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Ground-Water Levels in Huron County, Michigan, 2006-07

Open-File Report 2008–1248

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

Cover Photograph. Harbor Beach Breakwater Lighthouse, Huron County, Michigan. (Photograph by Carol Schadd at sunrise in the spring of 2004).

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By T.L. Weaver S.P. Blumer, and L.M. Fuller

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
milligram per liter (mg/L)	1000	micrograms per microliter (µg/µL)
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 (mmi)	1.852	kilometer (km)
yard	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

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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 initially operated four continuous water-level recorders, installed from 1988 to 1991 on wells in Bingham (H5r), Fairhaven (H9r), Grant (H2r), and Lake Townships (H25Ar) and summarized the data collected in an annual or bi-annual report (fig. 1). The agreement was altered in 2003, and beginning January 1, 2004, only wells H9r and H25Ar retained continuous water-level recorders, while wells H2r and H5r reverted to quarterly or periodic measurement status 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. Well H2r was selected for periodic measurement at that time because it is completed in the glacial aquifer, which is absent in much of Huron County and well H5r, which is completed in the Marshall aquifer, was selected because the water level in the well is often perturbed as a result of pumpage from nearby production wells and does not always reflect baseline conditions within the aquifer.

USGS also has provided training for County or Huron Conservation District personnel to measure the water level in 24 of the wells on a quarterly basis. USGS personnel accompany County or Huron Conservation District personnel on a semi-annual basis to provide a quality assurance/quality control check of all measurements being made. Water-level data collected from the wells is summarized in an annual or bi-annual report.

The altitude of Lake Huron and precipitation are good indicators of general climatic conditions and, therefore, provide an environmental context for groundwater levels in Huron County. Figure 2 shows the mean-monthly water-level altitude of Lake Huron, averaged from measurements made at Essexville and Harbor Beach (National Oceanic and Atmospheric Administration, 2008), and monthly precipitation measured in Harbor Beach, Sebewaing, and Bad Axe (National Oceanic and Atmospheric Administration, Danny Costello, written commun., 2007-08).

In December 2007, the water level in Lake Huron dropped to a new monthly mean low of 576.38 ft for the period from 1988 through 2007 (the previous low-water level of 576.57 ft was measured in March 2003). The net decline in the water level of Lake Huron from January 2006 through December 2007 was 0.68 ft. In 2006, annual precipitation measured at Harbor Beach was 3.2 in. above the long-term average of 31.1 in., with 10.6 in. measured during the 2006 growing season (May through August). In 2007, annual precipitation measured at Harbor Beach was 1.4 in. below normal, with 9.7 in. measured during the growing season.

In the two wells equipped with continuous water-level recorders, the water level rose 0.32 ft from January 1, 2006 to December 31, 2007 in well H9r, but declined 1.11 ft in well H25Ar. Curiously, well H9r is drilled adjacent to Saginaw Bay (Lake Huron), and, as previously noted, there was a 0.68 ft decline in the water level in Saginaw Bay during that period.

Twenty four wells were measured on a quarterly or periodic basis from December 2005 through December 2007 (well H26 was destroyed during summer 2007 reducing the total number of wells from 25). These wells are completed in the glacial, Saginaw and Marshall

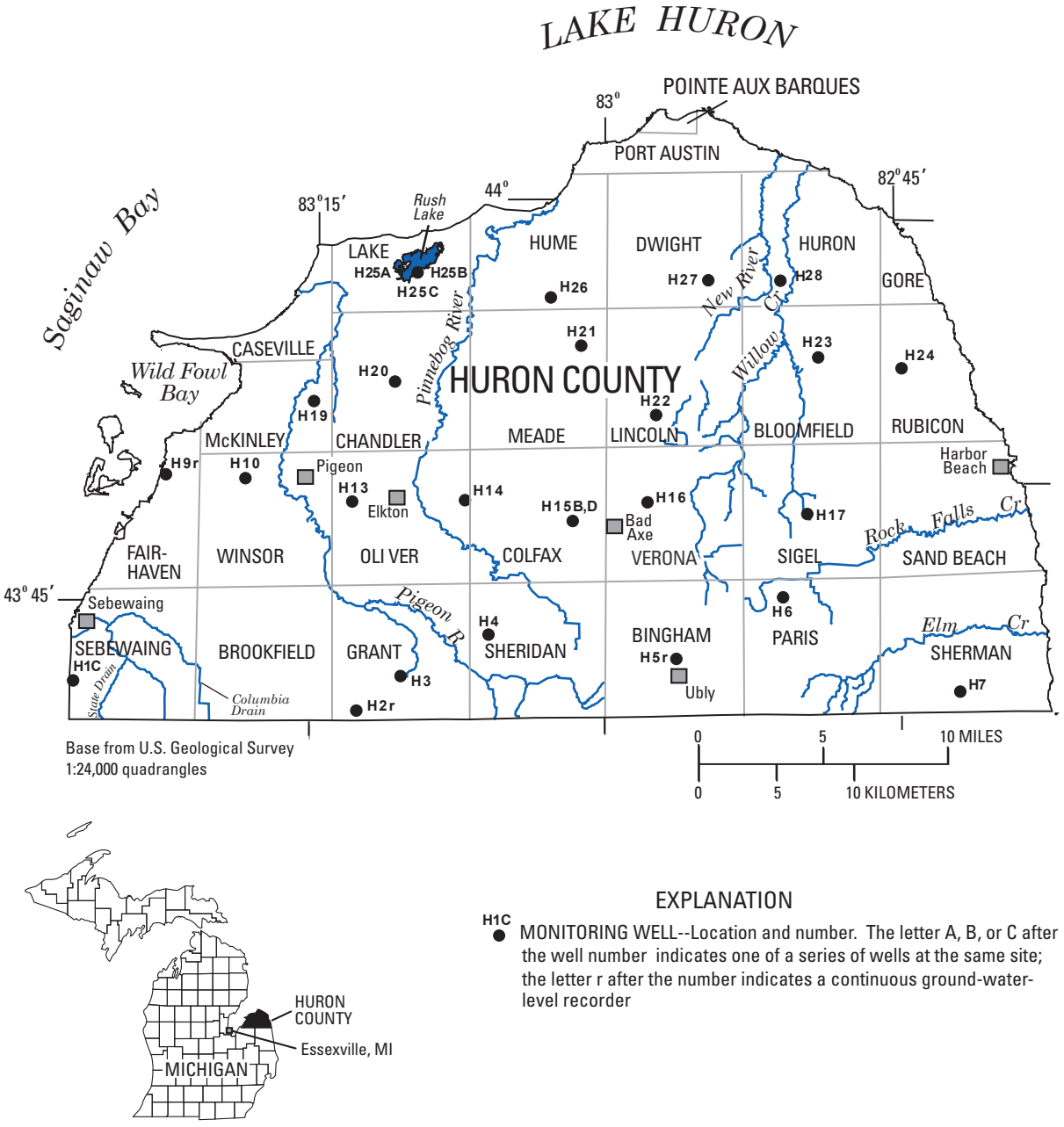

Figure 1. Location of monitoring wells in Huron County, Michigan.

aquifers, and the Coldwater confining unit. Although each quarterly or periodic measurement only provides a "snapshot" water level (measured in ft below land surface, and altitude, in ft above sea level), the data adequately define the generalized water-level trend in the aquifer near the well. Water levels in 6 quarterly-measured wells had net rises ranging from 0.09 to 1.45 ft for the period, while water levels in 18 of the wells had net declines ranging from 0.26 to 2.19 ft (tables 1 and 2; fig. 3).

Period-of-record (the time period during which water levels have been measured by U.S. Geological Survey or their cooperators) minimum depths to water (high-water levels) were measured in March and December 2006 in two quarterly-measured wells completed in the Saginaw aquifer in Oliver and Sebewaing Townships,

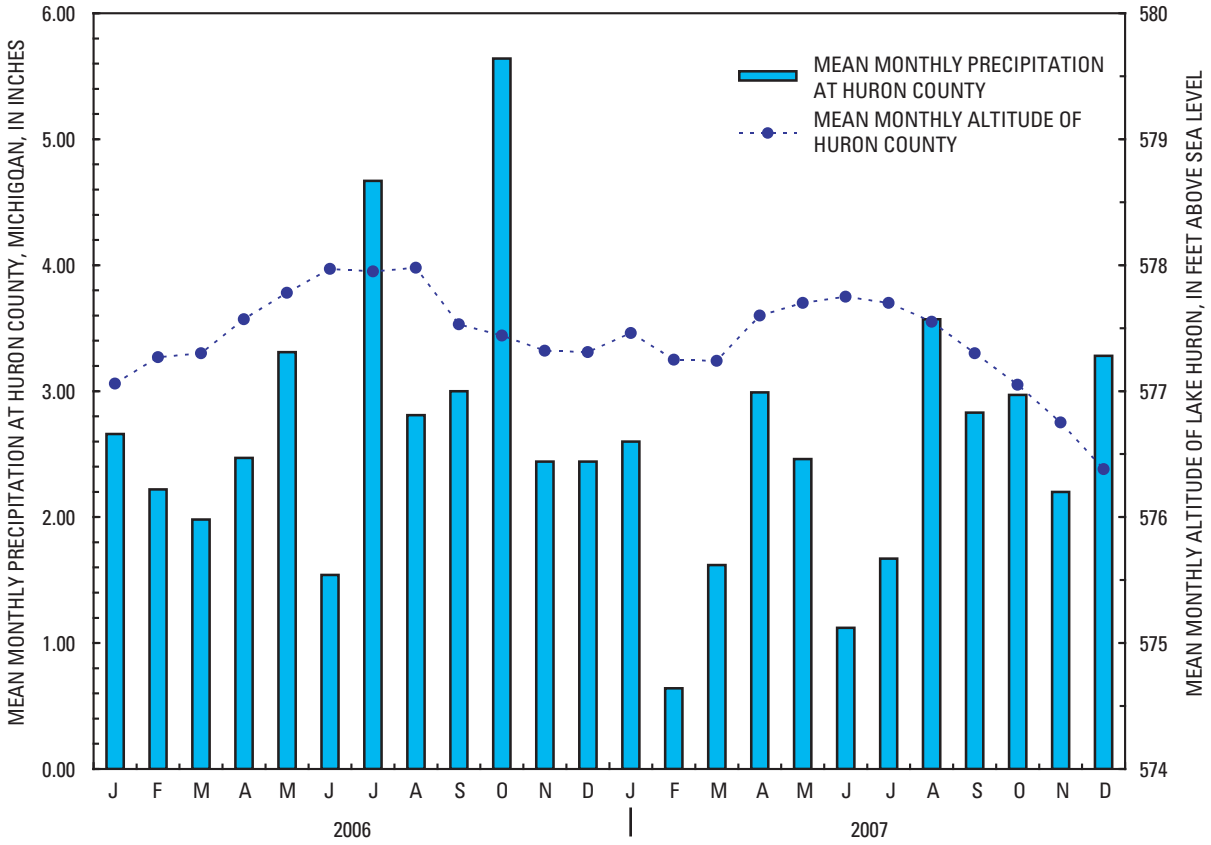

Figure 2. Mean monthly water-level altitude of Lake Huron from measurements made at Essexville and Harbor Beach, Michigan, and mean monthly precipitation from measurements made at Harbor Beach, Sebewaing, and Bad Axe, Michigan, January 2006 through December 2007. (November 2007 lake levels are only from measurements made at Harbor Beach; Bad Axe precipitation was not measured every month).

respectively. A period-of-record minimum depth to water was also recorded June 5, 2007 in well H9r, completed in the Michigan Formation/Marshall aquifer in Fairhaven Township. Period-of-record maximum depths to water were measured in September 2007 in two wells completed in the Marshall aquifer in Oliver and Dwight Townships. Notably, water levels in those two wells recovered about 1 to 3 ft between September and December 2007. No period-of-record minimum or maximum depths to water were measured in wells completed in either the glacial aquifer or the Coldwater confining unit from December 2005 through December 2007.

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 exceptions are communities adjacent to Lake Huron or Saginaw Bay and the Village of Pigeon (fig. 1), which use Lake Huron or Saginaw Bay 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

Table 1. Depth to water in wells measured quarterly and net change in depth to water from December 2005 through December 2007, Huron County, Michigan.

[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; --, indicates no water-level measurement in well; N.A., not applicable]

Well identifier	Aquifer code	Altitude of measuring point, in feet	Period of record maximum, in feet	Date of measurement									Net change 12/05 through 12/07
				12/05	3/06	6/06	9/06	12/06	3/07	6/07	9/07	12/07	
				Depth to water below land surface, in feet									
H1C	S	600	26.67	15.81	14.41	14.54	14.28	***13.08***	13.70	13.58	15.66	14.36	1.45
H3	M	731.7	34.80	28.97	28.01	27.94	29.98	28.39	28.27	28.68	31.11	29.72	-0.75
H4	M	751.6	14.98	13.49	11.71	12.06	13.80	12.07	12.27	12.38	14.48	13.77	-.28
H5r	M	795	16.38	12.24	10.56	11.03	12.25	10.78	11.18	11.43	13.05	12.65	-.41
H6	M	781.5	17.48	15.19	12.75	12.83	14.61	12.68	12.86	12.69	15.99	15.45	-.26
H7	C	726.8	16.94	16.16	15.66	15.54	15.86	15.62	15.24	15.23	15.89	15.85	.31
H10[a]	S	617.07	27.50	22.16	21.81	21.82	22.36	22.04	21.67	21.73	22.36	22.07	.09
H13	S	642.35	36.90	28.06	***26.40***	26.46	29.19	27.65	26.79	26.45	31.45	28.55	-.49
H14[b]	M	681.3	11.09	8.05	6.14	7.91	10.73	8.05	7.44	9.12	**13.31**	10.21	-2.16
H15B	M	751.2	23.21	18.29	15.97	16.98	21.13	16.70	16.57	16.85	20.92	18.58	-.29
H15D[c]	M	unknown	24.99	19.95	16.90	19.09	22.21	17.43	17.03	18.34	23.03	19.37	.58
H16	M	771.5	34.15	31.05	28.99	28.21	30.68	29.07	28.81	29.22	31.75	31.50	-.45
H17	M	751	28.09	8.43	5.81	5.86	7.55	6.06	6.06	6.00	18.22	9.33	-.90
H19	M	611.9	6.13	3.82	3.34	3.62	3.55	3.35	3.07	3.67	3.77	3.68	.14
H20	S	631	17.22	15.38	14.31	13.48	14.79	14.90	14.66	13.46	14.94	15.68	-.30
H21	M	702.9	13.21	9.63	8.21	8.53	9.88	8.04	8.52	8.36	11.35	10.96	-1.33
H22	M	695.5	18.68	15.13	13.51	13.91	15.89	13.99	13.73	13.64	16.84	16.84	-1.71
H23	C	721.8	10.37	8.49	8.51	8.42	8.51	8.19	7.97	8.01	8.21	7.99	.50
H24	C	691.5	29.04	25.70	25.07	25.30	25.84	25.32	24.97	25.02	26.08	26.00	-.30
H25B	M	601	5.70	2.55	1.31	1.72	4.05	1.97	1.97	1.93	4.64	3.92	-1.37
H25C	M	602.2	5.28	2.14	1.71	1.92	3.89	1.77	1.90	2.32	4.65	3.20	-1.06
H26[d]	M	662.7	16.10	4.27	2.02	2.03	--	--	--	--	--	--	N.A.
H27	M	716.5	37.66	35.63	32.62	33.39	35.58	33.64	33.34	33.41	**38.55**	37.37	-1.74
H28	M	691.7	24.30	20.87	18.14	19.50	21.41	18.29	18.73	19.38	23.66	23.06	-2.19

[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.

[d] Well was destroyed between the inspections in June and September 2006

Table 2. Depth to water in periodically measured well H2r and net change in depth to water from December 2005 through December 2007, Huron County, Michigan.

Altitude of measuring point, in feet	Period of record maximum	Date of measurement										
		12/15/05	1/5/06	2/28/06	3/6/06	5/3/06	6/8/06	6/26/06	8/30/06	9/8/06	11/7/06	12/4/06
		Depth to water below land surface, in feet										
746.00	36.29	33.43	32.97	31.50	31.78	31.34	31.82	32.43	34.31	34.38	32.91	32.47

Date of measurement										Net change 12/05 through 12/07
1/9/07	3/5/07	3/27/07	5/17/07	6/11/07	7/18/07	9/10/07	9/20/07	11/26/07	12/7/07	
Depth to water below land surface, in feet										
31.94	31.95	31.96	31.52	32.00	34.83	35.81	35.37	33.90	33.75	-0.32

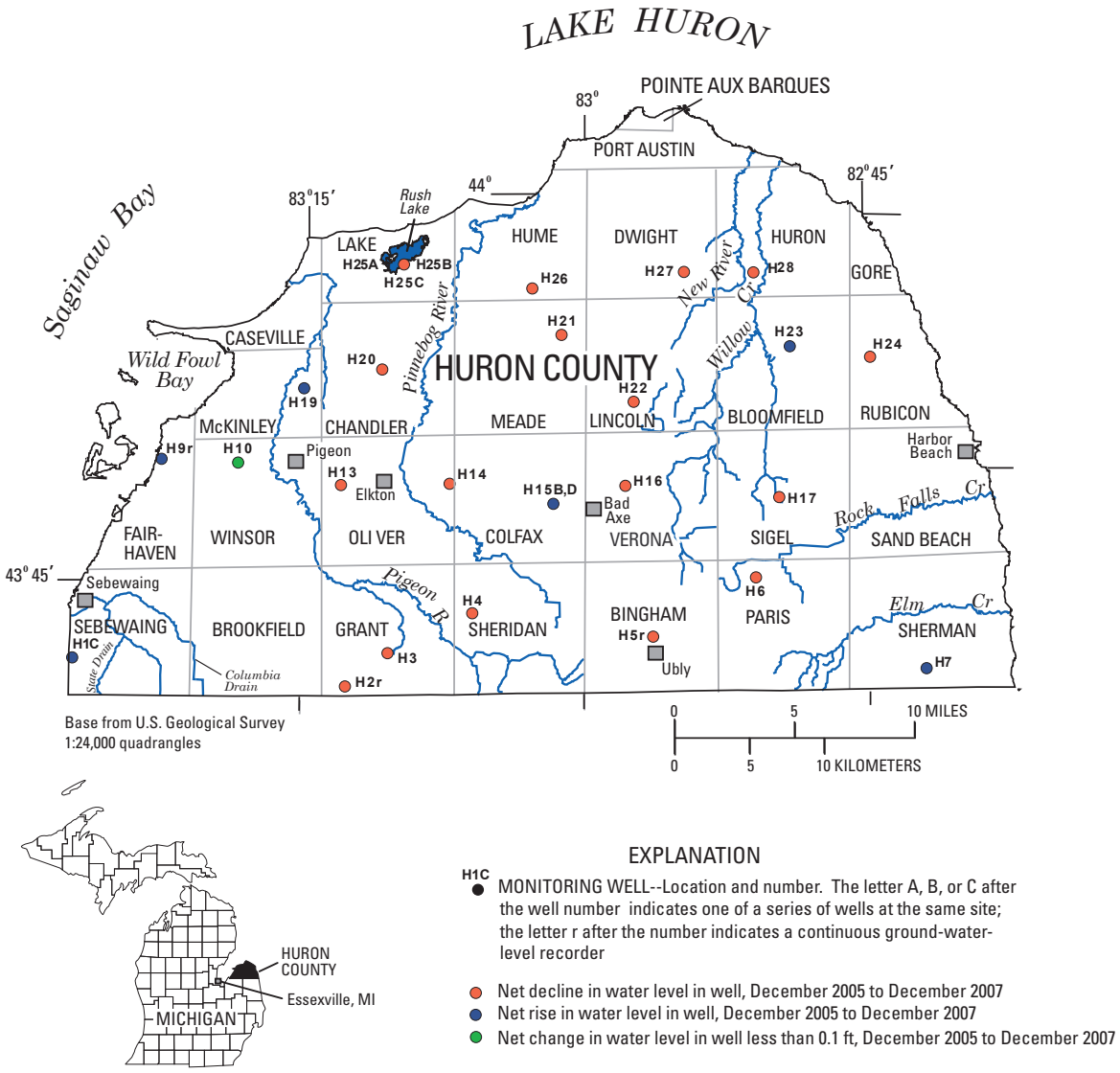

Figure 3. Net change in ground-water levels, Huron County, Michigan, December 2005 through December 2007.

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 summarize water-level measurements made during 2006-07 in 27 observation wells in Huron County (well H26 was destroyed during summer 2007 reducing the total number of wells to 26) and compare those measurements with levels of Lake Huron at Harbor Beach and Saginaw Bay at Essexville and precipitation measured at Harbor Beach, Sebewaing, and Bad Axe during the same period. Data from the previous study period (1988-2005) are also analyzed to provide a historical context for ground-water level trends observed during 2006-07. *Water levels for the quarterly measured wells are presented from December 2005 through December 2007 to provide a complete 2-year cycle that is approximately equivalent to the cycle presented for wells equipped with continuous water-level recorders (January 1, 2006 through December 31, 2007).*

Figure 2 shows the mean monthly water-level altitude of Lake Huron (averaged from sites at Essexville and Harbor Beach) from January 2006 through December 2007 (National Oceanic and Atmospheric Administration, 2008), and monthly precipitation measured in Harbor Beach, Sebewaing, and Bad Axe for the same period (Danny Costello, National Oceanic and Atmospheric Administration, written commun., 2008). In January 2006, the water level of Lake Huron was about 0.70 ft lower than January 2005. In 2006, the lake level rose about 1.00 ft from January through August, but declined about 0.70 ft from September through December. In January 2007, the water level was about 0.40 ft higher than January 2006, but rose less than 0.30 ft through June, and fell about 0.70 ft from July through October. By December 2007, the water level in Lake Huron had dropped to a new monthly low for the period from 1988 to 2007 of 576.38 ft. *The net decline from January 2006 through December 2007 was 0.68 ft.*

All precipitation records for this study were provided by National Oceanic and Atmospheric Administration (Danny Costello, National Oceanic and Atmospheric Administration, written commun., 2008). Prior to 2006, monthly precipitation measurements made in Bad Axe were readily available and complete. During the period of the current report, however, complete records are only available for Harbor Beach, and they were augmented by less complete records from Sebewaing and Bad Axe.

Long-term annual precipitation measured in Huron County is about 31.1 in. Monthly mean precipitation measured at Harbor Beach and augmented by intermittent records from Sebewaing and Bad Axe was about 34.3 inches in 2006 and 29.7 inches in 2007 (3.2 in. above average and 1.4 in. below average, respectively).

Distribution of precipitation during the growing season (May through August) is an important factor that influences how much aquifer recharge occurs during those months. Precipitation measured in Harbor Beach from May through August 2006 was 10.6 in., but only about 9.7 in. was measured during the same period in 2007. Typical of other parts of Michigan, particularly for areas near the Great Lakes, some climatic variation occurs in Huron County; mean precipitation measured during the growing season at Harbor Beach, Sebewaing, and Bad Axe was 12.3 inches in 2006 and 8.8 inches in 2007.

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 water-level recorder was installed in February 1991 and operated continuously, with the exception of the period from October 1998 through February 1999, until it was removed on December 31, 2003. Periodic water-level measurements (ten times in 2006, and ten times in 2007) have been made at H2r since that time.

Figure 4 shows the water level in well H2r for the period from January 2006 through December 2007 compared with monthly precipitation measured at Bad Axe, Michigan.

Unlike water levels in wells completed in deeper bedrock or confined glaciofluvial aquifers, levels in wells completed in unconfined glaciofluvial aquifers like H2r typically respond rapidly to precipitation. The water level in shallow, unconfined aquifers is affected mostly by recharge from precipitation and losses due to evapotranspiration. 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 have shown how rapidly the water level in well H2r can respond to precipitation events and, conversely, how even large-magnitude single-precipitation events may have little or no obvious effect on the water-level trend, particularly when they occur during the growing season when evapotranspiration is greatest (Sweat, 1999; Weaver and others, 2000; Weaver, 2001; Weaver and McGowan, 2002; Weaver and others, 2006).

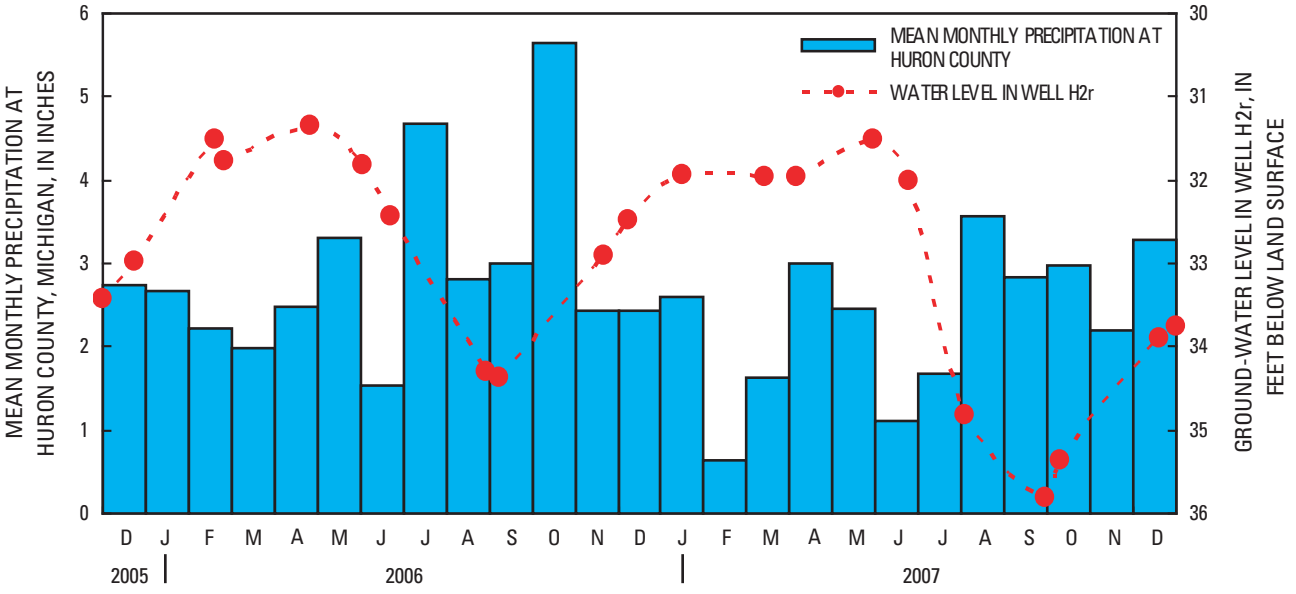

Figure 4. Depth below land surface of water in Grant Township well H2r and mean monthly precipitation measured at Harbor Beach, Sebewaing, and Bad Axe, Michigan, December 2005 through December 2007 (Bad Axe precipitation was not measured every month).

The water level in well H2r (measured in feet below land surface) was 33.43 ft on Dec. 15, 2005. From then through December 7, 2007, when the most recent periodic measurement of water level in the well was made, the net decline in water level was 0.32 ft (table 2). The greatest depth to water during 2006-07 (35.81 ft) was measured September 10, 2007 and minimum depth to water for the same period (31.34 ft) was measured May 3, 2006.

Saginaw Aquifer Wells

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. Hydrographs in figure 5 illustrate water levels measured quarterly and a generalized water-level trend for period from December 2005 through December 2007. Net change in water levels from December 2005 to December 2007 ranged from a 0.49 ft decline in well H13 (located in Oliver Township west of Elkton) to 1.45 ft rise in well H1C (located in Sebewaing Township). No notable trends in water levels of all four wells were noted during 2006-07, although two of the wells had their period-of-record minimum-measured depth to water in 2006 (well H13 in March and well H1C in December); none had a period-of-record maximum-measured depth to water in 2006-07.

The generalized trends of water levels in wells H10 and H13, located in adjacent Winsor and Oliver Townships, are similar to one another and different from the other two wells completed in the Saginaw aquifer. The water-level trend measured in well H20, which is located in Chandler Township, has typically differed from what has been observed in the other wells completed in the Saginaw aquifer (Weaver and others, 2006). A net rise in water level of 0.30 ft was measured in well H20 during 2006-07 and its water-level trend was most similar to Lake Huron levels, even though it is located much further from the lake than well H1C.

Water levels in two quarterly measured wells completed in the Saginaw aquifer experienced a net rise of 0.09 and 1.45 ft during the period from December 2005 to December 2007, while the water level in the other two quarterly measured wells declined 0.30 and 0.49 ft. No wells completed in the Saginaw aquifer had period-of-record maximum depths to water measured in 2006-07.

Marshall Aquifer Wells

The Fairhaven Township well (H9r) 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 it appears to be open to limestone, shale, and sandstone of the Michigan Formation and Marshall aquifer between 147 and 180 ft. Well H9r has been listed previously as being completed in the Saginaw or both the Saginaw and Marshall aquifers. Review of the drillers log and completion depth was done during the preparation of this report and well H9r appears to actually be completed in the

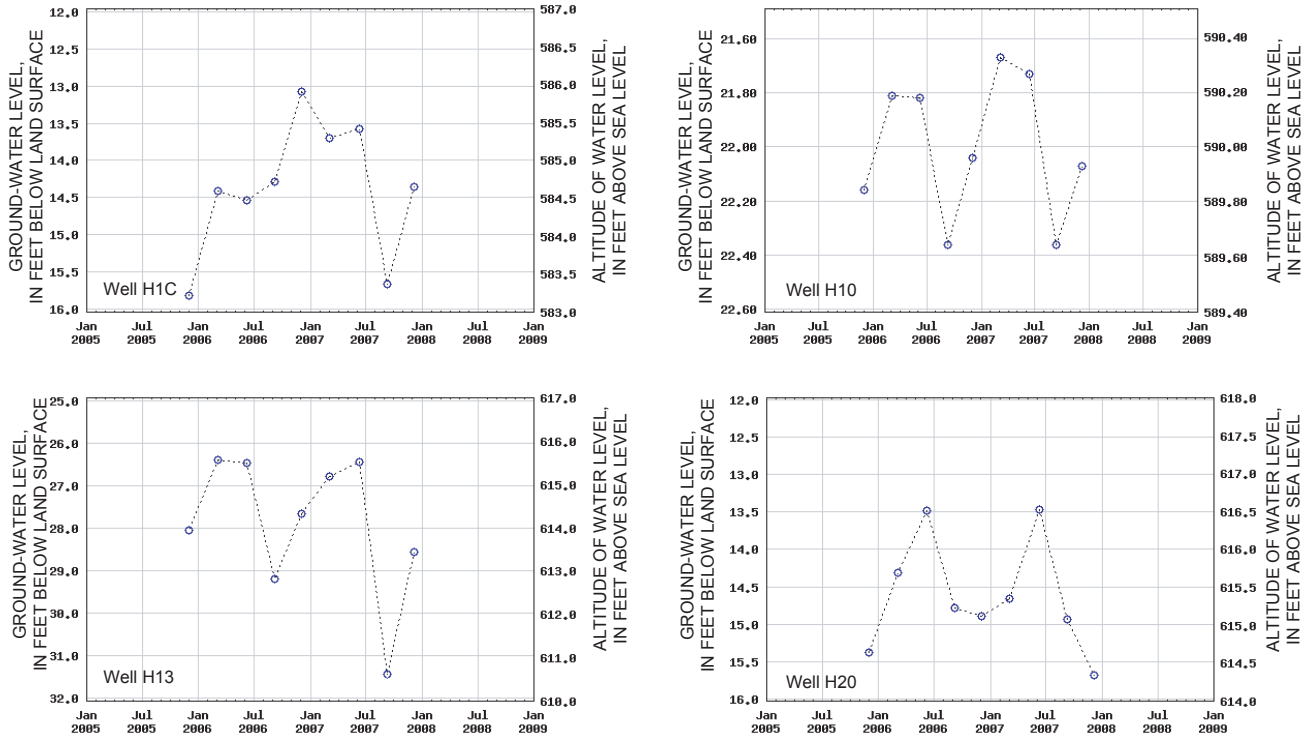

Figure 5. Altitude and depth below land surface of water measured quarterly in wells completed in the Saginaw aquifer from December 2005 through December 2007, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

Michigan Formation (which stratigraphically underlies the Saginaw aquifer) and/or the Marshall aquifer (which stratigraphically underlies the Michigan Formation). A continuous water-level 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 that typically *preceded* those of Lake Huron by 3 to 6 months. Data from 2004-05 and the current study period seem less conclusive. Periods of high water levels in H9r seem to precede high Lake Huron levels by one to two months while periods of lower lake levels seem to occur as much as four months after they occur in well H9r. Daily maximum water levels measured in well H9r and monthly mean altitude of Lake Huron during 2006-07 are shown on figure 6.

The period-of-record maximum depth to water in well H9r, of 12.30 ft, recorded on June 2, 1998, was not approached in 2006-07. A new period-of-record minimum depth to water of 2.66 ft was measured June 5, 2007. The net rise in maximum daily water level in well H9r from January 1, 2006 through December 31, 2007 was 0.32 ft, although a best-fit line indicated the general trend throughout the period is actually one of slight water-level decline. Rapid declines in the water level in H9r to about 6.3 to 6.4 ft occurred in August 2006, and April and August 2007. Although the source of the withdrawal(s) causing the rapid declines is unknown, similar declines were also noted in August 1998 and July 2001. In all instances, the rapidly depressed water level also recovered rapidly.

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 (fig. 1), and is the deepest of three adjacent wells at the site. A continuous water-level 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.

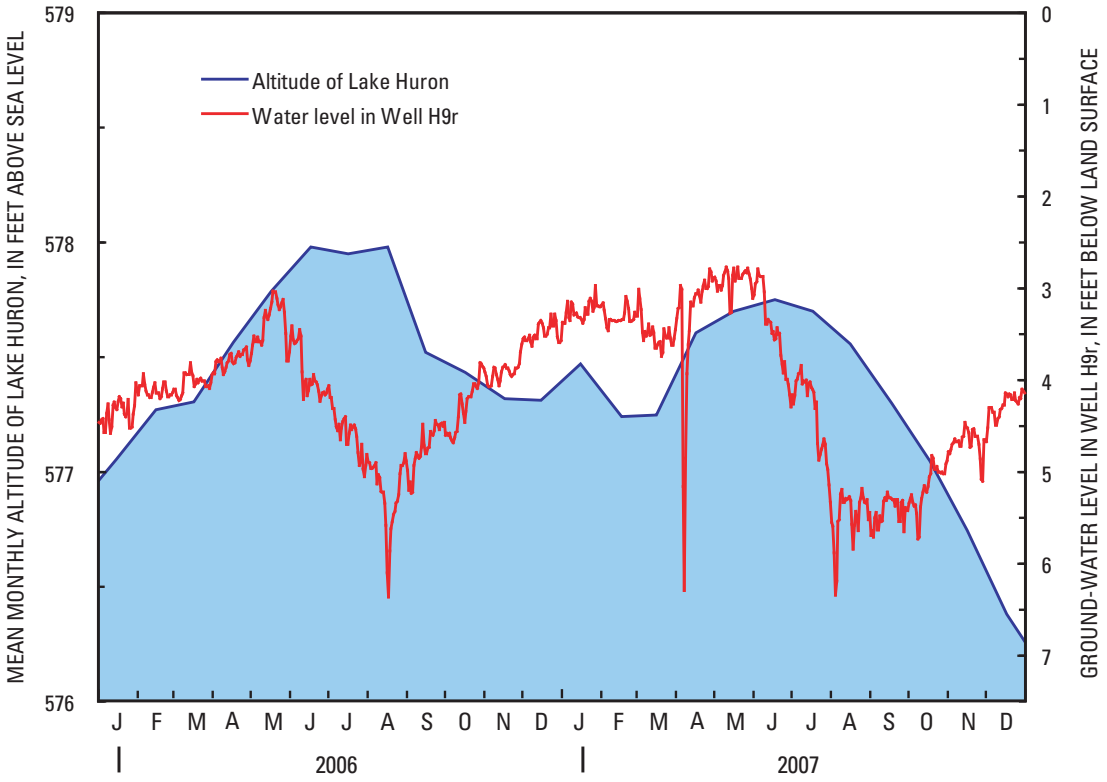

Figure 6. Depth below land surface of water in Fairhaven Township well H9r, and mean monthly water-level altitude of Lake Huron averaged from measurements made at Harbor Beach and Essexville, Michigan, January 2006 through December 2007.

On January 1, 2006, the water maximum depth to water in well H25Ar was 7.53 ft. In 2006, the minimum depth to water (6.20 ft) was measured April 15 and maximum depth to water (8.83 ft) was measured September 11. On January 1, 2007, the water level in well H25Ar was 6.90 ft. In 2007, the minimum depth to water (6.15 ft) was measured on April 27 and maximum depth to water (9.66 ft) was measured on October 15. The net decline in daily maximum water level in well H25Ar from January 1, 2006 through December 31, 2007 was 1.11 ft. In addition to normal seasonal variation, the water level in H25Ar can also be affected by withdrawals from nearby irrigation wells (fig. 7). The water-level trend measured in well H25Ar is similar to the trend measured in well H9R during the same period (fig. 6).

Hydrographs in figure 8a and 8b illustrate quarterly measured water levels in wells completed in the Marshall aquifer and generalized water-level trends for the period from December 2005 through December 2007.

Water levels measured quarterly in 17 wells completed in the Marshall aquifer are included in table 1. Wells are listed by an identifier shown in figure 1. During 2006, water-level trends in most of the wells were similar, with a rise in March and June, a large decline in September, followed by another rise in December. There was a fair amount of variation in the first two quarters in 2007, with some wells declining immediately while others rose through their respective June measurement. Every well declined in the third quarter, but all wells except H22 in Lincoln Township experienced some recovery prior to the December measurement. In most wells, the rise in water levels during the period from December 2006 to March 2007 was less pronounced than the same period in 2005-06, and the June to September decline in 2007 was typically greater than in 2006. From December 2005 to December 2007 there was a net decline in water levels in 14 wells ranging from 0.26 to 2.19 ft, and a net rise of 0.58 ft and 0.14 ft in wells H15D and H19, respectively. Well H26 was found destroyed in September 2006 and not considered in compilation of above data.

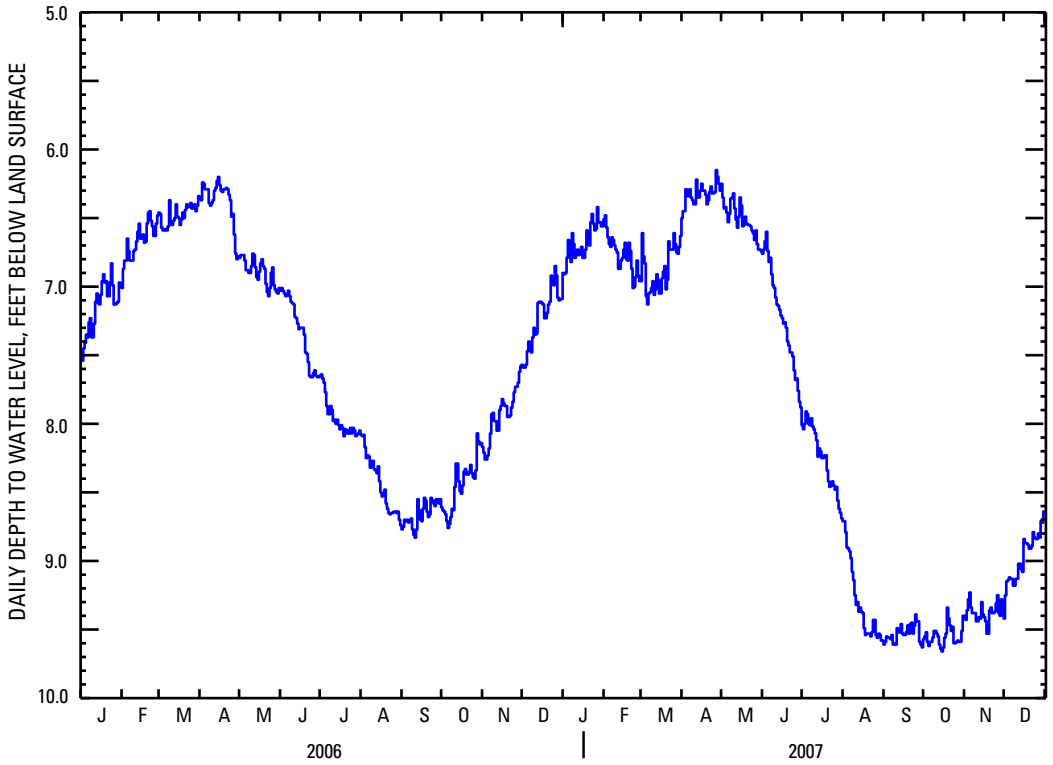

Figure 7. Depth below land surface of water in Lake Township well H25AR, January 2006 through December 2007, Huron County, Michigan.

No period-of-record minimum depths to water were measured in any wells completed in the Marshall aquifer during 2006-07. Period-of-record maximum depth to water was again measured in well H14 (previous record set in 2005) and well H27, located in Oliver and Dwight Townships, respectively.

H5r and several other wells completed in the Marshall aquifer are also affected by withdrawals from nearby municipal or agricultural wells. Because these wells are only measured quarterly, it is possible, if not likely, that the greatest depth to water in any given year occurs when water levels are not being measured. The water level in well H17 (located in Sigel Township) typically responds to nearby irrigation-well withdrawal more dramatically than most/all of the other wells in the study area. The water level in well H17 ranged over 20 ft in 1995, and except during the wettest years, typically ranges at least 10 ft. Measurements made in 2006 appear to miss any evidence of irrigation withdrawals as the water-level range is only about 2 ft, but the decline was more than 12 ft between measurements made in June and September 2007. In contrast, the decline in water levels in the other wells completed in the Marshall aquifer over the same period was in the range of 1 to 5 ft.

As noted in the previous studies, the water-level trends in well H19 (Marshall aquifer) and well H20 (fig. 5), interpreted as being completed in an outlier of the Saginaw aquifer several miles to the east, are largely the inverse of one another again during 2006-07. The lowest water level in well H20 was measured in December in 2005, 2006, and 2007. The water level in H20 may mimic precipitation, while the water level in H19 and other wells completed in the Marshall aquifer appear to lag three to six months. 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 two quarterly measured wells (H15D and H19) completed in the Marshall aquifer experienced a net rise during the period from December 2005 to December 2007, while water levels in the remaining 14 quarterly measured wells experienced a net decline during the same period (7 wells had net declines greater than 1 ft).

In the two wells equipped with continuous water-level recorders, the water level rose 0.32 ft from January 1, 2006 to December 31, 2007 in well H9r but declined 1.11 ft in well H25Ar.

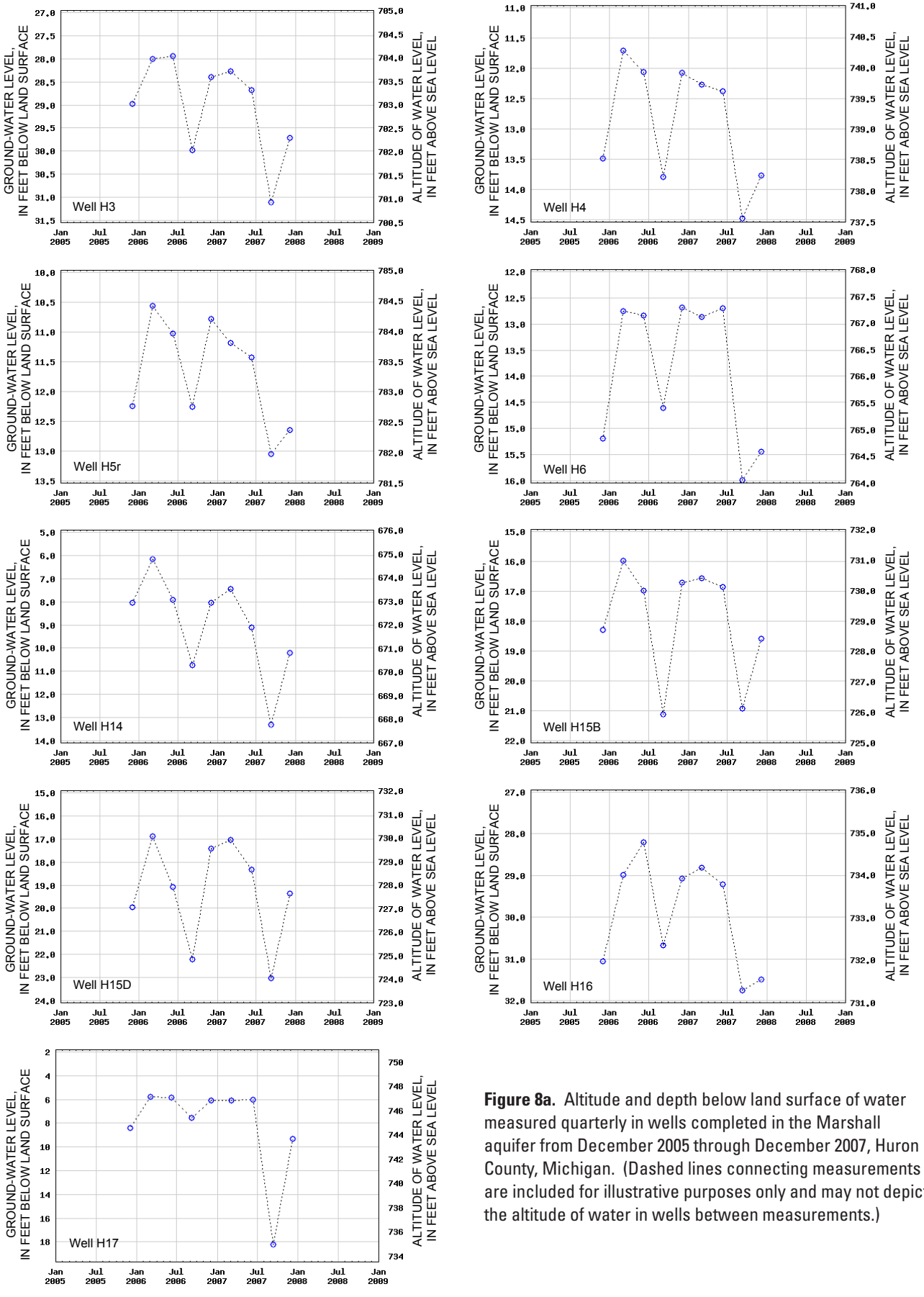

Figure 8a. Altitude and depth below land surface of water measured quarterly in wells completed in the Marshall aquifer from December 2005 through December 2007, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

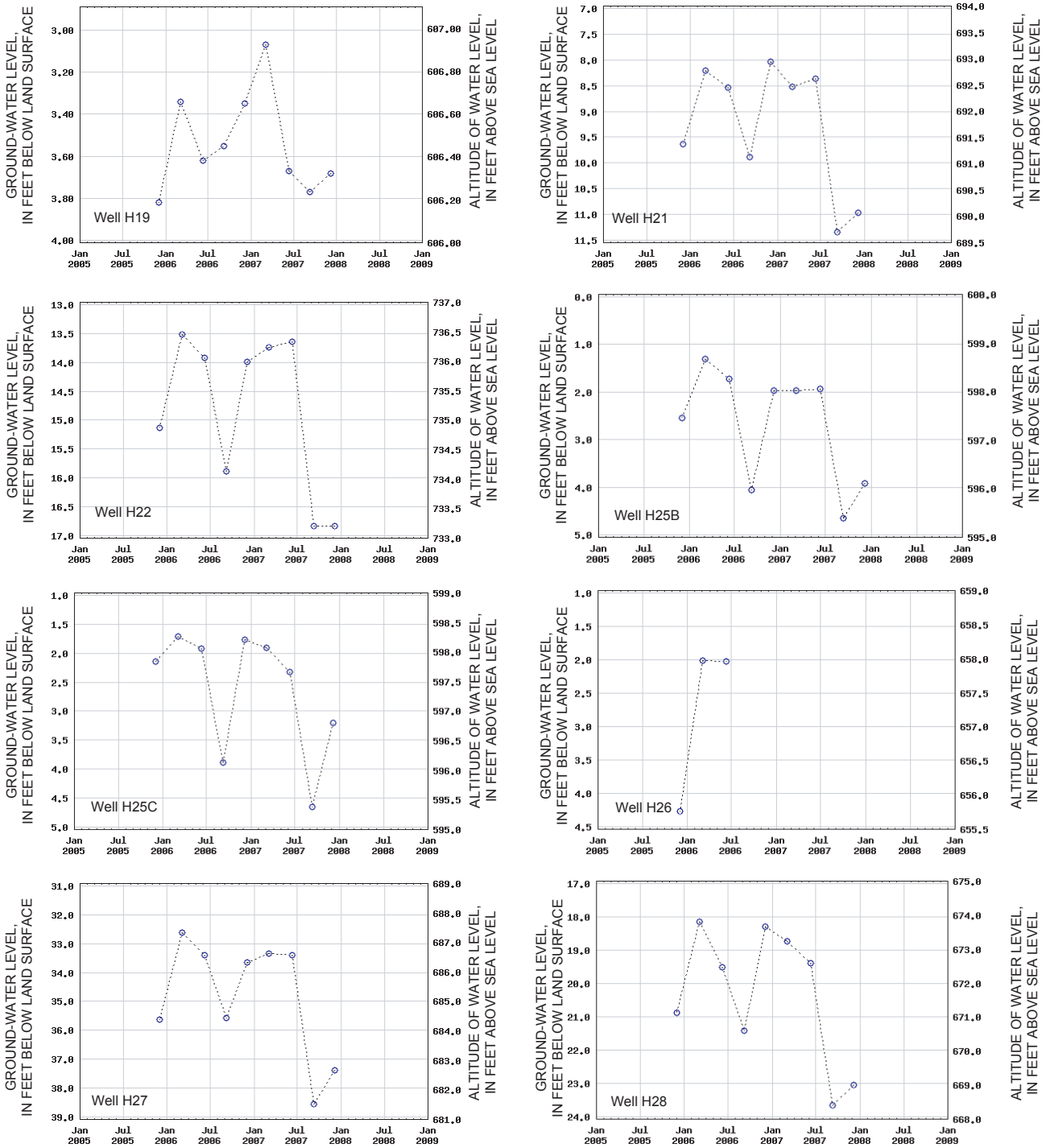

Figure 8b. Altitude and depth below land surface of water measured quarterly in wells completed in the Marshall aquifer from December 2005 through December 2007, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

Period-of-record minimum depth to water was recorded in well H9r in June 2007 while period-of-record maximum depth to water was measured in wells H14 and H27 in September 2007.

Coldwater Confining Unit Wells

There are no wells completed in the Coldwater confining unit with continuous water-level recorders because water levels typically do not 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 that are completed in shale, sandstone, and sandy shale of the Coldwater confining unit are included in table 1. The wells, which are listed by an identifier shown in figure 1, are all located on the east side of the county near Lake Huron. The hydrographs in figure 9 illustrate water levels and generalized water-level trends for the period from December 2005 through December 2007.

Water levels in wells H7 and H23 completed in the Coldwater confining unit experienced a net rise of 0.31 ft and 0.50 ft, respectively, during the period from December 2005 to December 2007 while the water level in well H24 experienced a net decline of 0.30 ft. No period-of-record maximum or minimum depths to water were measured in the wells during 2006-07.

Summary

During 2006-07, 7 wells located in Huron County experienced net water-level rises and 19 wells experienced net water-level declines. Net water-level rises (all 0.58 ft or less, except H1C, which had a net rise of 1.45 ft) were measured in 2 wells completed in the Saginaw aquifer, 3 wells completed in the Marshall aquifer, and 2 wells completed in the Coldwater confining unit. Net water-level declines up to 2.19 ft occurred in the single well completed in the glacial aquifer, 2 wells completed in the Saginaw aquifer, 15 wells completed in the Marshall aquifer, and 1 well completed in the Coldwater

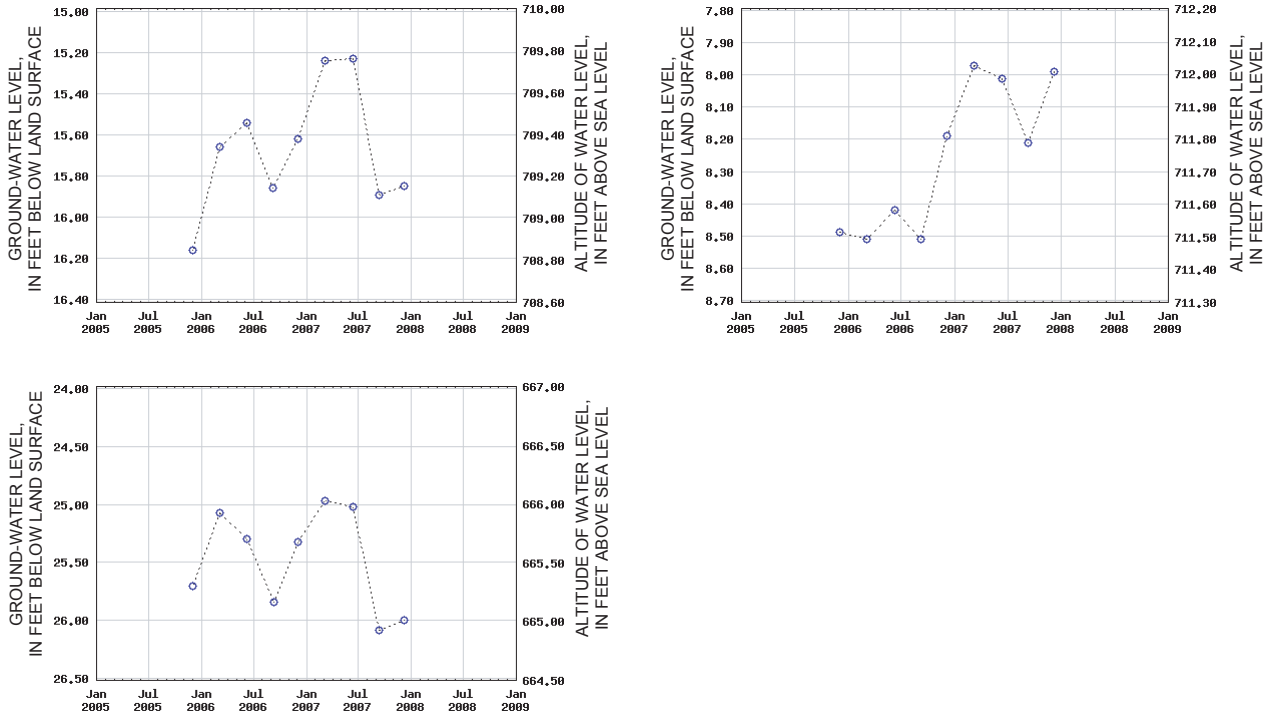

Figure 9. Altitude and depth below land surface of water measured quarterly in wells completed in the Coldwater confining unit from December 2005 through December 2007, Huron County, Michigan. (Dashed lines connecting measurements are included for illustrative purposes only and may not depict the altitude of water in wells between measurements.)

confining unit. Notably, net declines greater than 1.0 ft were measured in 8 wells completed in the Marshall aquifer.

Period-of-record minimum depth to water was measured in wells H13 and H1C in March and December 2006, respectively; completed in the Saginaw aquifer, and in June 2007 in well H9r, completed in the Michigan Formation and/or the Marshall aquifer. Period-of-record maximum depth to water was measured in wells H14 (for the second consecutive two-year period) and H27, completed in the Marshall aquifer, in September 2007.

From December 2005 through December 2007, the water level measured in well H1C, which is located close to Saginaw Bay (Lake Huron) experienced a net rise of 1.45 ft, even though the lake level declined about 0.70 ft during the same time 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 the aquifer to the surface, and hydraulic characteristics of any overlying geologic materials.

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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. Chris Hoard, ground-water hydrologist at the USGS Water Science Center in Lansing, graciously assisted with reviewing and interpreting driller's logs and generalized geology of the area near well H9r to help identify the aquifer unit that the well is completed in.

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