Summary of the Midchannel Springflows in Jackson River Below Gathright Dam Between April 24, 2010, and May 7, 2019

Open-File Report 2022–1047

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

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U.S. Geological Survey, Reston, Virginia: 2022

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Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Datum

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

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

Abbreviations

ADCP	acoustic Doppler current profiler
ADV	acoustic Doppler velocimeter
NOAA	National Oceanic and Atmospheric Administration
R^2	coefficient of determination
USGS	U.S. Geological Survey

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Abstract

Between April 2010 and May 2019, springflow was determined for a midchannel spring in Jackson River below Gathright Dam near Hot Springs, Virginia. The springflow was measured to assess if the spring was influenced by the elevation of Lake Moomaw. Local precipitation was also reviewed to determine whether variations in springflow were influenced by rainfall. The spring is approximately 250 feet downstream from the dam's discharge race channel, where the water is carried away from the base of the dam, and its flow was determined by the gain in streamflow between concurrent measurements made upstream and downstream from the spring. Throughout the study period, the springflow showed little variation over time, and no direct correlations were determined between the observed springflow and the elevation of Lake Moomaw or local precipitation data.

Introduction

The U.S. Army Corps of Engineers Norfolk District contacted the U.S. Geological Survey (USGS) in April 2010 regarding the determination of flow from a midchannel spring located in Jackson River below Gathright Dam near Hot Springs, Virginia. The spring is located midchannel approximately 250 feet downstream from the dam's discharge race channel. The spring can be located by means of a pipe that has been placed near the center of the spring; water can be observed discharging directly to the Jackson River around the pipe (**fig. 1**). As part of this effort, the USGS compared measured streamflows at the existing streamgage, 02011800 Jackson River below Gathright Dam near Hot Springs, Va., to measured streamflows for the newly established streamgage, 02011799 Jackson River above spring near Hot Springs, Va. (**figs. 2 and 3**) to compute the springflow. During the period from April 24, 2010, to May 7, 2019, the USGS made 30 concurrent site inspections with streamflow measurements at each streamgage location for comparison and calculation of springflows. The calculated springflows were compared with the daily elevation of Lake Moomaw at 08:00 a.m. (U.S. Army Corps of Engineers Norfolk District Water Management, 2020) and local precipitation totals from the National Oceanic and Atmospheric Administration (NOAA) weather station in Hot Springs, Va., USC 0444128 (National Oceanic and Atmospheric Administration, 2020).

Figure 1. Springflow at pipe at Jackson River below Gathright Dam near Hot Springs Virginia. Photograph by the U.S. Geological Survey.

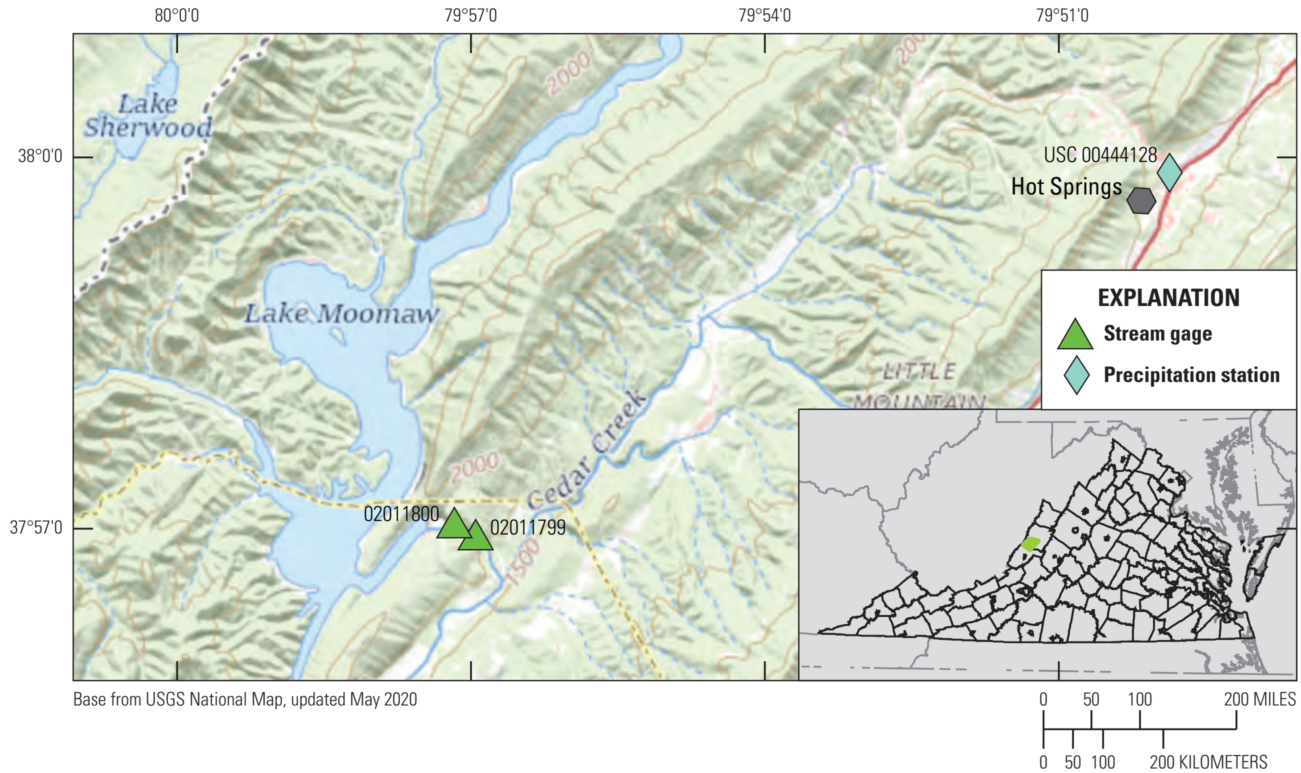

Figure 2. Location of the data collection sites near Lake Moomaw, Virginia, and Hot Springs, Va.

Data Collection and Springflow Determination

Site inspections of the USGS streamgages in Jackson River at 02011800 Jackson River below Gathright Dam near Hot Springs, Va., and 02011799 Jackson River above spring near Hot Springs, Va., below Gathright Dam, were made between April 27, 2010, and May 7, 2019, to determine the springflow. The site inspections included concurrent streamflow measurements above and below the spring to determine its flow (fig. 4). The mean streamflow was determined prior to computing the springflow for inspections that included more than one measurement.

Streamflow Measurement Methods

Streamflow measurements were made using an acoustic Doppler velocimeter (ADV), an acoustic Doppler current profiler (ADCP), and a Price AA current-meter (AA). To minimize bias associated with specific measurement equipment or a hydrographer's measurement technique, streamflow measurements were made by different USGS staff and streamflow measurement equipment, depending on the availability of each. Prior to the streamflow measurements, releases from the dam were stabilized and a temporary reference gage was deployed in the settling pool below the dam outflow to confirm a consistent water level and steady flow rate. The gage height, or water-surface elevation, of the downstream reference gage, 02011800, also was observed to confirm flow conditions; however, a lag in water-level stabilization because of travel time was observed at the beginning of some measurements. The lag in gage height stabilization at station 02011800 did not impact the measurements, as the water-levels at the measurement locations had already stabilized. For the 30 site inspections made, a total of 49 streamflow measurements were used from the upstream streamgage, 02011799 (table 1), and 47 streamflow measurements were used from the downstream streamgage, 02011800 (table 2).

Springflow Determination

Springflow was computed by determining the gain in flow of the reach between the upstream (02011799) and downstream (02011800) streamflow measurements. For inspections that included more than one streamflow measurement at a site, the average streamflow at that site was determined prior to computing the springflow. A plot showing the average measured streamflow at each inspection upstream and downstream of the spring is shown in figure 5. The gain in flow was calculated by determining the difference in measured streamflow between sites 02011800 and 02011799. Table 3 lists the

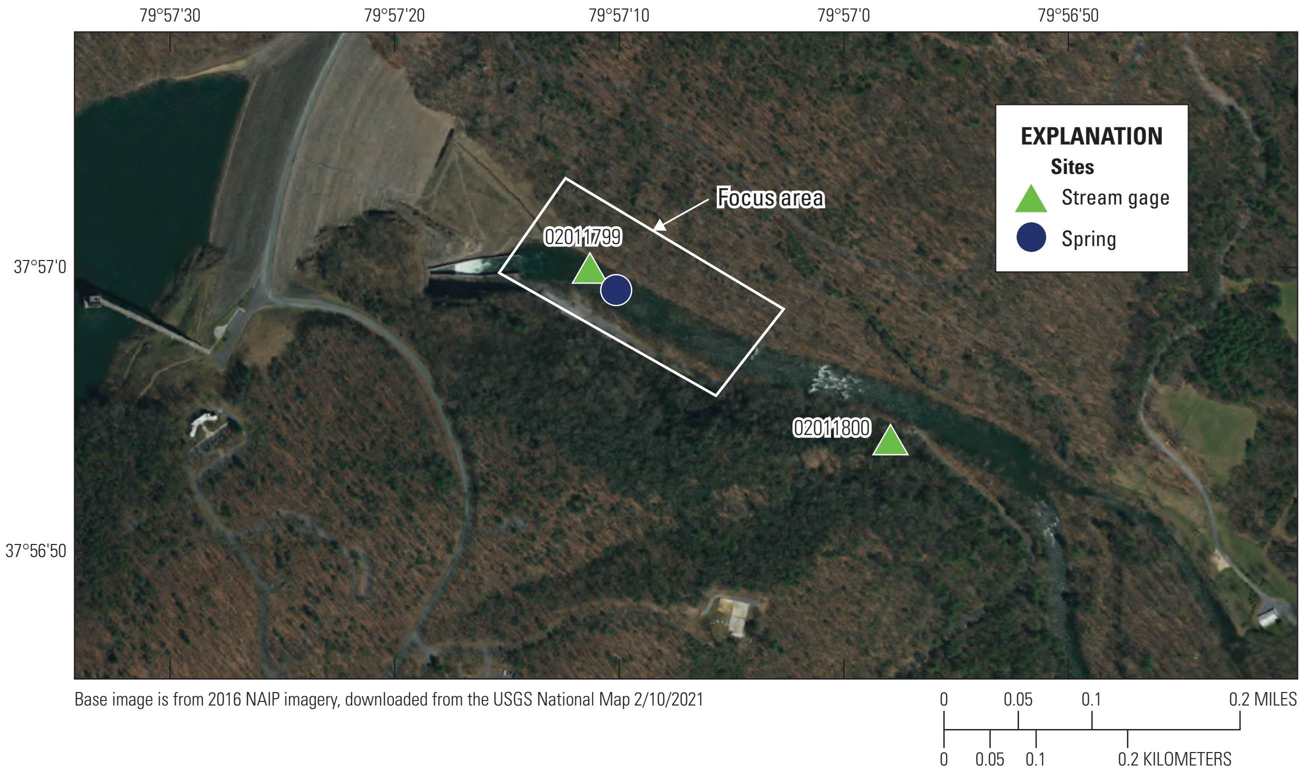

Figure 3. Location of U.S. Geological Survey streamgages 02011799 and 02011800 below Gathright Dam. Streamflow measurements were made within the focus area above and below the spring.

Figure 4. U.S. Geological Survey (USGS) hydrographers making concurrent streamflow measurements to compute springflow from the midchannel spring in Jackson River below Gathright Dam near Hot Springs, Virginia. Photograph by the USGS.

Table 1. Streamflow measurement data for U.S. Geological Survey streamgage 02011799 (U.S. Geological Survey, 2020a).

[Dates shown as month, day, year. All measurement times are Eastern Local Time. ft^3/s, cubic foot per second; ADV, acoustic Doppler velocimeter; ADCP, acoustic Doppler current profiler; >, greater than]

Measurement number	Measurement date	Measurement time	Streamflow (ft^3/s)	Percent uncertainty associated with the streamflow measurement	Streamflow measurement method
1	4/27/2010	7:59:00 a.m.	4.93	5	ADV
2	4/27/2010	8:33:00 a.m.	3.28	5	ADV
3	4/27/2010	9:10:00 a.m.	4.89	5	ADV
4	4/27/2010	9:47:00 a.m.	4.47	5	ADV
5	4/27/2010	10:27:00 a.m.	3.86	5	ADV
6	4/27/2010	10:29:00 a.m.	3.73	5	ADV
7	8/13/2010	8:28:00 a.m.	89.7	5	ADV
8	8/13/2010	9:03:30 a.m.	84.9	5	ADV
9	8/13/2010	9:10:30 a.m.	92.9	5	ADV
10	3/8/2011	12:31:30 p.m.	81	5	ADV
11	3/8/2011	1:14:30 p.m.	81.2	5	ADV
12	6/28/2011	8:11:00 a.m.	91.4	5	ADV
13	6/28/2011	9:15:00 a.m.	94.6	5	ADV
14	6/29/2011	9:47:30 a.m.	250	5	ADCP
15	6/29/2011	11:41:34 a.m.	263	5	ADCP
17	8/17/2011	11:00:44 a.m.	260	5	ADCP
18	8/17/2011	11:59:03 a.m.	255	5	ADCP
19	2/2/2012	12:17:00 p.m.	76.4	5	ADV
20	2/2/2012	1:20:00 p.m.	73.7	8	ADV
21	2/2/2012	1:42:00 p.m.	75.3	8	ADV
22	4/4/2012	8:28:00 a.m.	93.9	8	ADV
23	4/4/2012	8:42:00 a.m.	102	8	ADV
24	4/4/2012	9:05:00 a.m.	103	8	ADV
25	4/19/2012	8:25:00 a.m.	80.7	8	ADV
26	4/19/2012	8:59:30 a.m.	83.2	8	ADV
27	5/17/2012	8:24:00 a.m.	79.3	5	ADV
28	5/17/2012	9:07:00 a.m.	80.8	5	ADV
29	5/17/2012	9:22:00 a.m.	79.5	8	ADV
30	8/8/2013	8:20:44 a.m.	215	5	ADCP
31	1/31/2014	9:16:30 a.m.	85.3	8	ADV
32	1/31/2014	9:55:00 a.m.	95.5	8	ADV
33	3/26/2014	8:32:00 a.m.	88.7	8	ADV
34	5/28/2014	10:45:00 a.m.	92.5	8	ADV
35	6/18/2014	8:50:00 a.m.	92.6	8	ADV
36	12/11/2014	10:47:30 a.m.	168	8	ADV
37	1/7/2015	11:49:30 a.m.	162	8	ADV
38	3/3/2015	4:40:30 p.m.	140	8	ADV
39	11/18/2015	11:46:00 a.m.	149	8	ADV
40	1/7/2016	11:41:30 a.m.	275	5	ADV

Table 1. Streamflow measurement data for U.S. Geological Survey streamgage 02011799 (U.S. Geological Survey, 2020a).—Continued

[Dates shown as month, day, year. All measurement times are Eastern Local Time. ft^3/s, cubic foot per second; ADV, acoustic Doppler velocimeter; ADCP, acoustic Doppler current profiler; >, greater than]

Measurement number	Measurement date	Measurement time	Streamflow (ft^3/s)	Percent uncertainty associated with the streamflow measurement	Streamflow measurement method
41	2/24/2016	11:52:00 a.m.	2.19	>8	ADV
42	12/14/2016	11:10:30 a.m.	140	8	ADV
43	2/8/2017	12:51:00 p.m.	191	8	ADV
44	4/13/2017	12:29:30 p.m.	305	8	ADV
45	10/4/2017	10:35:30 a.m.	201	8	ADV
46	11/29/2017	11:03:00 a.m.	165	8	ADV
47	12/20/2017	12:39:00 p.m.	152	>8	ADV
48	1/25/2018	9:34:30 a.m.	150	8	ADV
49	2/7/2019	12:31:00 p.m.	182	5	ADV
50	5/7/2019	9:27:00 a.m.	270	8	ADV

Table 2. Streamflow measurement data for U.S. Geological Survey streamgage 02011800 (U.S. Geological Survey, 2020b).

[Dates shown as month, day, year. All measurement times are Eastern Local Time. ft^3/s, cubic foot per second; ADV, acoustic Doppler velocimeter; AA, Price AA current meter; ADCP, acoustic Doppler current profiler; >, greater than]

Measurement number	Measurement date	Measurement time	Streamflow (ft^3/s)	Percent uncertainty associated with the streamflow measurement	Streamflow measurement method
318	4/27/2010	8:00:30 a.m.	20.2	8	ADV
319	4/27/2010	8:33:30 a.m.	19.5	8	ADV
320	4/27/2010	9:13:30 a.m.	19.7	8	ADV
321	4/27/2010	9:47:00 a.m.	18.7	8	AA
329	8/13/2010	8:15:00 a.m.	108	5	ADV
330	8/13/2010	8:32:30 a.m.	109	5	AA
335	3/8/2011	12:27:00 p.m.	104	8	ADV
336	3/8/2011	1:17:00 p.m.	98.7	8	ADV
339	6/28/2011	8:43:00 a.m.	104	8	ADV
340	6/28/2011	9:49:00 a.m.	97.3	8	ADV
341	6/29/2011	11:02:30 a.m.	269	8	ADCP
342	6/29/2011	12:20:32 p.m.	274	5	ADCP
343	8/17/2011	10:26:48 a.m.	268	8	ADCP
344	8/17/2011	11:25:24 a.m.	270	8	ADCP
345	8/17/2011	12:18:00 p.m.	267	5	ADV
355	2/2/2012	1:01:00 p.m.	93.1	8	ADV
356	2/2/2012	2:09:30 p.m.	87.2	8	ADV
359	4/4/2012	8:27:59 a.m.	118	8	ADV
360	4/4/2012	9:02:00 a.m.	101	8	ADV
361	4/4/2012	9:47:30 a.m.	103	8	ADV

Table 2. Streamflow measurement data for U.S. Geological Survey streamgage 02011800 (U.S. Geological Survey, 2020b).—Continued

[Dates shown as month, day, year. All measurement times are Eastern Local Time. ft^3/s, cubic foot per second; ADV, acoustic Doppler velocimeter; AA, Price AA current meter; ADCP, acoustic Doppler current profiler; >, greater than]

Measurement number	Measurement date	Measurement time	Streamflow (ft^3/s)	Percent uncertainty associated with the streamflow measurement	Streamflow measurement method
362	4/19/2012	8:39:30 a.m.	115	8	ADV
363	4/19/2012	9:22:30 a.m.	110	8	ADV
364	4/19/2012	9:31:30 a.m.	85.1	8	ADV
366	5/17/2012	8:08:00 a.m.	95	8	ADV
367	5/17/2012	8:37:30 a.m.	102	8	ADV
368	5/17/2012	9:46:00 a.m.	102	8	ADV
377	8/8/2013	9:10:00 a.m.	244	5	ADCP
380	1/31/2014	9:19:00 a.m.	113	8	ADV
381	1/31/2014	9:54:00 a.m.	112	8	ADV
382	3/26/2014	8:26:30 a.m.	107	8	ADV
383	5/28/2014	10:44:30 a.m.	105	8	ADV
384	6/18/2014	8:51:30 a.m.	103	5	ADV
388	12/11/2014	10:49:00 a.m.	161	8	ADV
389	1/7/2015	11:44:00 a.m.	161	8	ADV
390	3/3/2015	4:24:59 p.m.	159	8	ADV
395	11/18/2015	11:47:30 a.m.	169	8	ADV
396	1/7/2016	11:38:30 a.m.	284	5	ADV
397	2/24/2016	11:49:30 a.m.	20.2	>8	ADV
403	12/14/2016	11:18:00 a.m.	152	8	ADV
404	2/8/2017	11:53:00 a.m.	210	8	ADV
405	4/13/2017	12:43:30 p.m.	313	8	ADV
408	10/4/2017	10:34:00 a.m.	215	8	ADV
409	11/29/2017	11:14:30 a.m.	171	>8	ADV
410	12/20/2017	12:39:00 p.m.	157	5	ADV
411	1/25/2018	8:45:30 a.m.	163	8	ADV
416	2/7/2019	1:37:00 p.m.	225	5	ADV
417	5/7/2019	9:29:00 a.m.	286	8	ADV

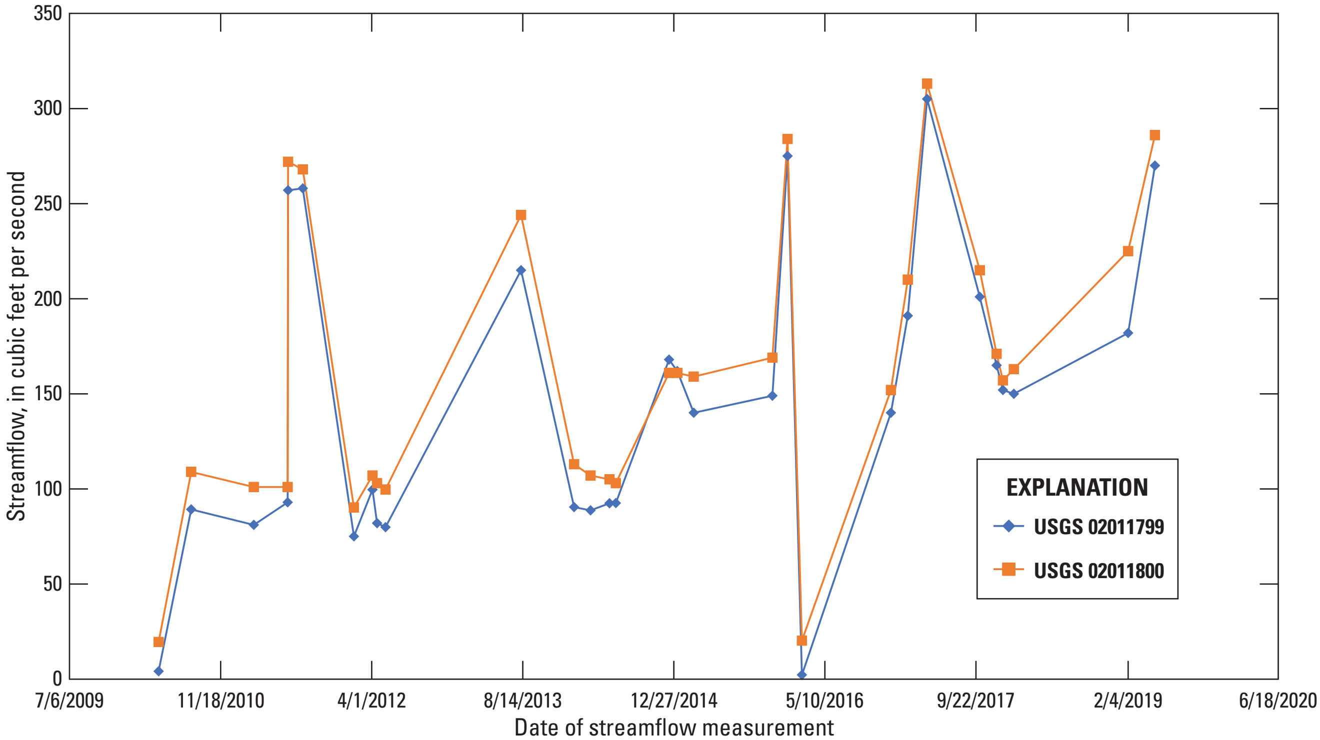

Figure 5. Average measured streamflow values at the U.S. Geological Survey streamgages 02011799 and 02011800 during site inspections.

Table 3. Summary of the average measured streamflow data for U.S. Geological Survey streamgages 02011799 and 02011800, calculated springflow, the water-surface elevation of Lake Moomaw at 08:00 a.m. Eastern Local Time (U.S. Army Corps of Engineers, 2020) and a 30-day precipitation total for the National Oceanic and Atmospheric Administration weather station USC 00444128 in Hot Springs, Virginia (National Oceanic and Atmospheric Administration, 2020).

[Dates shown as month, day, year. ft^3/s, cubic foot per second; NGVD 29, National Geodetic Vertical Datum of 1929; in., inch]

Date of inspection	Observed streamflow at 02011799 (ft^3/s)	Observed streamflow at 02011899 (ft^3/s)	Calculated springflow (ft^3/s)	Elevation of Lake Moomaw at 8:00 a.m. (ft above NGVD 29)	30-day total precipitation preceding the site inspection in Hot Springs, Virginia (in.)
4/27/2010	4.19	19.5	15.3	1,582.2	3.14
8/13/2010	89.2	109	19.8	1,572.2	0.84
3/8/2011	81.1	101	19.9	1,578.3	3.51
6/28/2011	93.0	101	8.00	1,580.4	3.35
6/29/2011	257	272	15.0	1,580.3	3.42
8/17/2011	258	268	10.0	1,572.3	2.15
2/2/2012	75.1	90.2	15.1	1,581.9	3.49
4/4/2012	99.6	107	7.40	1,582.0	2.21
4/19/2012	82.0	103	21.0	1,582.0	2.24
5/17/2012	79.9	99.7	19.8	1,582.8	4.96

Table 3. Summary of the average measured streamflow data for U.S. Geological Survey streamgages 02011799 and 02011800, calculated springflow, the water-surface elevation of Lake Moomaw at 08:00 a.m. Eastern Local Time (U.S. Army Corps of Engineers, 2020) and a 30-day precipitation total for the National Oceanic and Atmospheric Administration weather station USC 00444128 in Hot Springs, Virginia (National Oceanic and Atmospheric Administration, 2020).—Continued

[Dates shown as month, day, year. ft³/s, cubic foot per second; NGVD 29, National Geodetic Vertical Datum of 1929; in., inch]

Date of inspection	Observed streamflow at 02011799 (ft³/s)	Observed streamflow at 02011899 (ft³/s)	Calculated springflow (ft³/s)	Elevation of Lake Moomaw at 8:00 a.m. (ft above NGVD 29)	30-day total precipitation preceding the site inspection in Hot Springs, Virginia (in.)
8/8/2013	215	244	29.0	1,580.9	3.87
1/31/2014	90.4	113	22.6	1,582.0	1.89
3/26/2014	88.7	107	18.3	1,582.0	2.56
5/28/2014	92.5	105	12.5	1,582.0	4.49
6/18/2014	92.6	103	10.4	1,581.2	3.77
12/11/2014	168	161	0.00* (−7.00)	1,562.2	3.49
1/7/2015	162	161	0.00* (−1.00)	1,567.2	2.19
4/4/2012	99.6	107	7.40	1,582.0	2.21
4/19/2012	82.0	103	21.0	1,582.0	2.24
5/17/2012	79.9	99.7	19.8	1,582.8	4.96
3/3/2015	140	159	19.0	1,574.8	3.78
11/18/2015	149	169	20.0	1,572.9	3.75
1/7/2016	275	284	9.00	1,582.0	3.20
2/24/2016	2.19	20.2	18.0	1,584.0	4.67
12/14/2016	140	152	12.0	1,582.1	3.76
2/8/2017	191	210	19.0	1,582.1	3.03
4/13/2017	305	313	8.00	1,582.2	4.23
10/4/2017	201	215	14.0	1,568.4	0.66
11/29/2017	165	171	6.00	1,568.1	3.05
12/20/2017	152	157	5.00	1,567.0	0.44
1/25/2018	150	163	13.0	1,568.4	2.47
2/7/2019	182	225	43.0	1,582.0	2.73
5/7/2019	270	286	16.0	1,582.4	8.19

*Negative springflows are considered to be zero flow as they are within the associated error of the observed streamflow measurements.

summary of the average measured streamflow, calculated springflow, the water-surface elevation of Lake Moomaw at 08:00 a.m. Eastern Local Time, in feet above the National Geodetic Vertical Datum of 1929 (NGVD 29), and a 30-day precipitation total prior to the inspection for NOAA weather station USC 00444128 in Hot Springs, Va., on the day of the inspection. Springflow calculated from the 30 inspections made during the study period ranged from −7.00 to 43.0 cubic feet per second. The negative springflows are considered zero flow, as the differences are within the acceptable uncertainty of the streamflow measurements, the percent uncertainty of each measurement can be found in tables 1 and 2. Streamflow measurement uncertainties include uncertainties in the cross-section, the water-velocity profile, computational assumptions, and other systematic errors (Turnipseed and Sauer, 2010). While each year of the study contained limited springflow data points due to a small number of site inspection, the average annual springflow observed was calculated and entered in table 4. The average annual springflow is used to review how the flow of the spring varied over time.

Table 4. Average annual springflow observed and annual precipitation totals from National Oceanic and Atmospheric Administration weather station USC 00444128 in Hot Springs, Virginia (National Oceanic and Atmospheric Administration, 2020).

[NOAA, National Oceanic and Atmospheric Administration; ft^3/s, cubic foot per second; in., inch]

Year	Average annual springflow observed (ft^3/s)	Annual precipitation totals from NOAA weather station USC 00444128 (in.)
2010	17.6	35.91
2011	13.2	51.98
2012	15.8	38.5
2013	29.0	46.11
2014	12.8	38.18
2015	13.0	49.23
2016	13.0	47.62
2017	10.4	43.44
2018	13.0	69.22
2019	29.5	46.57

Results and Findings

To determine if the elevation of Lake Moomaw and the springflow show a direct relationship a statistical analysis of the springflow was examined using a linear regression model (fig. 6) between the calculated springflow and the elevation of the Lake Moomaw on the day of the site inspections. The linear regression analysis shows significant scatter or variability in the data points and a coefficient of determination (R^2) value of 0.2186. Analysis of the sample data indicated the lake elevation and springflow do not have a significant correlation.

Daily precipitation data from the NOAA weather station USC 00444128 was used to determine the total precipitation for the 30 days preceding the site inspections (table 3). The total does not include the day of the inspection, because the NOAA datasets are reported as daily totals and the precipitation may have occurred after the inspections. A linear regression analysis was also used on the 30-day precipitation total and the calculated springflows to determine if a relationship between recent precipitation and the springflow exists (fig. 7). The linear regression analysis results show significant scatter or variability in the data points and an R^2 value of 0.0076. The results of the analysis indicate that the precipitation prior to the measurement inspections does not affect calculated springflow.

A review of springflow and an analysis of how it relates to the elevation of Lake Moomaw and recent precipitation totals determined that neither variable displays a significant correlation with springflow. The average annual springflow observed (table 4) was reviewed to examine how the springflow varied over time. The annual springflow shows little variation of over time, with 8 of the 10 years falling within one standard deviation of the mean and the remaining 2 years within two standard deviations. Table 4 also includes total annual precipitation data from NOAA weather station USC 00444128 in Hot Springs, Va. A linear regression model (fig. 8) was used to compare the annual precipitation data with the annual mean springflow to determine if there are any correlations between the two datasets. The results of this analysis are similar to results from the analysis of springflow and 30-day precipitation totals, with the linear regression analysis indicating a significant scatter or variability in the data points and an R^2 value of 0.0015. Based on this analysis, annual climatological changes did not affect the rate of the average annual springflow.

Summary

During the period from April 2010 to May 2019 streamflow measurements from 02011799 Jackson River above spring near Hot Springs, Virginia and 02011800 Jackson River below Gathright Dam near Hot Springs Va., were used to determine the flow of a midchannel spring at the request of the U.S. Army Corps of Engineers Norfolk District. The calculated springflow data were analyzed to determine if correlations could be established between the elevation of Lake Moomaw or local precipitation data from Hot Springs, Va., and were evaluated for trends over time. Results of these analyses indicated no direct correlations between springflow and lake elevation. The local precipitation data indicated that the amount of springflow did not respond to changes in recent or long-term precipitation totals based on the observed

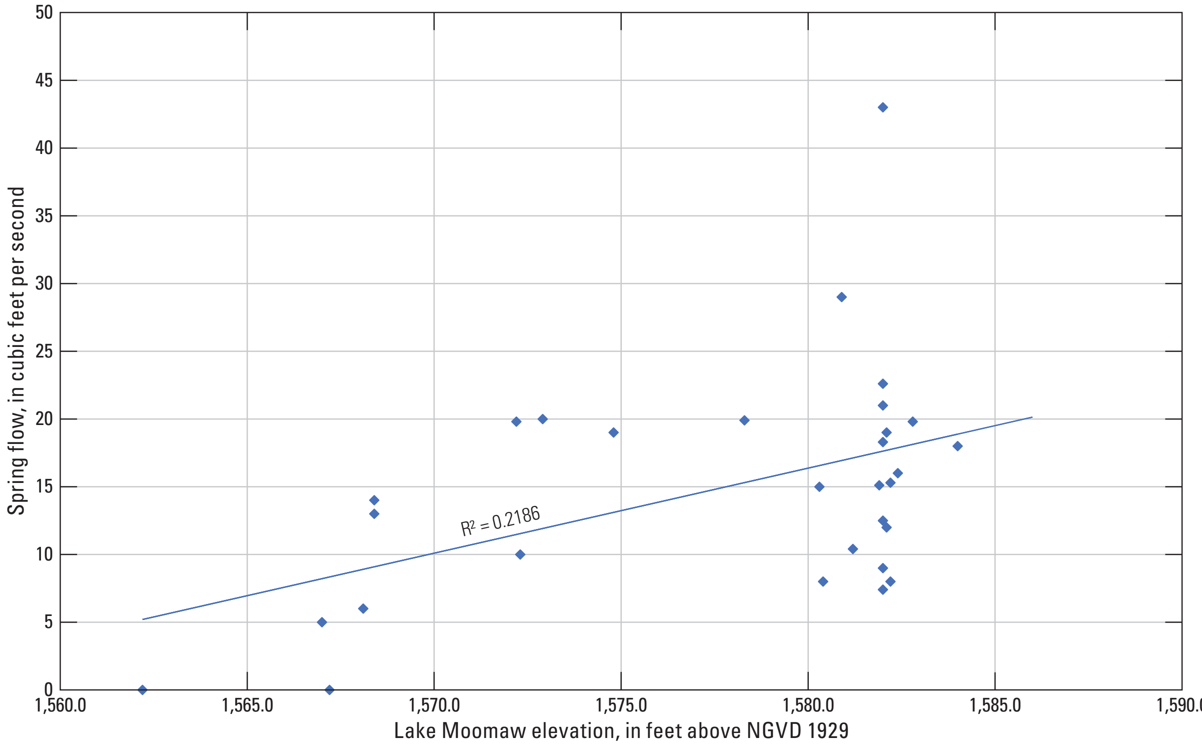

Figure 6. Linear regression analysis of springflow with elevation of Lake Moomaw between April 2010 and May 2019. R^2 is the coefficient of determination.

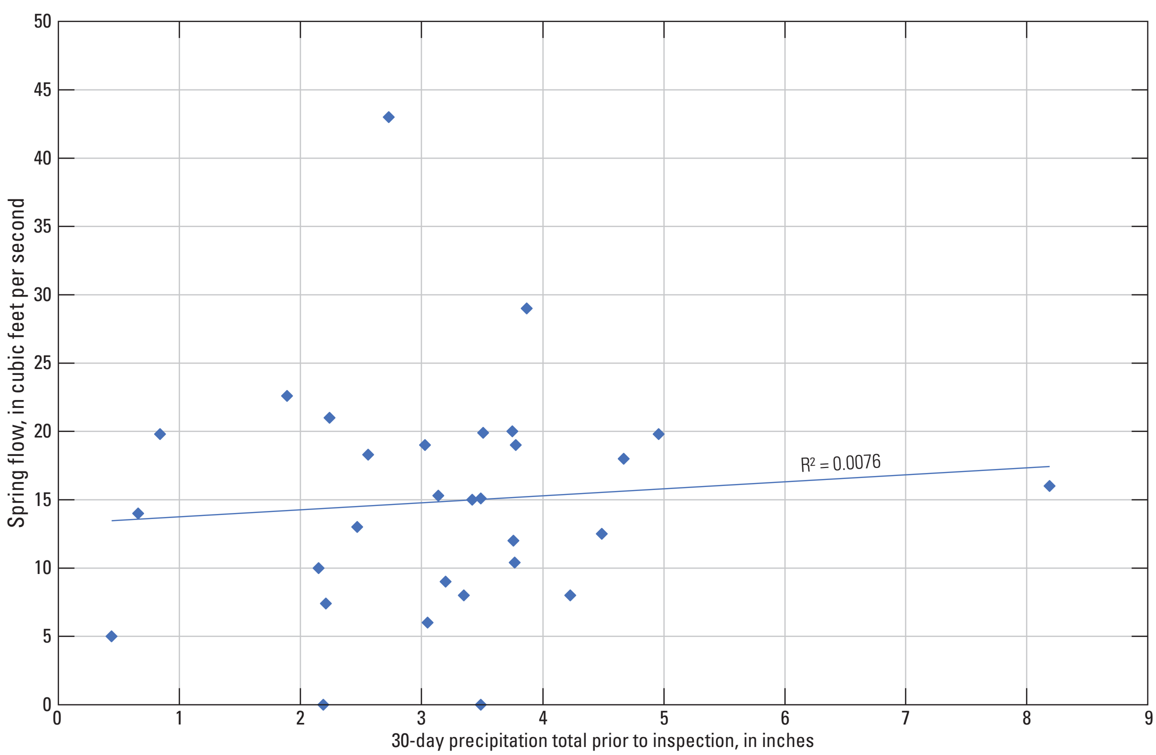

Figure 7. Linear regression analysis of the springflow with 30-day precipitation totals from National Oceanic and Atmospheric Administration weather station in Hot Springs, Virginia between April 2010 and May 2019. R^2 is the coefficient of determination.

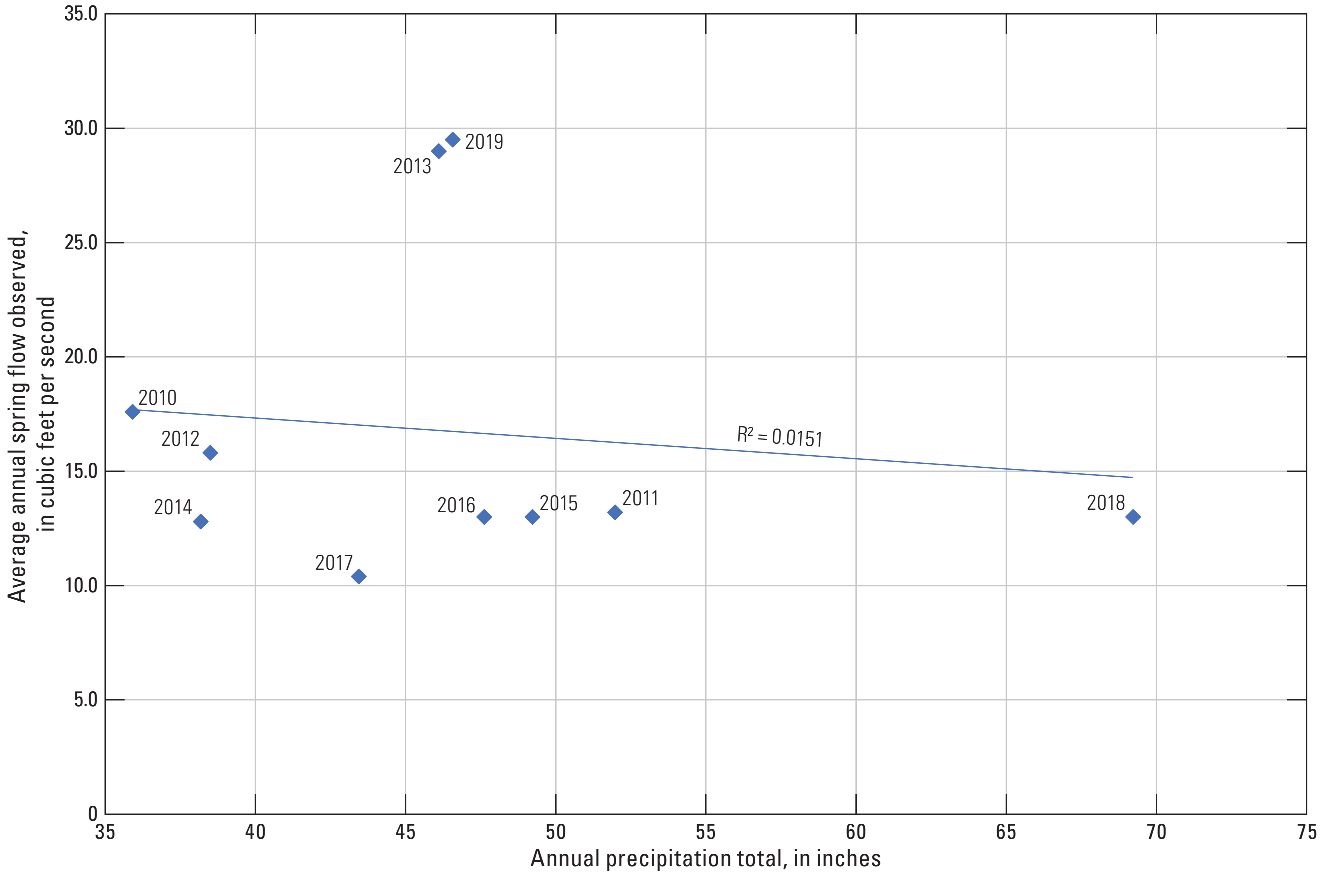

Figure 8. Linear regression analysis of the average annual springflow observed and the annual total precipitation amounts from National Oceanic and Atmospheric Administration weather station in Hot Springs, Virginia. R^2 is the coefficient of determination.

springflow values. Annual average springflow data were used to review trends over time, and the data showed little variation in flow over the study period.

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