Channel Gains and Losses in the Opequon Creek Watershed of West Virginia, July 25–28, 2005

By Ronald D. Evaldi and Katherine S. Paybins

Prepared in cooperation with Berkeley County Commission

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Contents

Figure

Table

Conversion Factors and Datums

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	square hectometer (hm^2)
square mile (mi^2)	259.0	square hectometer (hm^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per acre [(gal/d)/acre]	0.000935	cubic meter per day per square hectometer [$(m^3/d)/hm^2$]

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Vertical control information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

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

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

$$°C = (°F-32)/1.8$$

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Abstract

Discharge measurements were made during July 25–28, 2005, in streams and springs and at a wastewater-treatment-plant outfall in the Opequon Creek watershed of West Virginia to describe surface-water resources during low-flow. The greatest spring discharge measured was 6,460 gallons per minute, but 11 of 31 springs inspected were not flowing. Stream discharge measurements obtained at 69 sites defined gaining (influent) and losing (effluent) channel reaches. Drainage areas were determined for the channel measurement sites, and gains and losses of flow along the channels were expressed in terms of flow per unit drainage area to the reach. The greatest gain measured for a channel reach was approximately 11,100 gallons per day per acre, and the greatest loss was approximately 8,420 gallons per day per acre.

Introduction

Discharges of streams, springs, and a wastewater treatment plant outfall in the Opequon Creek watershed (fig. 1) in Berkeley and Jefferson Counties, W. Va., were measured during July 25–28, 2005. These measurements help describe surface-water resources during low-flow and provide data for calibration of a ground-water flow model being developed for the Opequon Creek watershed. Presentation of these measurements herein is the result of a cooperative effort with the Berkeley County Commission.

Description of the Study Area

The stream, spring, and outfall measurements described in this report were all made in the Opequon Creek watershed. Opequon Creek forms part of the boundary between Berkeley and Jefferson Counties in West Virginia and flows into the Potomac River northeast of Martinsburg (fig. 1). The Opequon Creek watershed is in the Great Valley, with gently rolling topography that ranges from about 310 to 800 ft in altitude. The watershed has a trellis drainage pattern; Opequon Creek flows generally parallel to bedrock strike, and its major tributaries flow across the strike. The area is underlain by limestone and some shale (Shultz and others, 1993). Faults (fig. 1) collect water along their length from tributary faults, fractures, and solution channels and serve as pathways for downgradient flow to points of discharge (Hobba and others, 1972).

The Opequon Creek watershed is an area of rapid population growth. The 2004 populations of Berkeley County (89,400) and of Jefferson County (47,700) were about 50 and 33 percent larger, respectively, than those in 1990 (U.S. Census Bureau, 2006). The West Virginia Division of Water and Waste Management did an ecological assessment of West Virginia streams draining directly to the Potomac River during 1998. They reported that most of Berkeley, Jefferson, and Morgan Counties were covered by forests except for the Opequon Creek watershed. They reported that drainage basins for 10 of the 15 sites that they sampled in the Opequon Creek watershed had less than 50 percent areal coverage by forests and that 3 basins had the greatest percentage of urban coverage of all sites sampled in the 3-county area (West Virginia Division of Water and Waste Management, 2005). They reported further that agriculture was the major land use in the Opequon Creek watershed during their 1998 study and that new residential construction and other developments were rapidly converting both forest and farmland into more urban environments.

Hydrologic Conditions

Streamflow at USGS gaging station 01616500 Opequon Creek near Martinsburg (site 39, table 1, fig. 1) averaged 106 ft^3/s (47,600 gal/min) during July 25–28, which was approximately equivalent to the 40 percent flow duration (flow equaled or exceeded 40 percent of the time) of summer flows reported by Wiley (2006). The station recorded a hydrograph rise to 210 ft^3/s (94,300 gal/min) on July 22, but this flow reflects runoff from the entire 273-mi^2 upstream drainage area and probably did not include any significant storm runoff from the study area; rainfall totaled only 0.02 in. during July 16–24 at Martinsburg (National Climatic Data center, 2005). Flows of the streams and springs measured during the study were assumed to be principally from ground-water discharge rather than from surface runoff, even though 0.12 in. of rain fell in

Martinsburg on July 25 and 0.13 in. fell July 27. Most rain was believed to have been evapotranspired as a result of high temperatures (62 to 97 °F) during July 25–28 in the Martinsburg area (National Climatic Data Center, 2005), except for some direct street runoff in the most urban sections of the watershed.

The long-term ground-water recharge of the Opequon Creek watershed upstream from the gaging station was estimated by Kozar and Mathes (2001) as 9.8 in./yr or, in terms of average annual streamflow, 197 ft^3/s (88,400 gal/min); thus, the flow of Opequon Creek was about 54 percent of the average annual ground-water recharge rate. A discharge measurement of 4.7 ft^3/s (2,100 gal/min) was made at the site of the discontinued USGS gaging station 01617000 Tuscarora Creek above Martinsburg (site 52; table 1, fig. 1). Kozar and Mathes (2001) estimated ground-water recharge of the Tuscarora Creek watershed upstream from the Tuscarora Creek station as 11.4 in./yr or, in terms of average annual outflow, 9.5 ft^3/s (4,260 gal/min); thus, the flow of Tuscarora Creek was about 49 percent of the average annual ground-water recharge rate.

Discharge Measurements

Discharge information was obtained during July 25–28, 2005, at 69 stream sites, 31 springs, and 1 wastewater-treatment-plant outfall in the Opequon Creek watershed of West Virginia (table 1, fig. 1). Some springs and stream channels were found to be dry. All flowing sites were measured by wading with current meters. Observations of width, depth, and velocity were made at intervals in a cross section of the stream or spring outflow. Measured discharge is the summation of the products of the subsection areas of the cross sections and their respective average velocities (Rantz and others, 1982). Equipment used for measuring flow was checked for accuracy before and after the study and was within acceptable operational limits. The accuracy of individual discharge measurements was dependent on channel or outflow conditions, and error generally was estimated to be less than 10 percent.

Streamflow diversions and evaporation affect the results of this study. Pumps were noted as running during the time of the outflow measurements at Kilmer Spring and at Lefevre Spring, but data were not adjusted because the amount of diversion was unknown. Other unknown diversions or unnatural inflows could have occurred during the study. The rate of evapotranspiration from the streams during the study was also unknown and was thus considered as channel loss.

The greatest measured spring discharge was 14.4 ft^3/s (6,460 gal/min) from Priest Field Spring (site S1; table 1, fig. 1), but 11 of 31 springs were found to be not flowing. Streamflow measurements were made at 60 sites, and no flow was observed at 9 locations (table 1). The greatest tributary streamflow to Opequon Creek was from Tuscarora Creek, which measured 17.0 ft^3/s (7,630 gal/min) at Burke Street (site 65; table 1, fig.1).

Channel Gains and Losses

Channels in carbonate terrane can lose flow along some reaches through solution openings in the streambed when the stream channel is above the ground-water level. This water can return to a channel by springs and seeps downstream, or possibly in an adjacent watershed where the ground-water level is above the stream channel. Through this process, various reaches of a stream channel can lose or gain water. A stream can be deficient in flow or completely dry if the ground-water level is below the stream channel and solution openings beneath the stream are extensive enough to divert streamflow underground, thus draining the area by subsurface routes. Gains or losses of flow along channels can be attributed to one or more of the following: evapotranspiration, unmeasured tributary inflow, surface-water diversions, subsurface flow in unconsolidated channel deposits, interaction with the ground-water system, flow to or from faults, or measurement error.

Opequon Creek was measured at three locations (sites 15, 39, and 66; table 1, fig. 1), and showed a gain of 8 ft^3/s (5,200,000 gal/d) from river miles 26 (site 15) to 11.6 (site 39) and a further gain of 32 ft^3/s (20,700,000 gal/d) to river mile 3.3 (site 66). This gain can also be expressed in flow per unit of intervening drainage area between the sites as a gain of about 116 (gal/d)/acre between Opequon Creek river miles 26.0 to 11.6 and a gain of about 567 (gal/d)/acre between river miles 11.6 and 3.3.

The tributaries to Opequon Creek were measured at 66 locations during July 25–28, 2005. Drainage areas were determined for the channel-measurement sites, and the gains and losses of flow along the channel were expressed in terms of flow per unit drainage area contributing to the reach (table 1, fig. 1). The greatest measured gain for a channel reach was 11,100 (gal/d)/acre between sites 42 and 43 on Evans Run, but flow in this channel reach may have been affected by leaking water lines, which were observed upstream from site 43. The greatest gain for a channel reach with no known artificial inflow was 5,110 (gal/d)/acre upstream from site 37, which includes a wetland area. The greatest loss measured for a channel reach was 8,420 (gal/d)/acre between sites 43 and 44 on Evans Run, which is immediately downstream from the greatest gaining reach measured during the study.

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Table 1. Discharge measurements in the Opequon Creek Watershed of West Virginia, July 25-28, 2005.

[ft^3/s, cubic feet per second; gal/min, gallon per minute; gal/d, gallon per day]

Site number	Latitude	Longitude	Drainage area, in acres	Discharge			Flow contribution, in (gal/d)/acre[1]	Site descriptions and remarks
				ft^3/s	gal/min	gal/d		
1	391731.1	775710.0	1,300	0	0	0	0	Turkey Run
2	391807.7	775859.2	3,740	3.88	1,740	2,510,000	1,030	Turkey Run at County Route 1
3	391808.2	775924.7	3,990	2.71	1,220	1,750,000	-3,030	Turkey Run
4	391830.7	780010.0	9,430	3.82	1,710	2,470,000	132	Turkey Run near mouth
5	392201.2	780500.9	6,470	1.99	890	1,290,000	199	Mill Creek at Carter Spring
6	392144.5	780420.5	6,910	1.99	890	1,290,000	0	Mill Creek
7	392141.8	780419.7	6,990	1.67	750	1,080,000	-2,490	Mill Creek downstream from fault
8	392046.5	780404.9	9,090	2.97	1,330	1,920,000	399	Mill Creek
9	392018.7	780326.4	9,610	3.49	1,570	2,260,000	656	Mill Creek
10	391946.7	780449.7	1,490	.986	442	637,000	427	Torytown Creek
11	391950.0	780431.9	1,630	.845	379	546,000	-647	Torytown Run downstream from fault
12	392000.3	780325.5	2,210	.688	309	445,000	-176	Torytown Run upstream from Lefevre Spring
13	391946.8	780225.9	14,000	7.90	3,550	5,110,000	1,080	Mill Creek
14	391854.3	780057.7	19,700	14.0	6,280	9,050,000	701	Mill Creek at Plank Road
15	391917.7	775921.9	129,900	104	46,700	67,200,000	---	Opequon Creek at State Route 51 (River mile 26)
16	391927.7	775907.3	768	0	0	0	0	Unnamed tributary to Opequon Creek
17	392026.6	775820.7	717	0	0	0	0	Unnamed tributary to Opequon Creek
18	392039.9	775813.7	768	.0003	.13	194	4	Unnamed tributary to Opequon Creek
19	392426.5	780335.5	2,360	.590	265	381,000	161	Middle Creek at Tabler Station Road
20	392234.0	780227.3	6,200	2.57	1,150	1,660,000	333	Middle Creek at Arden-Nollville Road
21	392216.6	780138.6	6,880	2.29	1,030	1,480,000	-267	Middle Creek at US Route 11 at Darkesville
22	392208.5	775954.8	8,810	4.66	2,090	3,010,000	793	Middle Creek at Shiley Road
23	392133.0	775847.5	9,220	4.71	2,110	3,040,000	79	Middle Creek
24	392123.1	775813.8	9,420	4.92	2,210	3,180,000	684	Middle Creek at Highway 34 near mouth
25	392138.5	780040.4	115	.048	21.5	31,000	269	Goose Creek
26	392135.3	780004.5	506	.042	18.9	27,100	-10	Goose Creek downstream from County Route 11/8
27	392117.9	775905.4	922	.081	36.4	52,400	61	Goose Creek
28	392112.6	775843.3	1,090	.015	6.73	9,700	-256	Goose Creek downstream from Platt Mountain Lane
29	392115.9	775808.8	1,200	.080	35.9	51,700	365	Goose Creek near mouth
30	392052.1	775457.0	781	1.27	570	821,000	1,050	East Branch Hopewell Run
31	392056.9	775525.6	2,000	1.25	561	808,000	-11	East Branch Hopewell Run upstream from Tabb Spring

Table 1. Discharge measurements in the Opequon Creek Watershed of West Virginia, July 25-28, 2005.—Continued

[ft³/s, cubic feet per second; gal/min, gallon per minute; gal/d, gallon per day]

Site number	Latitude	Longitude	Drainage area, in acres	Discharge			Flow contribution, in (gal/d)/acre[1]	Site descriptions and remarks
				ft^3/s	gal/min	gal/d		
32	392038.7	775607.2	3,060	.062	27.8	40,100	13	South Branch Hopewell Run
33	392116.7	775601.0	5,570	4.12	1,850	2,660,000	3,500	Hopewell Run at Leetown
34	392219.5	775625.0	7,020	5.56	2,500	3,590,000	643	Hopewell Run near mouth
35	392315.0	775514.5	2,490	0	0	0	0	South Branch Shaw Run
36	392337.9	775501.8	1,800	.868	390	561,000	312	East Branch Shaw Run upstream from Shaw Spring
37	392344.3	775518.0	4,520	2.69	1,210	1,740,000	5,110	Shaw Run downstream from Shaw Spring wetland
38	392416.4	775547.1	4,930	3.32	1,490	2,150,000	979	Shaw Run near mouth
39	392527.2	775616.1	174,700	112	50,300	72,400,000	---	Opequon Creek near Martinsburg (River mile 11.6)
40	392552.7	780207.8	742	.029	13.0	18,700	25	Evans Run at Arden-Nollville Road
41	392555.5	780101.7	1,470	0	0	0	-26	Evans Run at State Route 45
42	392535.7	775915.6	3,400	0	0	0	0	Evans Run at US Highway 11
43	392530.3	775851.5	3,650	4.29	1,930	2,770,000	11,100	Evans Run below ford (leaking water lines upstream)
44	392533.4	775842.7	3,670	4.04	1,810	2,610,000	-8,420	Evans Run about 0.5 mile downstream from Big Spring
45	392528.8	775629.3	4,570	2.94	1,320	1,900,000	-788	Evans Run near mouth
46	392704.4	780243.8	1,750	.433	194	280,000	160	Tuscarora Creek
47	392730.4	780245.0	250	.065	29.2	42,000	168	Unnamed spring tributary to Tuscarora Creek
48	392802.0	780128.2	3,600	2.50	1,120	1,620,000	805	Tuscarora Creek upstream from Nollville
49	392759.6	780021.6	5,740	2.88	1,290	1,860,000	115	Tuscarora Creek near Tuscarora Church
50	392811.2	775909.9	6,910	4.09	1,840	2,640,000	671	Tuscarora Creek near Kilmer Springs
51	392811.0	775846.7	7,190	4.69	2,110	3,030,000	1,350	Tuscarora Creek at North Tennessee Ave
52	392811.3	775819.6	7,430	4.68	2,100	3,020,000	-27	Tuscarora Creek above Martinsburg
53	392801.9	775808.2	7,600	4.84	2,170	3,130,000	598	Tuscarora Creek
54	392944.7	780038.7	851	.454	204	293,000	345	Dry Run downstream from County Route 13
55	392934.8	775958.5	1,290	.424	190	274,000	-45	Dry Run at Apple Knolls subdivision
56	392907.7	775915.8	1,850	.137	61.5	88,500	-329	Dry Run upstream of Southern tributary
57	392904.3	780102.1	531	0	0	0	0	Southern tributary to Dry Run at County Route 16
58	392903.4	775958.6	909	0	0	0	0	Southern tributary to Dry Run at County Route 13/1
59	392902.9	775822.7	3,560	.190	85.3	123,000	42	Dry Run dounstream from I-81

Table 1. Discharge measurements in the Opequon Creek Watershed of West Virginia, July 25-28, 2005.—Continued

[ft³/s, cubic feet per second; gal/min, gallon per minute; gal/d, gallon per day]

Site number	Latitude	Longitude	Drainage area, in acres	Discharge			Flow contribution, in (gal/d)/acre[1]	Site descriptions and remarks
				ft³/s	gal/min	gal/d		
60	392846.1	775757.4	3,910	.080	35.9	51,700	-206	Dry Fork upstream from railroad trestle
61	392841.3	775752.6	3,930	.048	21.5	31,000	-1,080	Dry Run downstream from railroad trestle
62	392800.8	775739.7	4,720	0	0	0	-39	Dry Run at Adams Street near mouth
63	392705.1	775715.6	15,900	13.8	6,190	8,920,000	1,610	Tuscarora Creek upstream from wastewater treatment plant
64	392706.1	775713.6	---	3.94	1,770	2,550,000	---	Wastewater treatment plant outfall
65	392654.8	775607.7	16,900	17.0	7,630	11,000,000	-467	Tuscarora Creek at Burke Street
66	393016.0	775351.6	211,200	144	64,600	93,100,000	---	Opequon Creek at Myers Bridge (River mile 3.3)
67	393129.0	775521.6	838	5.61	2,520	3,630,000	4,320	Hoke Run downstream of upper watercress ponds
68	393125.7	775516.9	3,520	.640	287	414,000	118	Unnamed tributary to Hoke Run downstream from US 11
69	393110.7	775435.2	5,410	6.95	3,120	4,490,000	431	Hoke Run downstream from railroad trestle
70	393115.1	775324.2	7,330	9.37	4,210	6,060,000	815	Hoke Run near mouth
S1	391759.3	780040.8	---	14.4	6,460	9,310,000	---	Priest Field Spring
S2	391805.4	775818.6	---	0	0	0	---	Turkey Run spring
S3	391805.5	775937.3	---	0	0	0	---	Channel below Schlack Farm Spring
S4	391954.7	780618.8	---	.054	24.2	34,900	---	Cool Spring
S5	391951.1	780537.2	---	.801	360	518,000	---	Porter Farm Spring
S6	391953.6	780328.7	---	.599	269	387,000	---	Lefevre Spring outflow (pump running)
S7	392159.9	780544.9	---	.005	2.24	3,230	---	Grey Springs
S8	392202.9	780500.2	---	0	0	0	---	Carter Spring
S9	392125.2	780504.8	---	.580	260	375,000	---	Springvale Spring
S10	392004.1	780314.8	---	0	0	0	---	Gum Spring
S11	392112.4	775746.7	---	0	0	0	---	Sulphur Springs tributary near mouth
S12	392239.7	780117.4	---	1.67	750	1,080,000	---	McDonald Spring
S13	392037.3	775436.9	---	1.34	601	866,000	---	Bell Spring
S14	392052.3	775457.0	---	0	0	0	---	Tile drain discharge to East Branch Hopewell Run
S15	392057.5	775501.6	---	0	0	0	---	Two Springs confluence
S16	392057.0	775526.5	---	.210	94.3	136,000	---	Tabb Spring
S17	392043.7	775543.4	---	1.64	736	1,060,000	---	Gray Spring at Leetown
S18	392401.5	775840.6	---	.005	2.24	3,230	---	Shade Spring
S19	392504.6	775816.9	---	0	0	0	---	Cold Spring Run
S20	392538.0	775910.8	---	1.24	557	801,000	---	Big Spring and Snodgrass Spring (combined)

Table 1. Discharge measurements in the Opequon Creek Watershed of West Virginia, July 25-28, 2005.—Continued

[ft^3/s, cubic feet per second; gal/min, gallon per minute; gal/d, gallon per day]

Site number	Latitude	Longitude	Drainage area, in acres	Discharge			Flow contribution, in (gal/d)/acre[1]	Site descriptions and remarks
				ft^3/s	gal/min	gal/d		
S21	392803.2	780130.0	---	.700	314	452,000	---	BellaVista Distillery Spring
S22	392758.8	775759.6	---	.426	191	275,000	---	Kilmer Spring overflow
S23	392710.4	775745.0	---	.879	395	568,000	---	Martinsburg water supply spring
S24	392546.9	775311.1	---	0	0	0	---	Dailey Spring
S25	392625.8	775417.3	---	.603	271	390,000	---	Couchman Spring
S26	392653.8	775526.9	---	.703	316	454,000	---	Blarton Spring
S27	392813.0	775237.3	---	.504	226	326,000	---	Swan Pond Spring
S28	393126.8	775542.2	---	5.83	2,620	3,770,000	---	Dennis Farm Spring upstream from upper watercress pond
S29	393114.3	775353.9	---	.060	26.9	38,800	---	Porterfield Sulphur Spring
S30	393113.1	775356.9	---	0	0	0	---	Unnamed spring near Porterfield Sulphur Spring
S31	393108.0	775345.6	---	.175	78.5	113,000	---	Spring on downstream side of tributary to Hoke Run

[1] Flow contributions are computed as the change in channel discharge between measurement sites divided by the change in drainage area between the sites. Contributions are negative for losing (effluent) reaches and positive for gaining (influent) reaches. See figure 1 for areas associated with the flow-contribution calculations for the indicated measurement sites.