	35.78	35.63	-.82
H28	M	691.70	24.30	19.88	18.22	17.94	21.84	23.12	18.34	18.67	21.98	20.87	-.99

[a] Period-of-record minimum depth to water (20.68 ft) was measured during non-quarterly sampling on July 8, 2004.

[b] Previous listed period-of-record maximum depth was probably measured before well equilibrated after being drilled.

[c] Well drilled September 1997; period of record maximum depth to water was previously listed in error as 25.34 ft. The correct number was 24.34 ft.

Table 2. Depth to water in periodically measured wells H2r and H5r, Huron County, Michigan, 2004.

[G, indicates well in unconsolidated glacial aquifer; M, indicates well in Marshall aquifer, --, indicates no water-level measurement in well].

Well identifier	Aquifer code	Altitude of measuring point, in feet	Depth to water below land surface, in feet											
Date of measurement			Period of record maximum	1/22/04	3/4/04	3/29/04	6/8/04	7/6/04	7/8/04	8/24/04	9/13/04	10/15/04	12/2/04	12/14/04
H2r	G	746..00	36.29	33.05	32.88	32.33	33.00	32.38	32.42	34.60	35.10	35.10	34.52	34.16
H5r	M	795.00	16.38	11.47	11.32	10.24	10.16	--	--	--	12.34	--	12.40	--

Table 3. Depth to water in periodically measured wells H2r and H5r, Huron County, Michigan, 2005.

[G, indicates well in unconsolidated glacial aquifer; M, indicates well in Marshall aquifer; --, indicates no water-level measurement in well].

Well identifier	Aquifer code	Altitude of measuring point, in feet	Depth to water below land surface, in feet									
Date of measurement			Period of record maximum	1/25/05	3/4/05	3/11/05	5/12/05	5/24/05	6/3/05	7/20/05	9/2/05	12/2/05	12/15/05
H2r	G	746.00	36.29	32.88	32.23	32.13	31.98	31.83	32.31	33.18	34.67	33.84	33.43
H5r	M	795.00	16.38	--	10.84	--	--	--	11.42	--	12.68	12.24	--

with rising water levels in the third and fourth quarters of both years. From December 2003 to December 2005 there was a net decline in water levels in seven wells ranging from 0.09 to 0.99 ft, and a net rise in water levels in nine wells ranging from 0.22 to 1.21 ft.

In March 2004, period-of-record minimum depths to water were measured in wells H25C and H26, located in adjacent Lake and Hume Townships, respectively. Wells H25C and H26 are completed 40 and 60 ft below land surface, respectively, while wells H25B and H25Ar, which are located within several ft of well H25C, are completed at 160 and 200 ft, respectively. In 2004-05, neither well H25Ar nor well H25B approached their respective period-of-record minimum-water levels, which were recorded or measured in March 1997. Period-of-record maximum depth to water in wells H14, H15B, H15D was measured during September 2005. Water levels in those wells recovered dramatically in the fourth quarter, ranging from 3.04 to 5.04 ft, as did the water level in well H17, which rose 8.62 ft during the same period.

The water level in well H17 (located in Sigel Township) typically responds to nearby irrigation well withdrawals. Water levels in well H17 ranged over 20 ft in 1995, and except during the wettest years, typically range at least 10 ft. In 2004-05, irrigation withdrawals occurred and water levels declined more than 17 ft between June and September 2004. In contrast, the decline in water levels in the other wells completed in the Marshall aquifer over the same period typically only ranged from 1 to 4 ft. Curiously, in 2005 about 4 to

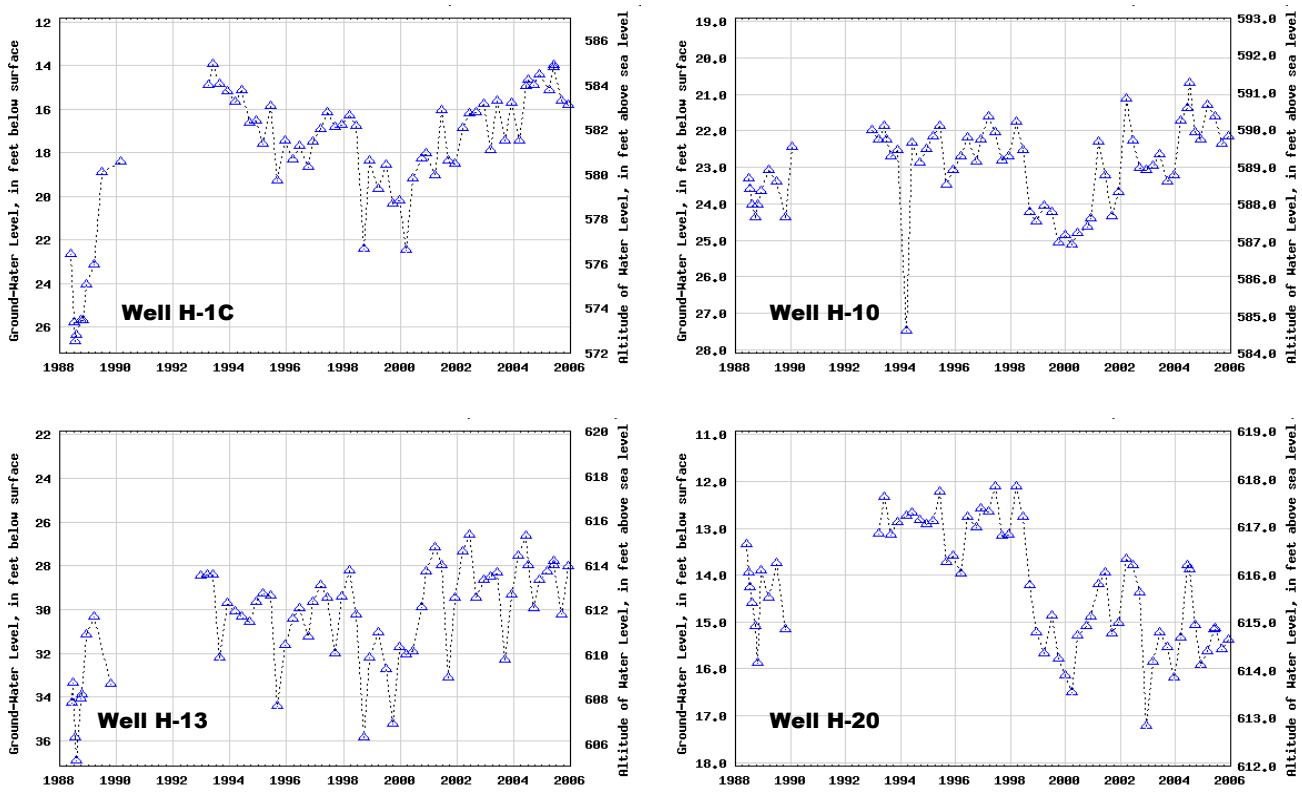

Figure 6. Altitude and depth below land surface of water measured quarterly in wells completed in the Saginaw aquifer for the period 1988 through 2005, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

5 inches less precipitation fell during the agricultural growing season than in the same period in 2004 (National Oceanic and Atmospheric Administration, 2005), but the decline in the water level in well H17 was only about 9 ft.

As noted in the previous study (Weaver and others, 2005) and illustrative of the hydraulic differences between geologic formations, with known external factors minimized, the water level trends in well H19, completed in the Marshall aquifer, and well H20 (fig. 6), interpreted as being completed in an outlier of the Saginaw aquifer several miles to the east, are largely the inverse of one another through 2004-05. The water level in H20 appears to mimic precipitation, while the water level in H19 appears to lag 3 to 6 months. This observation was not unexpected, but at this location the physical connection between the Saginaw aquifer, which conformably (directly) overlies the Marshall aquifer, would seem to provide a direct conduit between the two aquifer units. An impediment to water flow between the two aquifer units, such as a confining layer, must be present at this location, leading to the observed differences in water level trends.

Water levels in ten wells completed in the Marshall aquifer experienced a net decline during the period from January 2004 to December 2005, while water levels in eight wells experienced a net rise during the same period. Period-of-record minimum depth to water was measured in two wells in March 2004 and period-of-record maximum depth to water was measured in three wells in September 2005.

Coldwater Confining Unit Wells

There are no wells completed in the Coldwater confining unit with continuous-data recorders because water levels do not typically vary rapidly in this unit. Relatively stable or slowly changing water levels are typical of wells completed in low-hydraulic conductivity rocks from which little, if any, water is produced, and into, or through which, only small amounts of water can pass under non-stress conditions.

Water levels measured quarterly in three wells completed in shale, sandstone, and sandy shale of the Coldwater confining unit are included in table 1. Wells are listed by an identifier shown in figure 1. The hydrographs in figure 9 illustrate water levels and generalized water-level trends for the period from 1988 through 2005.

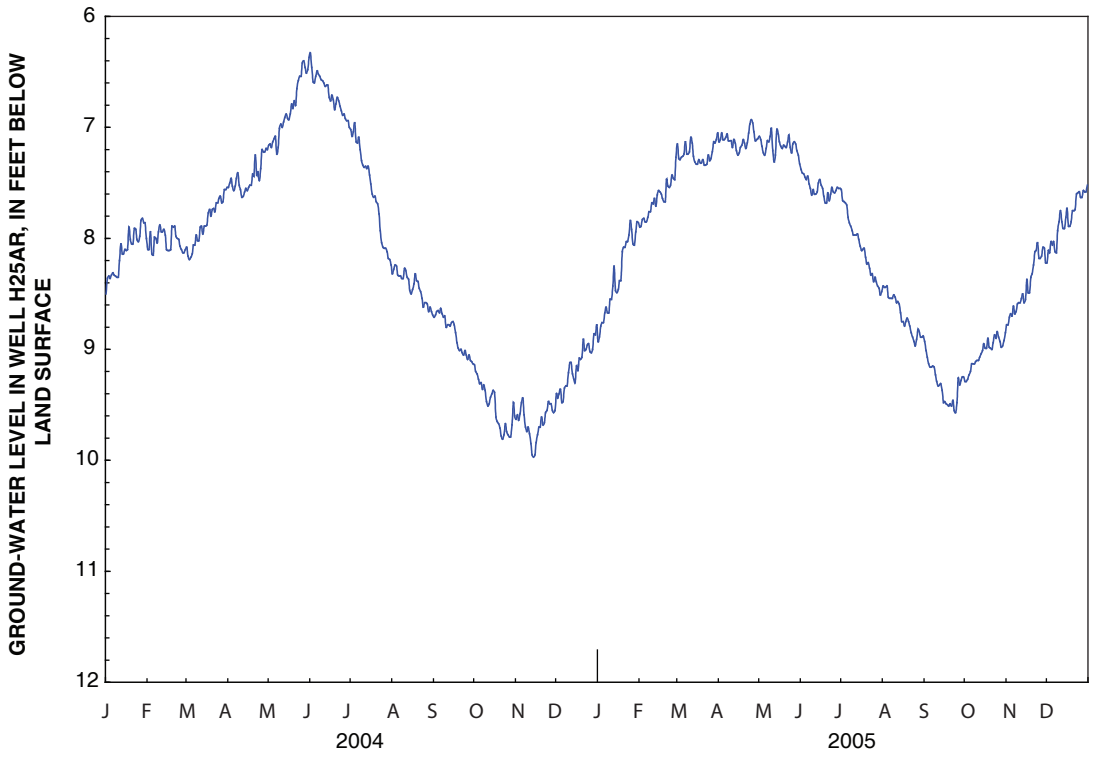

Figure 7. Depth below land surface of water in Lake Township well H25Ar, January 2004 through December 2005, Huron County, Michigan.

Water levels in two of three wells completed in the Coldwater confining unit experienced a net rise of 0.35 ft and 1.04 ft during the period from January 2004 to December 2005 while the water level in the third well experienced a net decline of 0.24 ft during the same period. No period-of-record maximum or minimum depths to water were measured in the wells during 2004-05.

Comparison with Regional Ground-Water Trends

The USGS maintains a number of observation wells for purposes of monitoring ground-water levels throughout Michigan. Many of the wells are equipped with continuous-data recorders including the Petersburg Deep well in Monroe County (fig. 10) and the Portage School 4 well in Kalamazoo County (fig. 11).

The Petersburg Deep well is completed at a depth of 72 ft in Devonian carbonate rocks. Quarries in Monroe County have mined the same rock units and are believed to have impacted water levels in the region, but the Petersburg Deep well appears to define generalized ground-water levels in the far-southeastern part of Michigan. The Portage School 4 well is completed at a depth of 102 ft in glacial sand and gravel and although the water level in Portage School 4 is affected somewhat by nearby public and industrial water supply well withdrawals, it appears to define generalized ground-water levels in southwestern Michigan. Figure 12 shows the depth below land surface of water in the Petersburg Deep, Portage School 4, and H9r wells normalized to Huron County well H25Ar for the period from January 2004 through December 2005. Water levels in the four wells typically range from about 6 to 53 ft below land surface, making a graphical comparison of the trends difficult without some modification. To simplify the comparison, water-level trends of Petersburg Deep, Portage School 4, and Huron County H9r wells were altered or "normalized" to have a range similar to well H25Ar. A constant which was added to the January 1, 2004 water level of each well to make them equal to the water level in H25Ar on January 1, 2004, was applied to data through December 31, 2005. The water-level trends measured in these four wells during 2004-05 were quite similar, although the water level

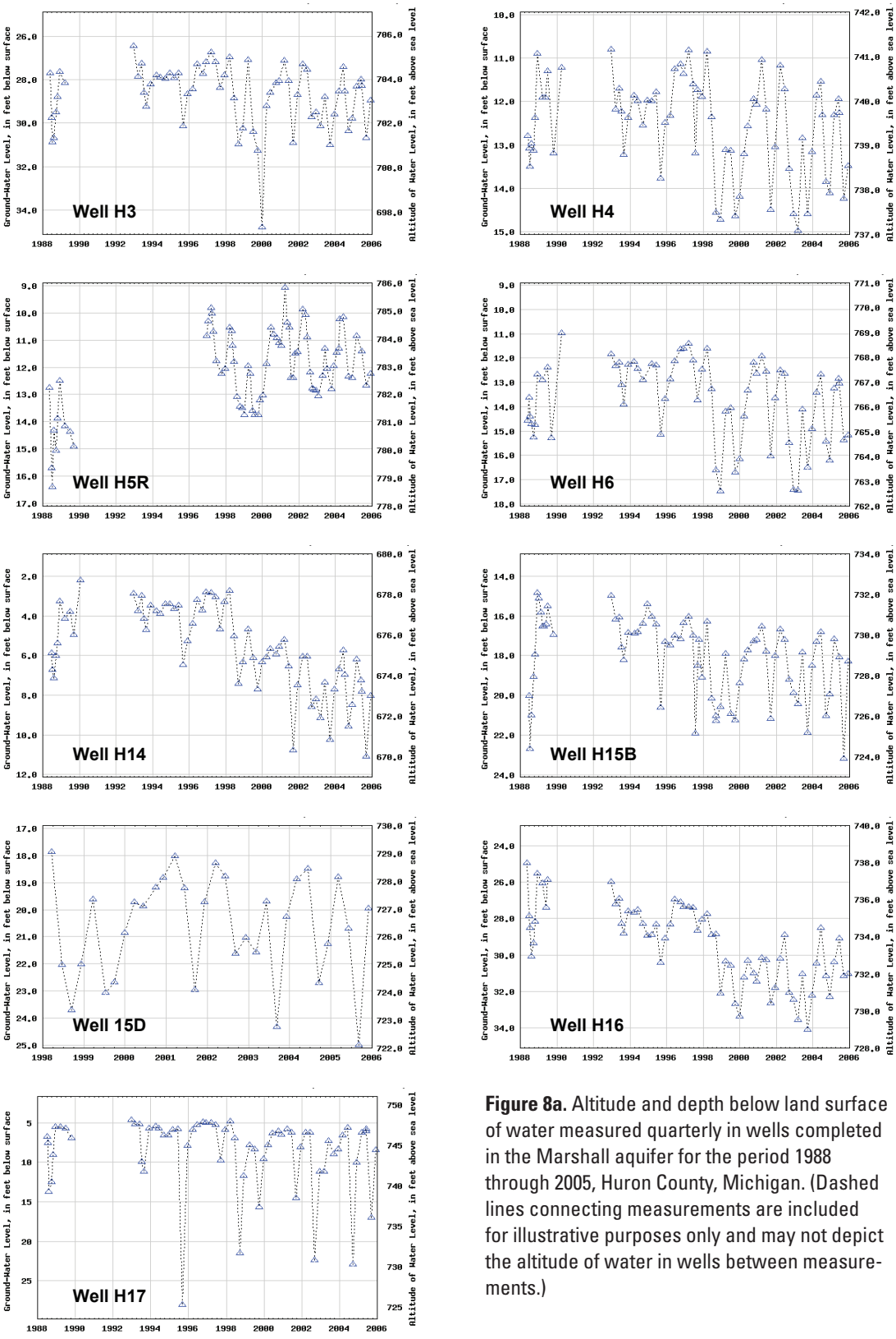

Figure 8a. Altitude and depth below land surface of water measured quarterly in wells completed in the Marshall aquifer for the period 1988 through 2005, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

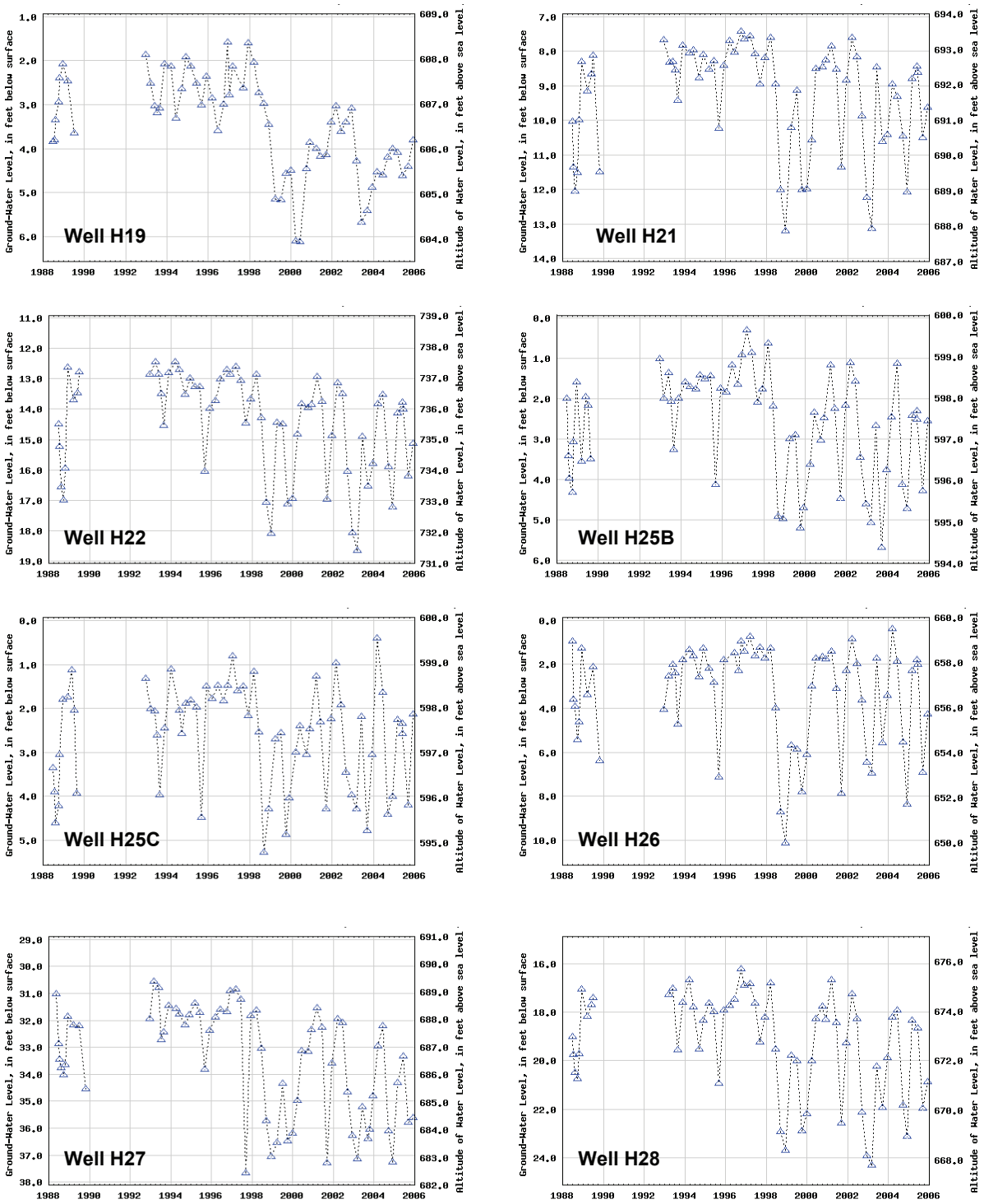

Figure 8b. Altitude and depth below land surface of water measured quarterly in wells completed in the Marshall aquifer for the period 1988 through 2005, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

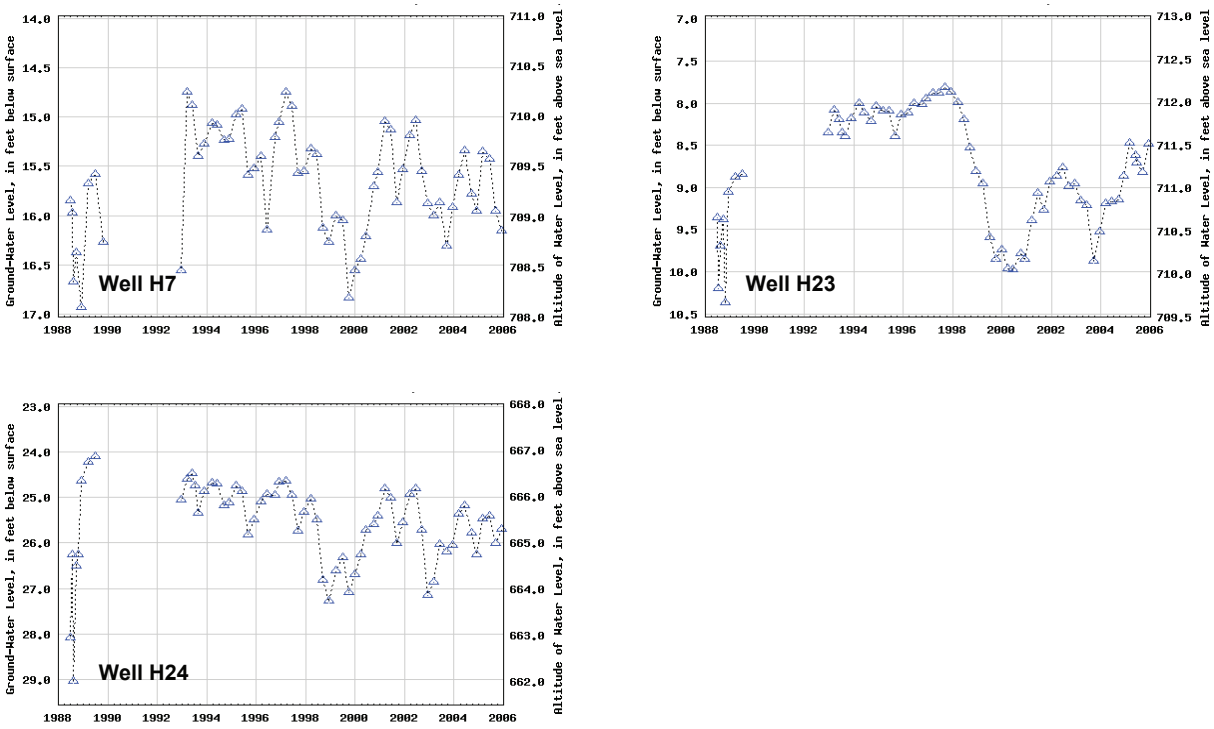

Figure 9. Altitude and depth below land surface of water measured quarterly in wells completed in the Coldwater confining unit for the period 1988 through 2005, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

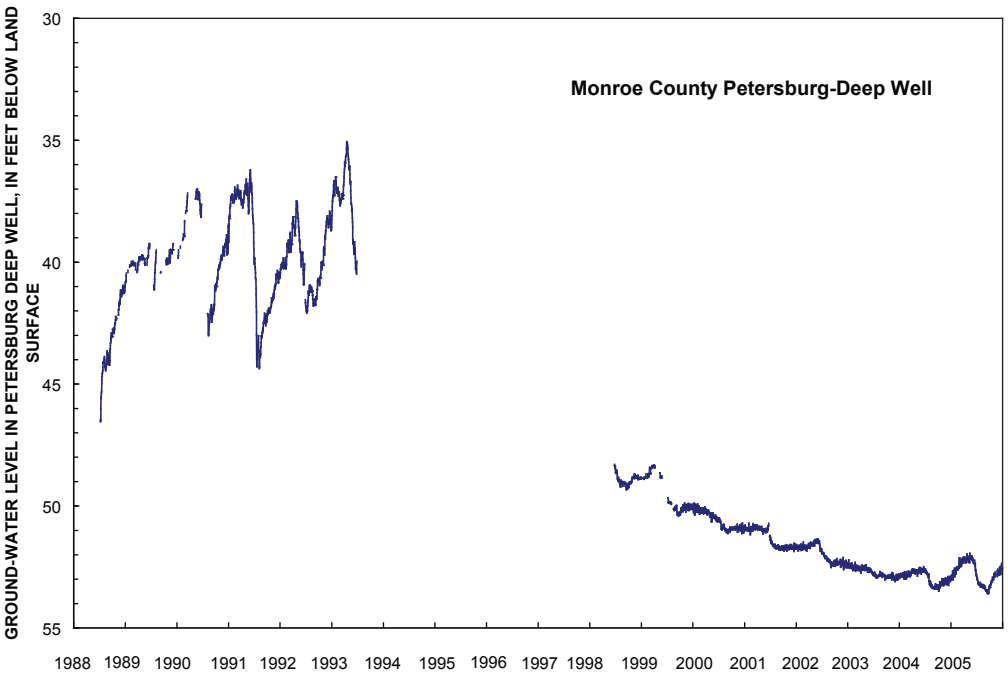

Figure 10. Depth below land surface of water in Petersburg Deep well, Monroe County, January 1988 through December 2005.

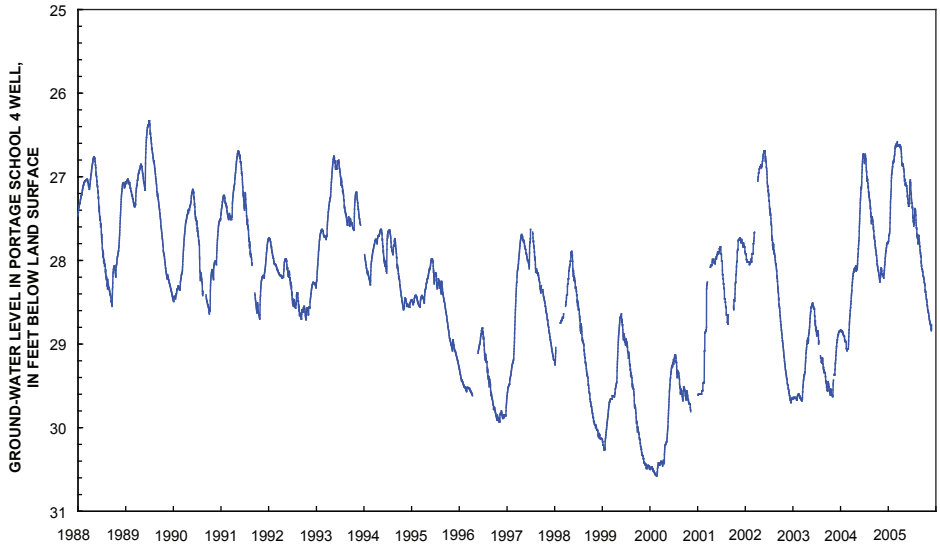

Figure 11. Depth below land surface of water in Portage School 4 well, Kalamazoo County, January 1988 through December 2005.

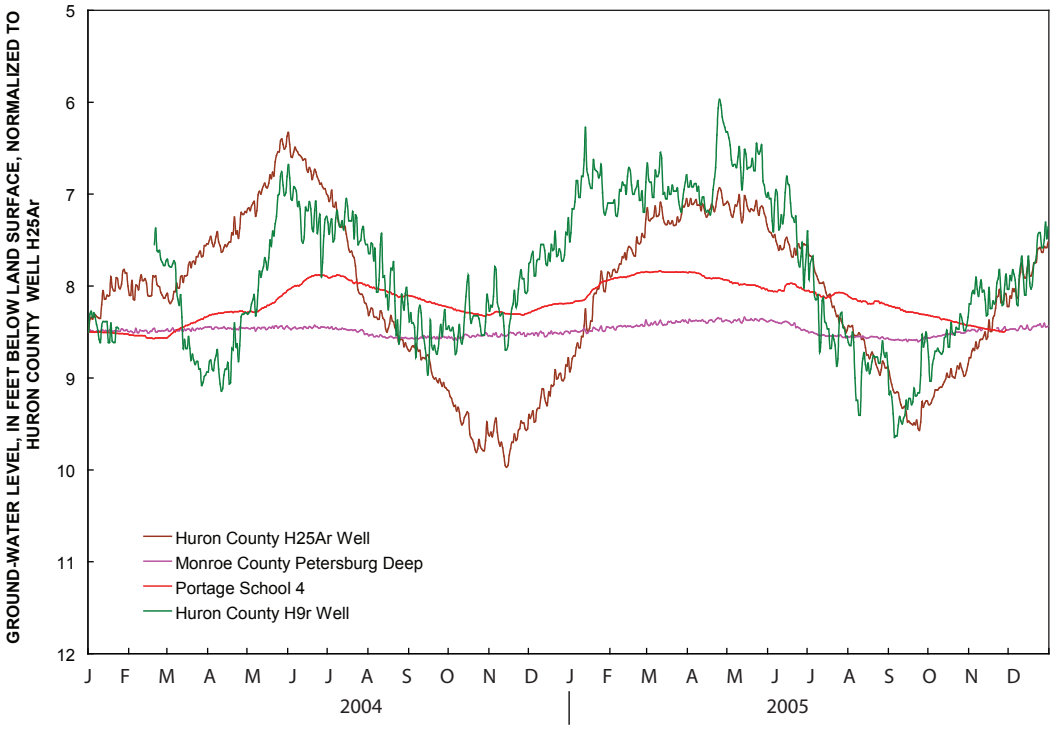

Figure 12. Depth below land surface of water in Petersburg Deep well, Portage School 4 well, and Huron County H9r well normalized to Huron County well H25Ar, January 2004 through December 2005. (Water-level trends of Petersburg Deep well, Portage School 4 well, and Huron County well H9r have been altered to have the same initial water level as well H25Ar and do not display absolute water levels in those wells.)

in the Portage School 4 well was still in decline in December 2005, while water levels in the other wells were rising (Weaver and others, 2005). Unlike the past few years, the water level in the Petersburg Deep well stabilized during 2004-05. The only known large-magnitude change near the well occurred at the end of 2002, when a large quarry located about 8 mi from the Petersburg Deep well discontinued de-watering operations (Howard Reeves, U.S. Geological Survey, oral commun., 2005). At this time, it is not known if stabilization of the water level in the Petersburg Deep well is due to cessation of de-watering at the quarry.

External factors that may affect ground-water levels include proximity to nearby production wells, variation in the amount and timing of precipitation and evapotranspiration, and proximity of the aquifer to either land surface or conductive overlying materials.

Summary

During 2004-05, the water-level trend in wells in Huron County was dissimilar; 17 wells experienced net rises and 10 experienced net declines. Net declines in water levels (all were less than 1 ft) occurred in 1 well completed in the Saginaw aquifer, 8 wells completed in the Marshall aquifer, and 1 well completed in the Coldwater confining unit. Net rises in water levels (all 1.31 ft or less) were measured in the single well completed in the glacial aquifer, 4 wells completed in the Saginaw aquifer, 10 wells completed in the Marshall aquifer, and 2 wells completed in the Coldwater confining unit. A wet growing season in 2004 appears to have minimized the decline in ground-water levels that typically occur in the third and fourth quarters of most years resulting in fairly high ground-water levels in 2005, even though precipitation during the growing season lagged several inches behind other years including 2004. Period-of-record minimum depth to water was measured in wells H25C and H26, completed in the Marshall aquifer, in March 2004, and period-of-record maximum depth to water was measured in wells H14, H15B, and H15D, completed in the Marshall aquifer, in September 2005.

From January 2004 through December 2004, almost no net change in water levels was measured in well H1C, which is located close to Saginaw Bay (Lake Huron) and which also had almost no net change during the same period. Well H9r, which also is located adjacent to Saginaw Bay, experienced a net rise of 0.71 ft during the same period.

Water-level trends in wells completed throughout Lower Michigan are affected by several external factors, including proximity to nearby production wells, amount and timing of precipitation events, evapotranspiration and type of prevalent ground cover, proximity of aquifer to the surface, and hydraulic characteristics of overlying geologic materials. Water-level trends in some wells in Huron, Kalamazoo, and Monroe Counties are similar, although the long-term trend of the water level in the Petersburg Deep well located in Monroe County differs somewhat.

Acknowledgments

Greg Renn of the Huron Conservation District made quarterly water-level measurements presented within this report. Danny Costello, staff hydrologist for National Oceanic and Atmospheric Administration in White Lake, Michigan, provided all the precipitation records used in this study. Tom Morgan, hydrologic technician at the USGS Water Science Center in Lansing, Michigan accompanied Greg Renn annually during the study period and provided quality assurance of water-level data presented in the report.

Cover photograph—Upland native grass with wildflower seeding around a wetland restoration, Huron County, Mich. Photograph by Greg Renn.

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