In Cooperation with the City of Ann Arbor, Michigan

Ground-Water/Surface-Water Relations along Honey Creek, Washtenaw County, Michigan, 2003

Open-File Report 2004-1387

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

Cover photograph. Honey Creek tributary at April Road (Site 13), Washtenaw County, Michigan. Photograph by Denis F. Healy, July 10, 2003.

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Conversion Factors, Horizontal Datum, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Concentration	
grains per gallon (grains/gal)	0.01712	micorgrams per liter (µg/L)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C). Concentrations of chemical constituents in water are given in micrograms per liter (µg/L).

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ABSTRACT

The U.S. Geological Survey (USGS), in cooperation with the city of Ann Arbor, Mich., investigated the ground-water/surface-water relations along the lower reaches of Honey Creek, Washtenaw County, Mich., and an unnamed tributary to Honey Creek (the discharge tributary) from June through October 2003. Streamflow in these reaches was artificially high during a naturally low-flow period due to an anthropogenic discharge. Ground-water/surface-water relations were examined by seepage runs (series of streamflow measurements for the computation of streams gains or losses) and measurements of the difference in head between the stream surface and shallow aquifer. Specific conductance and water-temperature measurements were used as ancillary data to help identify gaining and losing reaches. Three seepage runs and four runs in which hydraulic-head differences between the stream and shallow aquifer were measured (piezometer runs) were made during periods of base flow.

Streamflow measurements were made at 18 sites for the seepage runs. Instream piezometers were installed at 16 sites and bank piezometers were installed at 2 sites. Two deeper instream piezometers were installed at site 13 on September 4, 2003 to collect additional data on the ground-water/surface-water relations at that site.

The seepage runs indicate that the main stem of Honey Creek and the discharge tributary in the study area are overall gaining reaches. The seepage runs also indicate that smaller reaches of Honey Creek and the discharge tributary may be losing reaches and that this relation may change over time with changing hydraulic conditions. The piezometer-run measurements support the seepage-run results on the main stem, whereas piezometer-run measurements both support and conflict with seepage-run measurements on the discharge tributary. Seepage runs give an average for the reach, whereas piezometer head-difference measurements are for a specific area around the piezometer. Data that may appear to be conflicting actually may be showing that within a gaining reach there are localized areas that lose streamflow.

The overall gain in streamflow along with specific measurements of head differences, specific conductance, and water temperature indicate that ground water is discharging to Honey Creek and the discharge tributary. Although reaches and areas that lose streamflow have been identified, data collected during this study cannot confirm or disprove that the loss is to the regional ground-water system.

INTRODUCTION

The city of Ann Arbor, Mich., and the surrounding region rely heavily on ground water for municipal, domestic, and other water supplies. Currently about 20 percent of the city's municipal source water is ground water; however, Ann Arbor anticipates increased use of ground-water resources and plans to develop a regional ground-water-flow model suitable for guiding locations of new water supplies and for protecting these supplies.

Ground-water-flow models simulate the flow of ground water through physical, electric analog, or mathematical representations of the geologic, hydrologic, and anthropogenic environment of the area being studied. Models can vary in scope from local to regional and are used by water scientist and managers to understand the ground-water system and to predict changes in water flow and availability due to changes in the system and/or magnitude and changes in the concentrations of constituents in the ground water and the flow paths that the constituents follow.

Conceptual models describe the important features of the environment to be simulated and identify the processes taking place within that environment. They are used as frameworks on which to build the ground-water flow models. In the glaciated Midwest, a necessary prerequisite to developing a conceptual model of regional ground-water flow is an understanding of the relationship of ground water and surface water.

In the Great Lakes Region, regional ground-water flows occur in both glacial deposits and bedrock aquifers depending on the hydraulic properties of the aquifer and confining units, and the topographic relief (Grannemann and others, 2000). In the study area, the local ground-water-flow system is recharged by or discharges to surface water bodies, including lakes, ponds, and small streams. The regional system discharges to the Huron River.

At a local scale, the ground-water/surface-water relations in stream channels are of two types, one in which water is exchanged with the local or regional ground-water system and the other in which water is exchanged between the stream and the hyporheic zone defined by subsurface flow paths that begin in the stream and return to the stream (Harvey and Bencala, 1993; Wroblicky and others, 1998). The hyporheic zone can be viewed as the subset of localized finer-scale interactions between the channel and ground water that occur within the larger-scale patterns of loss and gain of channel water (Harvey and Wagner, 2000).

During the summer and fall of 2003, the U.S. Geological Survey (USGS), in cooperation with the city of Ann Arbor, identified gaining and losing reaches in Honey Creek, a small stream tributary to Huron River, to characterize the ground-water/surface-water relations as a prerequisite for a regional ground-water flow model of the Ann Arbor area.

Purpose and scope

The purpose of this report is to describe the ground-water/surface-water relations of Honey Creek and its tributaries. Streamflow, differences in hydraulic head between the stream and shallow aquifer, specific conductance, and water-temperature measurements are used as multiple lines of evidence to determine losing or gaining reaches.

Field-data collection for this study was from June through October 2003. During this time, three sets of stream gain-loss measurements were made at 18 sites at base flow. From these measurements, the loss or gain in streamflow for 10 reaches between tributary sites 13 and 6, and Honey Creek sites 5 and 1 were calculated. Also during this time, four surveys were conducted during which hydraulic head, specific conductance, and water-temperature differences between the stream and shallow aquifer were measured using 18 instream piezometers and two bank piezometers at 16 sites.

Study area

Honey Creek drains a small 23.2-mi^2 basin mainly just west of Ann Arbor in Scio Township, Washtenaw County, in southeast Michigan (fig. 1). Honey Creek flows into the Huron River upstream of Ann Arbor and its tributaries are small and many are intermittent. Part of or all of four Honey Creek tributaries included in the study have been incorporated into the Washtenaw County drain system (fig. 1). The Honey Creek basin is underlain by Mississippian age Coldwater Shale which is overlain by stratified glacial deposits that range in thickness from about 200-270 ft. Land use/ land cover in the basin is approximately 15 percent urban; 33 percent agriculture; 25 percent upland forest; 17 percent open land; and 10 percent lowlands, wetlands, and water (Michigan Department of Natural Resources, 2001). During the study, residential housing was constructed near sites 11 and 12 and sites 8 and 9 (fig. 1). Commercial and residential development was active along Honey Creek upstream from site 15 (fig. 1).

During the period of this study, treated water was discharged into the unnamed tributary of Honey Creek that is downstream of Sister's Lake Drain (fig. 1). Streamflow measurements showed that the magnitude of this discharge was near or greater than the streamflow contribution to Honey Creek from the part of the basin upstream of the study area. The discharge outfall is upstream of site 13 and the unnamed tributary is henceforth referred to as the "discharge tributary" (fig. 1).

The upstream site in this study was at Zeeb Road upstream from the confluence of the discharge tributary with Honey Creek (site 15 in fig. 1). This reach of the creek runs through the major road intersection of Zeeb Road with Jackson Road and Interstate 94 and has been extensively engineered with culverts and riprap (fig. 2). Downstream from Interstate 94, the Honey Creek streambed appeared to be in a natural condition with the channel disturbed only near road intersections (fig. 3). Land use along these reaches is suburban and low-density housing with some agriculture. The creek bottom ranges from hard sand and gravel to soft fine-organic sediments.

The Honey Creek tributaries were also disturbed near road intersections and along some reaches where they ran along commercial development and residential housing. There is an impoundment on the discharge tributary between sites 12 and 11, henceforth referred to as the "little lake" (fig. 1). A smaller settling pond is just downstream from site 11.

METHODS OF INVESTIGATION

Seepage runs

The difference in streamflow between an upstream and downstream site is

$$\Delta Q = Q_S + Q_A + Q_G,$$

where ΔQ is the difference in streamflow, Q_S is the sum of surface-water inflows and outflows, Q_A is the sum of atmospheric inflows and outflows, and Q_G is the sum of ground-water inflows and outflows. Sets of measurements over short periods to determine ΔQ at multiple sites along a stream are commonly called seepage runs.

Along the study reach, the surface-water inflows consisted of small tributaries and drains and the treatment discharge between sites 13 and 14 (fig. 1). Streamflows in the tributaries and drains were measured upstream from their confluence with the main study reach. Site 1 is the only surface-water outflow for the study reach.

Atmospheric deposition and evapotranspiration are the main pathways for atmospheric inflows and outflows. The

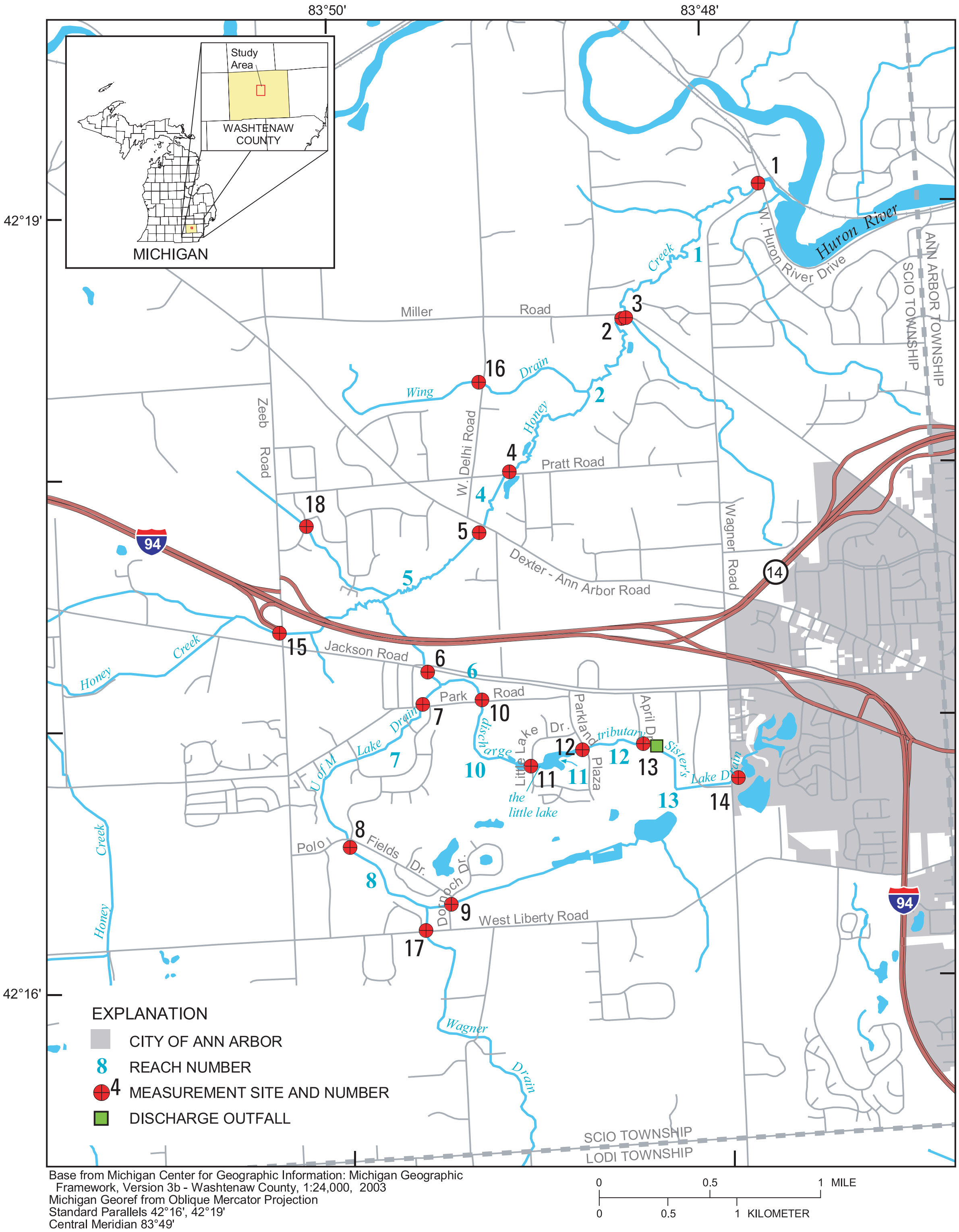

Figure 1. The Honey Creek study area, Washtenaw County, Michigan.

Figure 2. Culvert, riprap, and drain downstream from the intersection of Zeeb Road and Honey Creek (site 15), Washtenaw County, Mich., July 29, 2003.

seepage runs were made during good weather when there was no wet atmospheric input into the watershed. From potential evapotranspiration values published on the World Wide Web by Michigan Automated Weather Network (Michigan State University, 2003), estimated instream evapotranspiration in the time between upstream and downstream measurements was estimated as two or more orders of magnitude less than the streamflow in Honey Creek, and therefore was considered negligible for gain-loss computations.

Streamflow measurements were made during periods of base flow to avoid transient flows from bank storage or time-lagged infiltration from storms. Base-flow conditions were identified by examining hydrographs for the nearby streamflow-gaging stations USGS 04173500, Mill Creek near Dexter, Mich., and USGS 04174518, Malletts Creek at Ann Arbor, Mich. (U.S. Geological Survey, 2003). The hydrologic response of the suburban Honey Creek basin was assumed to be intermediate between that of the urban Malletts Creek basin and the more agricultural Mill Creek basin.

During seepage runs, streamflow measurements were made at 17 or 18 sites (fig. 1, table 1). Depending on flow conditions and measurement cross sections, measurements were made with a Price AA meter, Price pygmy meter, acoustic Doppler velocimeter (ADV), or portable Parshall flume. Standard USGS methods, as described in detail in Rantz and others (1982) and the ADV operations manual (SonTek, 2003) were used to make measurements and compute the streamflows.

Seepage runs were made on June 18, August 20, and September 10, 2003. Attempts at seepage runs were made on July 16 and July 29 when the pump and treat system was shut down for maintenance, but field observations showed that the lower flows were not in equilibrium with bank storage and with instream storage in the ponds and wetlands along the stream.

To determine whether a reach was gaining or losing, the percentage difference between the sum of the upstream measurements and the downstream measurement was computed by dividing the difference between the measurements by their average then multiplying by 100. Previous studies have shown that the standard deviation of consecutive measurements is approximately 2.2 percent (Rantz and others, 1982). To account for this possible measurement error, a percentage difference at which there was a 95 percent probability that the measured streamflows were different was computed. For the 2.2-percent standard deviation, this 95 percent probability percentage difference was 4.3 percent. To be more conservative, this figure was rounded up to 5 percent for this study. Any computed percentage difference between the upstream and downstream measurements greater than 5 percent was considered a real gain or loss and for the purposes of this report, hereafter called a significant gain or loss.

When streamflow is low, small differences in the measurements may produce large percentage differences. To compensate for this, it was decided that the average streamflow of the upstream and downstream sites had to exceed 0.5 ft^3/s before the greater than 5-percent gain or loss would be considered significant.

Because the treatment discharge was much larger than the streamflow at site 14, fluctuations in this discharge could have masked any loss or gain in this reach. For this

Figure 3. Bridge at site 4, Honey Creek at Pratt Rd near Ann Arbor, Mich., on September 10, 2003.

Table 1. Honey Creek study sites, Washtenaw County, Mich.
[°, degrees; ′, minutes; ″, seconds; --, piezometer not installed at site]

Site number	USGS identi-fication number	[1]USGS site name	Latitude	Longitude	Depth to center of well screen from stream-bed (feet)
1	04174310	Honey Creek at Huron River Drive	42° 19′ 04.7″	-83° 47′ 44.2″	3.07
2	04174300	Honey Creek at Miller Rd near Foster, Mich.	42°18′ 33.6″	-83° 48′ 28.5″	2.86
3	04174299	Honey Creek trib at Miller Rd	42° 18′ 34.0″	-83° 48′ 27.5″	2.55
4	041742955	Honey Creek at Pratt Rd	42° 17′ 58.4″	-83° 49′ 05.3″	2.85
5	04174295	Honey Creek at Dexter-Ann Arbor Rd near Scio, Mich.	42° 17′ 44.3″	-83° 49′ 15.7″	3.38
6	04174293	Honey Creek trib at Jackson Rd	42° 17′ 11.3″	-83° 49′ 33.4″	2.65
7	041742914	U of M Lake Drain at Park Rd	42° 17′ 04.4″	-83° 49′ 34.6″	2.95
8	041742912	U of M Lake Drain at Polo Fields Dr	42° 16′ 31.6″	-83° 49′ 59.2″	2.73
9	041742907	U of M Lake Drain at Dornoch Dr	42° 16′ 16.7″	-83° 49′ 27.6″	4.36
10	041742926	Honey Creek trib at Park Rd – instream piezometer	42° 17′ 04.9″	-83° 49′ 16.3″	5.31
		[2]bank piezometer			5.19
11	041742924	Honey Creek trib at Little Lake Rd	42° 16′ 49.2″	-83° 49′ 01.2″	2.67
12	041742922	Honey Creek trib at Parkland Plaza Rd	42° 16′ 52.5″	-83° 48′ 44.6″	3.63
13	04174292	Honey Creek trib at April Rd – shallow piezometer	42° 16′ 53.5″	-83° 48′ 25.3″	3.28
		[3]mid-level piezometer			5.75
		[3]deep piezometer			8.31
		[3]bank piezometer			4.39
14	041742916	Sister's Lake Drain at Dolph Park	42° 16′ 45.2″	-83° 47′ 55.6″	4.65
15	04174288	Honey Creek at Zeeb Rd	42° 17′ 21.5″	-83° 50′ 20.8″	3.08
16	041742965	Wing Drain at West Delhi Rd	42° 18′ 19.8″	-83° 49′ 13.7″	2.60
17	04174291	Wagner Drain at Liberty Rd	42° 16′ 11.0″	-83° 49′ 35.5″	--
18	04174294	Honey Creek trib at Stonegate Rd	42° 17′ 47.0″	-83° 50′ 10.8″	--

[1] All site names in their official form conclude with "near Ann Arbor, Mich.", unless otherwise noted.
[2] The depth of the center of the well screen below the streambed is calculated from the streambed elevation at the instream piezometer.
[3] The depth of the center of the well screen below the streambed is calculated from the streambed elevation at the shallow instream piezometer.

reason, no estimate was made as to whether the reach between sites 14 and 13 was losing or gaining.

The equations used to compute the change in streamflow in the reach upstream from specific sites are presented in table 2. For the remainder of this report, reaches will be referred to by the site number of the site at the downstream end of the reach; for example, reach 1 is bounded by site 1 downstream and sites 2 and 3 upstream (table 2).

Piezometer measurements

The piezometers used for this study were small-diameter wells with 0.5 ft well-screen openings backed by 80 gauze (approximately 0.007 inch opening) wire mesh. The piezometers were made from 11/4-in.-diameter well drive points and steel pipe. Water levels in the piezometers and the stream surface level were measured with a steel or electric tape measure from a designated reference point on the top of the piezometer. At sites 10 and 13, the two sites where there were multiple

Table 2. Equations used to compute streamflow differences in study reaches in Washtenaw County, Mich.
[Q number, measured streamflow at site (number)]

Reach upstream from site	Reach designation	Equation
1	1	$Q_1 - Q_2 - Q_3$
2	2	$Q_2 - Q_{16} - Q_4$
4	4	$Q_4 - Q_5$
5	5	$Q_5 - Q_6 - Q_{15} - Q_{18}$
		$Q_5 - Q_7 - Q_{10} - Q_{15} - Q_{18}$ (August 20, 2003)
6	6	$Q_6 - Q_7 - Q_{10}$
7	7	$Q_7 - Q_8$
8	8	$Q_8 - Q_9 - Q_{17}$
10	10	$Q_{10} - Q_{11}$
11	11	$Q_{11} - Q_{12}$
12	12	$Q_{12} - Q_{13}$

piezometers, the difference in the elevations of the top of piezometers were surveyed, and all water-level measurements were referenced to the top of shallow-depth instream piezometer.

Piezometers were installed at sites 1 through 16 by manually forcing the piezometer into the streambed to the point of resistance, which was the level where a relatively large increase in force was required to drive the piezometer deeper. The depth of the center of the well screen below the streambed for each piezometer is given in table 1. For sites 10 and 13, this depth was referenced to the streambed at the shallow-depth instream piezometer.

Piezometer data were collected on July 25, August 20, September 10, and October 10, 2003. Additional piezometer data were collected on July 10 and during attempted seepage runs on July 16 and July 29. On these dates the pump and treat system was shut down and the flow system was not in equilibrium with bank and instream storage. Piezometer data were collected during the seepage run of June 18; however, quality-control concerns about the methods and equipment used during this run make the validity of these data questionable. These data are not used or presented in this report. The piezometer at site 16 was measured only on June 18; this piezometer was pulled on September 4 to be installed at another site.

Two additional instream piezometers were installed at site 13 on September 4 to collect more data on the ground-water/surface-water relations at that site. Additional piezometer data were collected for site 13 on September 8, 17, and 30.

Hydraulic head

The difference in water levels measured in a stream and in a piezometer in or near the stream will indicate the ground-water-flow potential (Freeze and Cherry, 1979). The water level relative to an arbitrary datum is referred to as the hydraulic head (referred to herein as “head”) at that point. The head reflects the energy of the water due to elevation and pressure. The reference point for each site was arbitrarily set at an elevation of 20 ft. The head for each water level was calculated as 20 ft minus the tape measurement. For sites 10 and 13, the heads presented in this report were adjusted to the reference points of the shallow instream piezometers. Head measurements at one site have no relation to head measurements at other sites because the reference points at the different sites were not surveyed to the same datum.

The ground-water-flow potential or head difference was computed by subtracting the head measured at the stream surface from the head of the shallow aquifer measured in the piezometer. A positive difference (shallow aquifer head higher than the stream head) indicates a pressure gradient towards the stream; a negative difference (shallow aquifer head lower than the stream head) indicates a pressure gradient away from the stream. Tape reading accuracy was ± 0.01 ft. Stream-surface levels were estimated during many measurements because of the surface oscillations that are caused by nonlaminar flow. Many of the piezometers were at slight angles. Because of these uncertainties, a conservative ± 0.05 ft was used for this project to determine whether the measured head difference indicated a positive (head difference ≥ 0.05 ft), negative (head difference ≤ -0.05 ft), or neutral (-0.05 ft< head difference < 0.05 ft) flow potential.

Specific conductance and water temperature

Conductance is a measure of the ability of a solution to conduct electricity and is reported in microsiemens per centimeter (µS/cm). Pure water has low conductance. As ion concentrations increase, conductance of the solution increases; therefore, the conductance measurement provides an indication of ion concentration (Hem, 1985). Because conductance is temperature-dependent, a reference measurement, specific conductance, is used to compare the conductance of solutions at different temperatures. Specific conductance is the conductance corrected to 25 °C.

For this study, specific conductance and water temperature were measured in the piezometer and in the stream near the piezometer at each site according to procedures detailed in Wilde and Radtke (1998). At sites 10 and 13, measurements were made in each piezometer and in the stream. A combination probe was lowered to the bottom of the piezometer and raised a few inches from the bottom so the probe was in the open-screen section of the piezometer. The probe was allowed to stabilize for both temperature and conductance before the readings were recorded. The accuracy of the specific conductance measurements was ± 2 percent. The accuracy of the water temperature measurements was 0.5 °C, and they were rounded to the nearest 0.5 °C.

Data from these measurements cannot be used directly to show the movement of the ground water; instead, the data were used to support or not support the interpretation of the head potential. Because the specific conductance of the treatment discharge was much higher than the ground-water specific conductance, the measurement from the piezometer and the stream were compared for magnitude of difference. A large difference suggested no interaction between the ground water and surface water or that ground water was flowing toward and discharging to the stream. A decrease in the difference suggested interaction between the ground water and surface water: the less the difference, the stronger the interaction. The decrease in the difference, however, may also be due to increased conductance in the ground water.

Water-temperature data were used as ancillary data to assist in the interpretation of the head measurements. The difference between the water temperature measured in the piezometer and in the stream at each site was compared in a similar manner as the specific conductance data. Temperature relations between the ground water and surface water, however, are more complex than that for specific conductance. During the late summer and early fall, there may be large diurnal fluctuations in stream-water temperature. The magnitude of water temperatures measured in the piezometer and stream may be close in the morning and very different in the afternoon. If the area around the piezometer is a losing reach, then the diurnal fluctuation may also be observed in the ground-water temperature measurements, but the peak may be muted and time lagged.

The ground-water temperatures were also examined for continuity over the period of the study. Measured temperatures showing little or no change during the study would indicate little or no interaction between the ground water and stream. Continuity of water temperature, however, is not proof that ground water is flowing towards the stream. For example, there may be no interaction if the stream and ground water are flowing along parallel streamlines.

GROUND-WATER/SURFACE-WATER RELATIONS

Seepage runs give data on a regional scale in that they give an average for an entire reach (Dumouchelle, 2001). Head measurements indicate ground-water-flow potential near the piezometer. The data from the different methods will be presented individually.

Seepage runs

Streamflow measurements for the 18 sites and the magnitude and percentage difference in the reaches above the sites (as determined from the equations in table 2) for the seepage runs on June 18, August 20, and September 10 are presented in table 3. Streamflow measurements made on July 16 and July 29 are presented in appendix Table 1-1.

In table 3, both the magnitude and percentage difference of the change can be observed. Over the three seepage runs, losing reaches were found a total of seven times in reaches 1, 4, 8, and 10. Four of the seven losing reaches met the criteria to be considered a significant losing reach: reach 1 on August 20, reach 4 on June 18, and reach 10 on August 20 and September 10. Over the three seepage runs, gaining reaches were found a total of 19 times in reaches 2, 4, 5, 6, 7, 10, 11, and 12. Of the 19 gaining reaches, 11 met the criteria to be considered a significant gaining reach: reach 2 on June 18 and August 20; reach 5 on June 18, August 20, and September 10; reach 6 on June 18 and September 10; reach 10 on June 18; reach 11 on August 20 and September 10; and reach 12 on August 20. Reach 10 was the only reach to show both a significant loss (August 20) and a significant gain (June 18). The significant losing and gaining reaches for each seepage run are shown on figure 4.

In addition to the individual reaches discussed above, the following reaches were examined for loss or gain: 1) between sites 13 and 10 on the discharge tributary and 2) between sites 3, 5, and 16 and site 1 on the main stem. The percentage difference for both reaches was computed by use of the streamflows presented in table 3. The magnitude of the streamflow

Table 3. Streamflow measurements with magnitude and percent difference between sites in Washtenaw County, Mich.
[--, no data; % percentage]

	June 18, 2003			August 20, 2003			September 10, 2003		
	Streamflow	[1]Difference		Streamflow	[1]Difference		Streamflow	[1]Difference	
Site	ft^3/s	ft^3/s	[2]%	ft^3/s	ft^3/s	[2]%	ft^3/s	ft^3/s	[2]%
1	[3]7.29	-0.09	-0.3	7.27	-0.49	-6.5	5.85	.00	0.0
2	7.33	.71	10	7.72	0.71	9.6	5.83	.23	4.0
3	.05	υ	υ	.04	υ	υ	<.02	υ	υ
4	[3]6.57	-.77	-11	7.01	-0.11	-1.6	5.60	.11	2.0
5	[3]7.34	2.37	38	7.12	1.88	30	5.49	.70	14
6	[3]3.42	.43	13	--	--	--	3.10	.58	21
7	0.19	.12	46	.06	.06	200	.04	.04	200
8	0.07	.00	.0	.00	.00	.0	.00	-.02	-200
9	0.07	υ	υ	.00	υ	υ	<.02	υ	υ
10	2.80	.34	13	3.12	-1.22	-33	2.48	-.57	-21
11	[3]2.46	.07	2.9	4.34	.69	17	3.05	.26	8.9
12	2.39	.09	3.8	3.65	.63	19	2.79	.03	1.1
13	[3]2.30	[4]τ	[4]τ	3.02	[4]τ	[4]τ	2.76	[4]τ	[4]τ
14	0.11	υ	υ	.79	υ	υ	.18	υ	υ
15	1.55	υ	υ	2.06	υ	υ	1.69	υ	υ
16	0.05	υ	υ	.00	υ	υ	.00	υ	υ
17	0.00	υ	υ	.00	υ	υ	.00	υ	υ
18	--	--	--	<.1	υ	υ	<.03	υ	υ

[1] Difference is measured with respect to the upstream-site streamflow as determined from equations in table 2. Negative difference denotes a loss of streamflow; positive difference denotes a gain in streamflow.
[2] The percentage difference is the difference between the upstream and downstream measurements as determined from equations in talbe 2, divided by the average of the upstream and downstream measurements and multiplied by 100.
[3] Value is an average of two or more individual streamflow measurements.
[4] No estimate for this reach is computed because the treatment discharge was much larger than the streamflow at site 14, and fluctuations in this discharge could mask any loss or gain in this reach

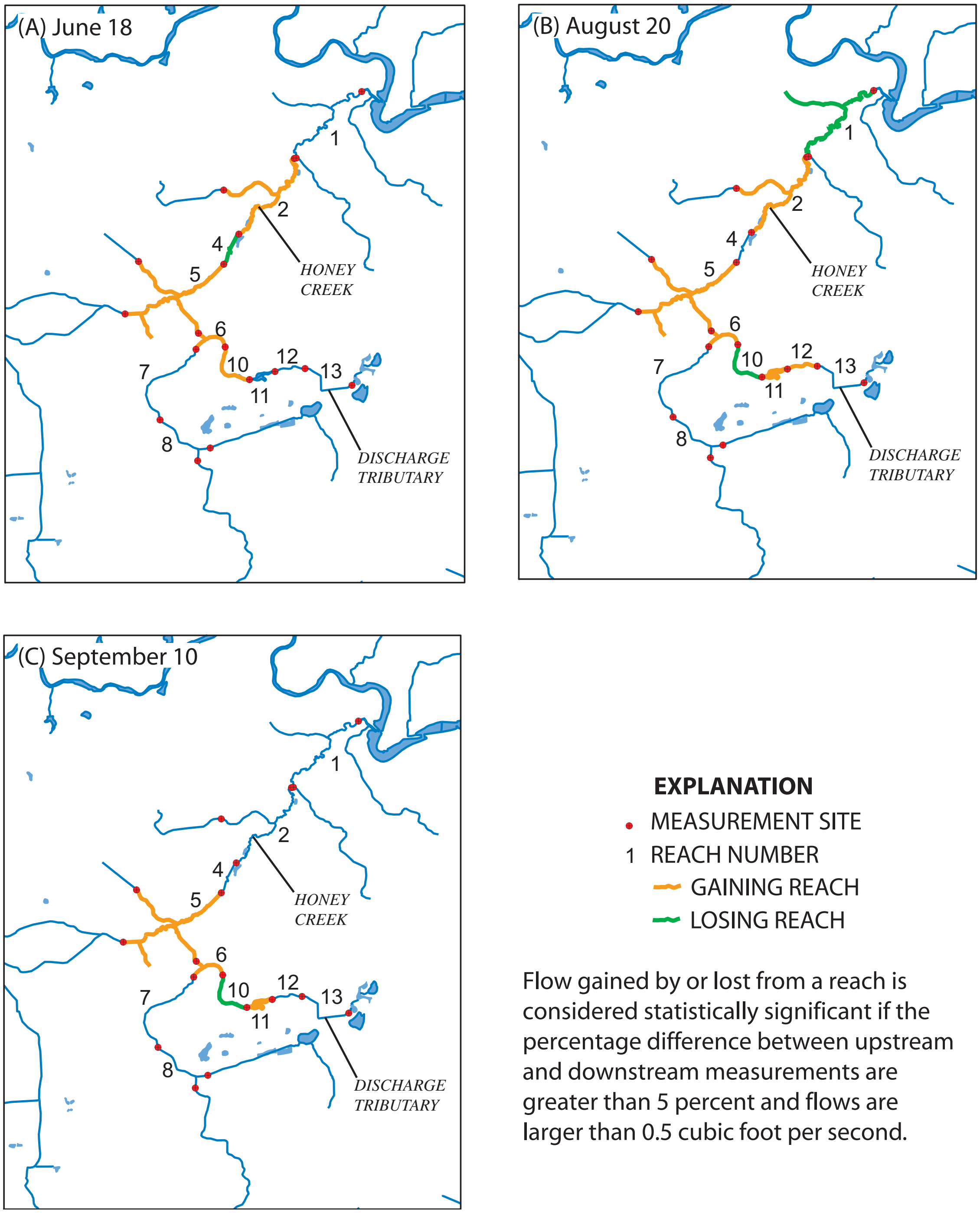

Figure 4. Reaches of Honey Creek with statistically significant streamflow gain or loss as measured during seepage runs (A) June 18, (B) August 20, and (C) September 10, 2003, Honey Creek, Washtenaw County, Mich. (See fig. 1 for locations of measurement sites.)

difference and the percentage difference for the reach between sites 13 and 10 on the discharge tributary on June 18 were 0.50 ft^3/s and 20 percent, on August 20 were 0.10 ft^3/s and 3.2 percent, and on September 10 were –0.28 ft^3/s and -10.7 percent. For the three runs, one showed a significant gain; the second, no significant difference; and the third, a significant loss. The magnitude of the streamflow difference and percentage difference between sites 3, 5, and 16 and site 1 on June 18 were -0.15 ft^3/s and -2.0 percent, on August 20 were 0.11 ft^3/s and 1.5 percent, and on September 10 were 0.34 ft^3/s and 6.0 percent. For the three runs, two showed no significant difference and the third, a significant gain.

Piezometer measurements

The head, specific-conductance, and water-temperature data measured at each piezometer and corresponding stream location, and the magnitude of the head difference between the stream and shallow aquifer are listed in table 4. The head, specific-conductance, and water-temperature data and the magnitude of the head difference measured at the four piezometers at site 13 in September and October are listed in table 5. The head, specific conductance, and water temperature data measured on July 10, July 16, and July 29 are presented in appendix Table 1-2.

Head difference

Head difference is the difference between the heads measured in the stream and shallow aquifer and is measured with respect to the stream level. A positive head difference indicates flow potential towards the stream; a negative head difference indicates flow potential away from the stream.

Head differences at the Honey Creek main stem sites 1, 2, 4, 5, and 15 and tributary sites 7 and 14 showed a positive or neutral flow potential for all measurements. Head differences at the discharge tributary sites 10, 11, 12, and 13, including the bank piezometers at sites 10 and 13, showed a negative or neutral flow potential for all measurements. Head differences at tributary site 3 and discharge tributary site 6 showed negative flow potentials on July 25, positive flow potentials on August 20 and September 10, and neutral flow potentials on October 10. Head differences at tributary site 9 showed negative flow potential on August 20, positive flow potential on July 25 and October 10, and a neutral flow potential on September 10. The U of M Lake Drain at site 8 was dry three of the four measurement dates. On October 10, head difference measured at site 8 showed a negative flow potential.

Head-difference measurements at site 4 seem more strongly positive than what would be expected because reach 4 was a significantly losing reach on June 18 and showed no significant change on August 20 and September 10. This strong positive flow potential may be due to shallow ground-water flow from a small pond on the east bank of Honey Creek just upstream from site 4, or the site may be in an area where the hyporheic zone is discharging to the stream, or a combination of the two factors may be the cause. In any case, it is a good example of how local area head-difference measurements differ from reach-averaged seepage-run results.

The head differences of –0.52 ft at the discharge tributary site 6 on July 26 and of –0.46 ft at the U of M Lake Drain site 8 on October 10 may be due to anthropogenic influences. The site 6 head difference may be the result of a misread tape, but this cannot be verified; therefore, the head difference is reported in table 4 as it was recorded on the field notes. The streamflow observed at site 8 on October 10 appeared much larger than the observed streamflow at either site 7 or site 9, the sites downstream and upstream from site 8 on the U of M Lake Drain. It is likely that the anomalously high streamflow observed at site 8 was due to a short-duration discharge from a well or fire hydrant to reach 8 or the Wagner Drain.

The magnitudes of the four significantly negative head differences measured at site 11 were the largest measured during the study. Only site 7 had a significantly positive head difference of the same magnitude. Site 11 is between the little lake and the settling pond on the discharge tributary, and the strong negative head difference may be an artifact of the piezometer location. The water levels in the little lake and the settling pond had an elevation difference of at least 3 ft. The discharge tributary leaves the little lake through a culvert under Little Lake Road and discharges back to the streambed about 20 ft upstream from the piezometer location. The culvert keeps the stream at about the same elevation as the little lake at its discharge point, but ground-water levels develop a natural gradient between the little lake and the settling pond. At site 11, water is flowing from the stream to the hyporheic zone.

Five measurements of head, specific conductance, and water-temperature were made at discharge tributary site 13 after the installation of the mid-level and deep piezometers (table 5). Two of the measurements were part of piezometer measurement runs on September 10 and October 10. The other three runs were made only to measure this piezometer nest. Head differences for the shallow piezometer showed a small positive flow potential on September 8 (0.05 ft) and neutral flow potentials on the other four measurement days. Head differences for the mid-level, deep, and bank piezometers showed negative potential on all measurement days.

Overall head-potential measurements at site 13 during September and October showed a strong negative potential away from the discharge tributary (table 5). Between the mid-level and deep piezometers, the negative head potential exceeded more than 4.4 ft on all five measurement runs. From the resistance met during the driving of the piezometers, there appears to be a cohesive layer beneath this reach of the discharge tributary channel. This layer may be isolating this section of the discharge tributary from the deeper ground-water system. The strong negative potential may mean that the deep piezometer penetrated a sand layer with a higher hydraulic conductivity than shallower layers or that there is drawdown in this area from nearby pumping wells. However, the reason for

Table 4. Head, specific-conductance, and water-temperature measurements from sites 1 – 15 with head difference the between stream and the shallow aquifer, 2003, Washtenaw County, Mich.

[--, no data]

Site	Date	Head (feet)			Specific conductance (microsiemens per centimeter)		Water temperature (degrees Celsius)	
		Stream	Shallow aquifer	Difference[1]	Stream	Shallow aquifer	Stream	Shallow aquifer
1	25-Jul	--	--	--	--	--	--	--
	20-Aug	17.10	17.15	0.05	1,222	320	20.5	16.5
	10-Sep	17.03	17.09	.06	1,330	422	17.5	15.5
	10-Oct	17.06	17.02	-.04	1,441	402	14.5	12.5
2	25-Jul	19.50	19.50	.00	1,447	818	22.0	14.5
	20-Aug	19.57	19.70	.13	1,222	995	21.0	15.0
	10-Sep	19.52	19.63	.11	1,330	812	18.5	14.5
	10-Oct	19.49	19.62	.13	1,450	1,003	15.0	13.0
3	25-Jul	19.00	18.92	-.08	1,085	671	21.5	15.5
	20-Aug	19.01	19.09	.08	1,145	1,442	22.0	16.0
	10-Sep	18.99	19.06	.07	1,127	1,237	18.5	15.5
	10-Oct	19.08	19.12	.04	1,229	1,214	14.0	12.0
4	25-Jul	--	--	--	--	--	--	--
	20-Aug	19.11	19.74	.63	1,224	809	20.5	17.0
	10-Sep	19.09	19.62	.53	1,343	981	18.5	16.0
	10-Oct	19.07	19.75	.68	1,512	1,003	15.5	13.0
5	25-Jul	18.45	18.80	.35	1,480	1,366	22.0	10.5
	20-Aug	18.69	19.05	.36	1,226	1,142	20.5	10.5
	10-Sep	18.59	18.93	.34	1,350	1,458	18.5	10.5
	10-Oct	18.51	18.91	.40	1,531	1,445	16.0	10.5
6	25-Jul	17.64	17.12	-.52	1,772	690	22.0	18.0
	20-Aug	17.66	17.71	.05	1,395	578	22.0	19.5
	10-Sep	17.60	17.67	.07	1,649	487	20.0	18.0
	10-Oct	17.64	17.61	-.03	1,739	361	15.5	14.0
7	25-Jul	17.86	18.46	.60	830	809	15.5	15.0
	20-Aug	17.91	18.72	.81	788	813	17.0	16.0
	10-Sep	17.90	18.68	.78	828	828	15.0	16.0
	10-Oct	17.94	18.59	.65	898	784	14.0	13.5
8	25-Jul	--	--	--	--	566	--	17.0
	20-Aug	--	17.18	--	--	629	--	18.5
	10-Sep	--	17.05	--	--	552	--	18.0
	10-Oct	17.28	16.92	-.46	497	632	14.5	14.5
9	25-Jul	18.20	18.34	.14	1,185	334	18.5	13.5
	20-Aug	18.99	18.84	-.15	849	333	17.5	14.0
	10-Sep	18.94	18.97	.03	782	268	16.0	14.0
	10-Oct	18.98	19.06	.08	863	240	11.0	12.0
10 stream	25-Jul	19.24	19.07	-.17	1,804	794	22.0	17.5
	20-Aug	19.22	19.17	-.05	1,420	717	21.5	18.5
	10-Sep	19.25	19.03	-.22	1,679	722	19.5	16.5
	10-Oct	19.14	19.04	-.10	1,785	656	15.0	14.5
10 bank	25-Jul	19.24	19.06	-.18	1,804	750	22.0	15.0
	20-Aug	19.22	19.20	-.02	1,420	654	21.5	16.0
	10-Sep	19.25	19.07	-.18	1,679	695	19.5	16.0
	10-Oct	19.14	18.98	-.16	1,785	767	15.0	14.5
11	25-Jul	18.19	17.27	-.92	1,806	1,737	20.0	20.5
	20-Aug	18.43	17.56	-.87	1,466	1,345	20.5	21.0
	10-Sep	18.22	17.41	-.81	1,717	1,240	18.5	19.0
	10-Oct	18.23	17.37	-.86	1,807	1,462	15.0	14.0
12	25-Jul	19.16	19.00	-.16	1,920	1,577	16.0	16.0
	20-Aug	19.17	19.05	-.12	1,605	1,325	16.5	17.5
	10-Sep	19.09	19.03	-.06	1,801	1,612	15.0	16.5
	10-Oct	19.17	19.04	-.13	1,789	1,041	14.0	14.0
13 stream	25-Jul	18.46	18.46	.00	1,916	1,703	16.0	15.0
	20-Aug	18.61	18.54	-.07	1,598	1,877	17.0	16.0
	10-Sep	18.50	18.54	.04	1,798	1,931	15.0	15.5
	10-Oct	18.48	18.45	-.03	1,794	1,872	14.0	14.0
13 bank	25-Jul	18.46	18.31	-.15	1,916	1,595	16.0	15.5
	20-Aug	18.61	18.39	-.22	1,598	1,593	17.0	16.5
	10-Sep	18.50	18.39	-.11	1,798	1,592	15.0	16.0
	10-Oct	18.48	18.30	-.18	1,794	1,496	14.0	13.5
14	25-Jul	19.16	19.21	.05	980	938	22.0	18.5
	20-Aug	19.38	19.60	.22	737	955	22.0	19.5
	10-Sep	19.29	19.42	.13	768	969	19.0	19.0
	10-Oct	19.33	19.47	.14	765	981	14.5	15.0
15	25-Jul	18.65	19.17	.52	1,034	685	22.5	17.5
	20-Aug	18.70	18.98	.28	967	314	17.0	14.5
	10-Sep	18.71	18.70	-.01	1,010	807	15.5	14.5
	10-Oct	18.59	18.55	-.04	1,085	593	15.5	13.0

[1] The difference in head is measured with respect to the stream level. A negative head difference indicates flow potential away from the stream; a positive head difference indicates flow potential towards the stream.

Table 5. Head, specific conductance, and water-temperature measurements at site 13 with head difference between the stream and shallow aquifer during September and October 2003, Washtenaw County, Mich.
[--, no data]

Piezometer	Date	Head (feet)			Specific Conductance (microsiemens per centimeter)		Water temperature (degrees Celsius)	
		Stream	Piezometer	[1]Difference	Stream	Piezometer	Stream	Piezometer
Shallow	8-Sep	18.49	18.54	0.05	1,600	1,745	16.0	16.0
	10-Sep	18.50	18.54	.04	1,798	1,931	15.0	15.5
	17-Sep	18.46	18.49	.03	--	--	--	--
	30-Sep	18.55	18.54	-.01	--	--	--	--
	10-Oct	18.48	18.45	-.03	1,794	1,872	14.0	14.0
Mid-level	8-Sep	18.49	18.38	-.11	1,600	1,570	16.0	15.0
	10-Sep	18.50	18.27	-.23	1,798	1,894	15.0	15.5
	17-Sep	18.46	18.29	-.17	--	--	--	--
	30-Sep	18.55	18.10	-.45	--	--	--	--
	10-Oct	18.48	17.80	-.68	1,794	1,900	14.0	14.0
Deep	8-Sep	18.49	13.13	-5.36	1,600	1,092	16.0	14.0
	10-Sep	18.50	12.93	-5.57	1,798	1,299	15.0	14.0
	17-Sep	18.46	13.24	-5.22	--	--	--	--
	30-Sep	18.55	13.57	-4.98	--	--	--	--
	10-Oct	18.48	13.39	-5.09	1,794	508	14.0	13.5
Bank	8-Sep	18.49	18.38	-.11	1,600	1,315	16.0	16.0
	10-Sep	18.50	18.39	-.11	1,798	1,592	15.0	16.0
	17-Sep	18.46	18.32	-.14	--	--	--	--
	30-Sep	18.55	--	--	--	--	--	--
	10-Oct	18.48	18.30	-.18	1,794	1,496	14.0	13.5

[1] The difference in head is measured with respect to the stream level. A negative head difference indicates flow potential away from the stream; a positive head difference indicates flow potential towards the stream.

this large head potential is unknown.

Specific conductance and water temperature

If continuous specific conductance and water-temperature data had been collected, the continuity of the data would enable inferences to be made about the relation between the ground water and the stream water. The discrete samples collected do not show these relations but can be used as ancillary data to help in the interpretation of the head data.

Specific conductance values in the shallow aquifer at sites 1, 6, and 10 were 703 to 1,378 µS/cm less than the comparable specific conductance values in the stream at these sites (table 4). The relatively large magnitude of the difference in specific conductance implies little or no outflow of stream water to the shallow aquifer at these sites.

Specific conductance values in the shallow aquifer at sites 2 and 4 were 227 to 629 µS/cm less than the comparable specific conductance values in the stream at these sites (table 4). This difference is smaller in magnitude than the differences measured at sites 1, 6, and 10 and may indicate more interaction between the stream and the shallow aquifer.

Specific conductance values in the shallow aquifer at sites 5, 11, 12, and 13 showed differences from the comparable stream measurements that ranged from -279 to 748 µS/cm (table 4). The magnitude of the specific conductance values in the shallow aquifer (1,041-1,931 µS/cm) at these sites indicates that there may be a high degree of interaction between the stream and the shallow aquifer. However, it is possible that the ground water at these sites had a specific conductance near that of the stream and that ground-water flow was towards the stream.

The difference between ground-water temperature measured in the piezometers and the corresponding stream-water temperature varied from -11.5 to 1.5 °C. However, because of the diurnal fluctuation in stream-water temperature and possibly in ground-water temperature at some sites, the magnitude of this difference by itself does not give any information about the interaction between ground water and stream water.

The ground-water temperature measured at site 4 was 10.5 °C for all four measurements (table 4). These were the four lowest temperature measurements made during the study. Although not conclusive in itself, the consistency of these measurements indicates that there was no ground-water/surface-water interaction at the piezometer depth.

Additional data were collected at site 13 after the installation of the mid-level and deep piezometers. These data showed decreasing specific conductance and water temperature with depth on September 8 and 10 (table 5). On October 10, specific conductance increased from the shallow to the mid-level piezometer; the increase was slight and within the measurement error of the instrument. Specific conductance decreased by 1,392 µS/cm from the mid-level to the deep piezometer, indicating that the bottom of the zone receiving stream infiltration was above the piezometer depth.

At site 13, ground-water measurements on September 8 showed a negative temperature gradient from the shallow to the deep piezometer (table 5). On September 10 and October 10, ground-water temperatures in the shallow and mid-level piezometers were the same, then decreased to the deep piezometer.

COMPARISON OF RESULTS OF SEEPAGE RUNS AND PIEZOMETER MEASUREMENTS

Two primary methods, seepage runs and head difference between the stream and shallow aquifer were used to examine the ground-water/surface-water relations along Honey Creek and the discharge tributary. Seepage runs give average loss or gain for a reach but cannot describe the heterogeneity of the loss or gain over that reach. The head measurements give site-specific data that cannot be extrapolated to other areas in the reach. For the most part on the main stem, the two methods gave confirming results, whereas on the discharge tributary, the two methods gave both confirming and varying results.

The seepage runs show that the main stem of Honey Creek downstream from site 15 was an overall gaining stream. For the three runs, the increase from the combined streamflow of sites 3, 6 (7 and 10 on August 20), 15, 16, and 18 to the streamflow at site 1 was 36 percent on June 18, 31 percent on August 20, and 19 percent on September 10.

Smaller reaches within this larger reach showed variability in the relation between the stream and shallow aquifer. The statistically significant differences in streamflow indicate that reach 5 was a gaining reach on all three runs, reach 2 was a gaining reach on two of the three runs, and reaches 1 and 4 were each a losing reach on one of the runs (fig. 4).

Head differences between the stream and shallow aquifer at sites on the main stem of Honey Creek were mostly significantly positive; no significant negative head difference was measured at any of the main stem sites. These measurements support the seepage-run result that the main stem was overall a gaining stream. The consistency of the piezometer water-temperature measurements at site 5 supports the head-difference indication at that site that ground water was flowing towards the creek. The specific-conductance measurements at site 1 indicate little or no interaction between the stream and shallow aquifer at the depth the measurements were made.

Results of the seepage runs on the discharge tributary were mixed. The discharge tributary between sites 13 and 10 had a significant gain in streamflow of 20 percent on June 18, an insignificant change in streamflow of 3.2 percent on August 20, and a significant loss in streamflow of -11 percent on September 10. Site 6 was not measured during the August 20 seepage run. The discharge tributary between sites 13 and 6 had significant gains in streamflow of 39 percent on June 18 and 12 percent on September 10. Reach 10 was the only reach on the discharge tributary to have significant losses, a loss of -33 percent on August 20 and a loss of -21 percent on September 10 (fig. 4, table 3), whereas this reach had a significant gain of 13 percent during the June 18 seepage run. These measurements demonstrate the temporal variability of ground-water/surface-water relations by showing that under different hydrologic conditions, a reach may be losing or gaining. It was noted, however, that during the June 18 seepage run, the streamflow measurement for site 10 was made upstream from Park Road, whereas during the August 20 and September 10 seepage runs, the streamflow measurements for site 10 were made downstream from Park Road. It is, therefore, possible that the measurements showed a substantial loss of streamflow to the hyporheic zone because of the restriction at the Park Road culvert.

The head differences between the stream and shallow aquifer at sites along the discharge tributary vary in their support of the seepage-run results. The head differences measured at site 6 on August 20 and September 10 were significantly positive, supporting the seepage-run results of a gaining reach. The head differences measured at site 10 for the instream piezometers were significantly negative, supporting the seepage-run results of a losing reach. The head difference measured at the bank piezometer was nonsignificant on August 20 and significantly negative on September 10. Head-difference measurements at site 12 and at both piezometers at site 13 were significantly negative on August 20, in contrast to the seepage-run result that reach 12 was a gaining reach.

The ancillary specific-conductance and water-temperature measurements from sites on the discharge tributary also showed mixed agreement with the seepage-run results. Specific-conductance measurements at sites 6 and 10 indicated little mixing of stream water and ground water at the piezometer depth. This supports the seepage-run results for reach 6 but conflicts with the losing-reach results for reach 10. Specific-conductance measurements at sites 12 and 13 on August 20 indicated mixed water that was predominantly surface water at the piezometer depth. This seems to conflict with the seepage-run result that reach 12 was gaining; however, reach 12 may have been gaining water that had entered the hyporheic zone upstream from site 13.

The overall gain in streamflow along with local measurements of head differences, specific conductance, and water temperature indicated that ground water was discharging to Honey Creek and the discharge tributary. Although reaches and areas that lose streamflow have been identified, it cannot be determined as a result of this study whether the loss is to the regional ground-water system.

SUMMARY AND CONCLUSIONS

The USGS, in cooperation with the city of Ann Arbor, Mich., investigated the ground-water/surface-water relations along Honey Creek during summer and fall 2003. Honey Creek drains a small 23.2-mi^2 basin in Washtenaw County in southeast Michigan. The basin is covered by stratified glacial deposits that range in thickness from approximately 200 ft to 270 ft. Land use/ land cover in the basin is approximately 15 percent urban; 33 percent agriculture; 25 percent upland forest; 17 percent open land; and 10 percent lowlands, wetlands, and water.

Two methods, seepage runs and measurements of the hydraulic-head difference between the stream and shallow aquifer, were used to examine the ground-water/surface-water relations along Honey Creek. Specific-conductance and water-temperature measurements were used as ancillary data to assist in the interpretation of the head measurements. Three seepage runs and four piezometer-measurement runs were made June through October 2003.

Because the seepage runs were made during periods of base flow and no wet atmospheric input, the difference between the sum of upstream streamflow measurements and the downstream streamflow measurement will give the quantity of the ground-water loss or gain. Seepage runs give average loss or gain for a reach but cannot indicate whether loss or gain is uniform over that reach. During seepage runs, streamflow measurements were made at 17 or 18 sites. Standard USGS methods, as described in detail in Rantz and others (1982) were used to make and compute the measurements.

Instream piezometers were installed at sites 1 through 16, bank piezometers were installed at sites 10 and 13, and two deeper instream piezometers were also installed at site 13. The measurements of head, specific conductance, and water temperature made at the piezometer sites are site specific and cannot be extrapolated to other areas in the reach. Head differences were computed by subtracting the stream-surface head from the shallow aquifer head measured in the piezometer. A positive head potential (shallow aquifer head greater than the stream-surface head) indicated flow towards the stream; negative head potential (shallow aquifer head less than stream-surface head) indicated flow away from the stream.

The seepage runs indicated that the main stem of Honey Creek below site 15 and the discharge tributary below site 13 were overall gaining reaches. The seepage runs also indicated that smaller reaches of Honey Creek and the discharge tributary may be losing reaches and that this relation may change over time with changing hydraulic conditions. The piezometer runs support the seepage-run results on the main stem, whereas the piezometer runs both support and conflict with seepage-run measurements on the discharge tributary. Seepage runs give an average for the reach, whereas piezometer head-potential measurements are for a specific area. Data that may appear to be conflicting actually may be showing that within a gaining reach there are localized areas that lose streamflow. Although reaches and areas that lose streamflow have been identified, it cannot be determined as a result of this study whether the loss is to the regional ground-water system.

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Appendix 1. Seepage-run and piezometer-run measurements

Table 1-1. Streamflow measurements for the July 16 and July 29, 2003, seepage runs, Honey Creek, Washtenaw County, Mich.

[ft^3/s, cubic feet per second; --, no data]

Site	July 16 ft^3/s	July 29 ft^3/s
1	--	--
2	--	6.66
3	--	.02
4	--	5.65
5	3.51	6.36
6	1.11	--
7	.03	.02
8	--	.00
9	--	.00
10	.98	--
11	.43	2.63
12	.11	.52
13	.08	.69
14	.08	.04
15	.97	2.67
16	.05	.00
17	.00	.00
18	--	.01

Table 1-2. Head, specific conductance, and water-temperature measurements from the July 10, July 16, and July 29, 2003, piezometer runs, Honey Creek, Washtenaw County, Mich.

[--, no data]

Site	Date	Head (feet)		Specific conductance (microsiemens per centimeter)		Water temperature (degrees Celsius)	
		Stream	Piezometer	Stream	Piezometer	Stream	Piezometer
1	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
2	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
3	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
4	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
5	10-Jul	--	--	--	--	--	--
	16-Jul	18.35	18.80	1,348	1,438	19.0	10.0
	29-Jul	--	--	--	--	--	--
6	10-Jul	--	--	--	--	--	--
	16-Jul	17.44	16.97	1,760	734	19.5	18.5
	29-Jul	--	--	--	--	--	--
7	10-Jul	17.96	18.19	830	809	18.0	15.0
	16-Jul	17.89	18.36	834	812	15.0	14.0
	29-Jul	--	--	--	--	--	--
8	10-Jul	--	--	--	--	--	--
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
9	10-Jul	18.95	17.56	935	390	23.0	12.5
	16-Jul	--	--	--	--	--	--
	29-Jul	--	--	--	--	--	--
10 stream	10-Jul	19.20	19.15	1,670	878	23.5	14.5
	16-Jul	19.03	19.03	1,875	876	21.0	15.0
	29-Jul	--	--	--	--	--	--
10 bank	10-Jul	--	--	--	--	--	--
	16-Jul	19.03	18.95	1,875	818	21.0	15.5
	29-Jul	--	--	--	--	--	--
11	10-Jul	18.07	17.31	1,769	1,604	21.0	21.5
	16-Jul	17.86	16.99	1,876	1,693	20.5	20.5

Table 1-2. Head, specific conductance, and water-temperature measurements from the July 10, July 16, and July 29, 2003, piezometer runs, Honey Creek, Washtenaw County, Mich.--Continued

Site	Date	Head (feet)		Specific conductance (microsiemens per centimeter)		Water temperature (degrees Celsius)	
		Stream	Piezometer	Stream	Piezometer	Stream	Piezometer
	29-Jul	--	--	--	--	--	--
12	10-Jul	18.91	18.98	1,082	1,525	21.0	21.5
	16-Jul	18.64	18.76	1,166	1,548	17.0	16.0
	29-Jul	--	--	--	--	--	--
13 stream	10-Jul	18.20	18.21	1,025	2,035	24.0	14.5
	16-Jul	18.00	17.06	1,048	2,020	17.0	15.0
	29-Jul	18.14	18.15	1,139	2,036	17.5	15.0
13 bank	10-Jul	18.20	18.14	1,025	1,622	24.0	16.0
	16-Jul	18.00	--	1,048	1,617	17.0	15.0
	29-Jul	18.14	18.08	1,139	1,564	17.5	16.0
14	10-Jul	--	--	--	--	--	--
	16-Jul	19.11	19.22	1,047	958	19.0	18.0
	29-Jul	19.11	19.11	924	929	18.5	18.5
15	10-Jul	--	--	--	--	--	--
	16-Jul	18.69	19.20	1,022	661	20.5	17.5
	29-Jul	--	--	--	--	--	--