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

Floods of June 28-29, 1998 in Ohio

By G. F. Koltun

Water-Resources Investigations Report 99-4192

In cooperation with the
Ohio Department of Natural Resources

U.S. DEPARTMENT OF THE INTERIOR
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Columbus, Ohio
1999

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
Area		
square mile (mi^2)	2.590	square kilometer
Volume		
cubic foot (ft^3)	28.32	liter
Flow rate		
cubic foot per second (ft^3/s)	.02832	cubic meter per second
Mass		
ton, short (2,000 lb)	0.9072	megagram
ton (short) per day	0.9072	megagram per day

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

During a 96-hour period extending from June 26 to June 30, 1998, a stalled frontal system produced a series of storms that dumped 10 inches or more of rain on parts of Ohio. The storms occurred at the end of a relatively wet month, resulting in flooding and widespread damage throughout much of central, east-central, and southeastern Ohio. Twenty-three Ohio counties were declared Federal and State disaster areas as a result of the storms and flooding with an estimated economic impact of nearly $178 million. Twelve storm or flood-related fatalities were reported. Flooding was most severe in the Ohio counties of Guernsey, Noble, and Washington, which lie roughly along a north-south line coincident with the band of heaviest rainfall. Some streams in those counties had peak streamflows with estimated recurrence intervals in excess of 100 years.

This report describes the meteorologic factors contributing to the floods and provides information on the resulting damages. Peak-streamflows, estimated recurrence intervals, and high-water elevation or stage data are reported for selected locations in the State.

INTRODUCTION

Storms during June 26–30, 1998, resulted in flooding and widespread damage throughout much of central, east-central, and southeastern Ohio. A total of 23 Ohio counties[1] were declared Federal and State disaster areas, thousands of people were evacuated, more than 100 roads were closed because of flooding, and tens of thousands of people were without power. Twelve people died in Ohio as a result of the storms and flooding; six of the deaths occurred in Noble County alone. Several of the communities that were severely affected by the June 1998 floods had endured severe flooding only 18 months earlier (Jackson and others, 1997).

Flood data are needed by Federal, State, and local agencies in order to make informed decisions about floodplain management and to provide information to assist in managing future flood emergencies. Given the extent and severity of the June 1998 floods, the U.S. Geological Survey (USGS), in cooperation with the Ohio Department of Natural Resources (ODNR), Division of Water, began a project to gather and describe pertinent flood information.

Purpose and Scope

This report describes the floods that occurred in Ohio in late June 1998. Peak-streamflow, estimated recurrence interval[2] and (or) high-water elevation or stage data are presented for selected locations within the State. The meteorologic factors contributing to the floods are described, and information is provided on the resulting damages.

Acknowledgments

This report represents a compilation of information supplied by many agencies and individuals. The author acknowledges the general support and contributions of the ODNR, Division of Water. Special thanks are extended to David H. Cashell and Michael Schiefer, both of ODNR, for their contributions to this report describing damages and elevations of high-water marks. The author also thanks Julia Dian-Reed and Richard Kane of the National Weather Service (NWS) for their contributions and guidance on the meteorology associated with the floods.

[1]Two counties were declared disaster areas as a result of storms that occurred on June 24–25, 1998.

[2]Recurrence interval, in years, is equal to the reciprocal of the annual exceedance probability for a flood of the given magnitude. It represents a long-term average frequency with which one would expect to experience a flood of the given magnitude and, as such, does not preclude the occurrence of two or more large recurrence-interval floods in any given shorter time span.

METEOROLOGY ASSOCIATED WITH THE FLOOD

The storms that produced the June 1998 floods were similar to the storms that produced severe flooding in southern Ohio 18 months earlier, in March 1997. Both storms involved frontal systems that stalled over Ohio with moisture-laden air being supplied from the Gulf of Mexico. Unlike the March 1997 floods, the June 1998 floods were immediately preceded by a fairly wet period that may have contributed to the severity of the floods.

Antecedent Conditions

May 1998. Precipitation for much of Ohio was below normal[3] during May 1998. The National Oceanic and Atmospheric Administration (NOAA) divides the State into 10 climatological divisions. As shown in figure 1, the northern divisions experienced significantly below-normal rainfall, the central divisions experienced moderately to slightly below normal rainfall, and the southern divisions experienced slightly above-normal rainfall.

June 1998. Rain fell at some place in Ohio on every day in June. Light, scattered showers fell during the first week of the month, with maximum total accumulations of less than 2 in. Most NOAA precipitation monitoring sites reported less than 1 in. of accumulation for the same period. Storms were common throughout June 9–17, during which many of the NOAA precipitation monitoring sites reported one or more single-day accumulations of rainfall in excess of 1 in. More rain fell around the State during the period June 18–25, with total accumulations for the period generally being much less than for June 9–17. As figure 1 shows, precipitation for June was above normal in all 10 NOAA divisions and in excess of 230 percent of normal in the three southern divisions. According to Cashell (1998), June 1998 ranks as the second wettest June for the State as a whole since 1883.

Storms of June 26–30, 1998

On Thursday, June 25, 1998, a weak low-pressure system was positioned over the western Great Lakes and a trailing cold front was positioned across Wisconsin, Iowa and eastern Nebraska. Warm, moist air was being carried from the Gulf of Mexico to Ohio by strong winds from the southwest. By 8:00 a.m. on Friday, June 26, 1998, the low-pressure system had moved east, and the trailing cold front was slowing down and dipping farther south across central Michigan to northern Illinois. The first heavy rainfall occurred in east-central Ohio between late Friday afternoon the 26th and early Saturday the 27th. By Saturday morning, the cold front had progressed farther to the south-southeast and became nearly stationary. At that point, the frontal boundary ran from northwestern Ohio to southeastern Ohio. This nearly stationary frontal boundary acted as a corridor or focus for a series of showers and thunderstorms, a phenomenon known as "training". When training occurs, rain falls repeatedly over the same general areas, frequently aggravating flooding due to highly saturated ground conditions. Depending on the size and conditions at the frontal boundary, training can last for 24 hours or more and cover several hundred square miles, or it can occur on a much smaller scale and last only a few hours.

A frontal boundary is an area where warm and cool air collide; such collision can result in lifting of the warm air mass and instability along the front, creating thunderstorms. In some cases, secondary, smaller scale frontal boundaries (called surface boundaries) form, resulting in scattered areas of even greater instability. During June 26–29, 1998, several surface boundaries formed in southeastern Ohio, as well as in some sections of central Ohio, resulting in several training episodes.

A surface boundary formed south of the front by late Saturday (the 27th) and moved southeast, causing more rainfall. The largest rainfall amounts occurred between June 27 and June 29, with more rainfall occurring earlier in the period for areas in the northwest and later in the period for areas in the southeast. Storms continued through June 30, however, most areas received 0.5 in. of rainfall or less from these final storms.

Isolines[4] of total accumulated precipitation for the 96-hour period from 8 a.m. eastern daylight time (EDT) on June 26, 1998, to 8 a.m. EDT on June 30, 1998 (fig. 2) show that Guernsy, Morgan, Noble, and Washington Counties received the most rainfall, with accumulations in excess of 10 in. By comparison, the 100-year, 5-day (120-hour) rainfall for this area is 6.98 in. (Huff and Angel, 1992).

A fairly isolated pocket of heavy rainfall also occurred in southwestern Franklin County and northwestern Pickaway County, with accumulations in excess of 9 in. The heaviest rainfall occurred in the Franklin-Pickaway County area during the early morning hours of June 29, 1998, when very unstable air along a surface boundary combined with very high moisture within the lowest layers of the atmosphere. The prevailing conditions set up a training pattern that resulted in 5 or more inches of rainfall over the area in less than 6 hours, an amount in excess of the 100-year, 6-hour rainfall for that area (Huff and Angel, 1992).

[3]"Normal" refers to the average value for the period 1961–90.

[4]Isolines are lines on a map (or chart) with each line representing a constant value of some feature.

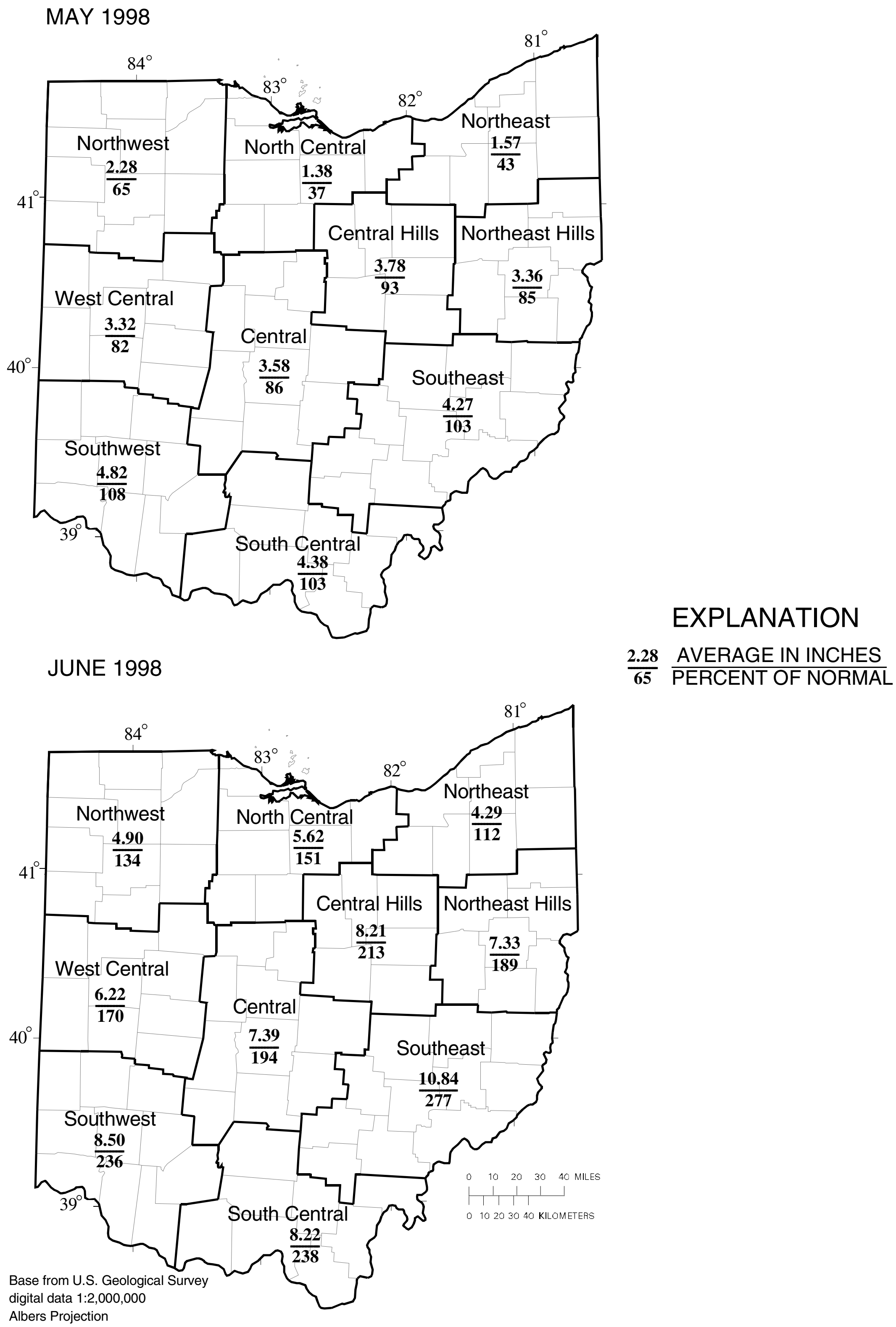

Figure 1. Regionally averaged monthly total precipitation and percentage of normal precipitation by National Weather Service Division, May and June 1998.

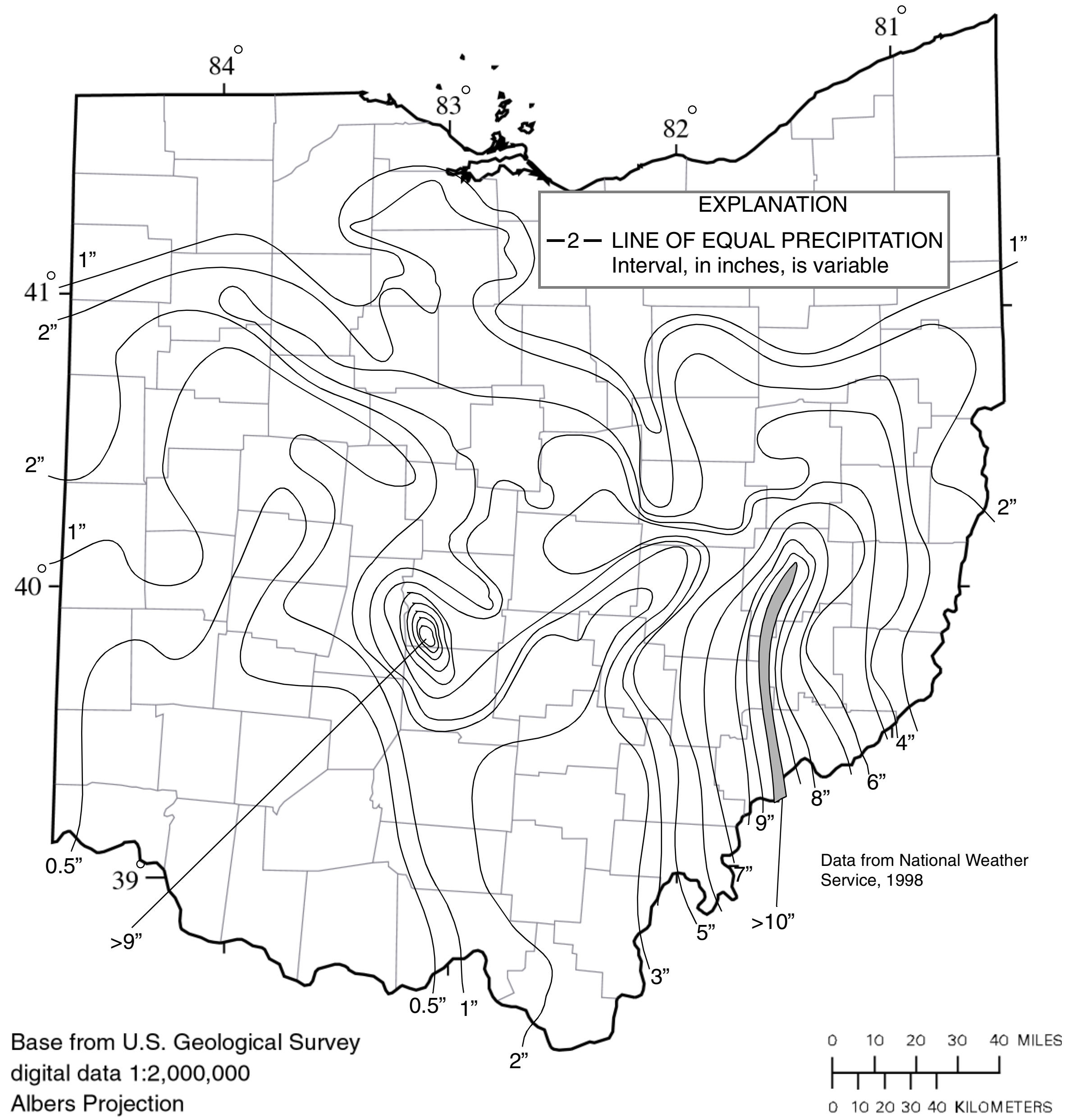

Figure 2. Isolines of total accumulated precipitation for the 96-hour period from 8 a.m. eastern daylight time (EDT) on June 26, 1998, to 8 a.m. EDT on June 30, 1998.

In addition to heavy rainfall, the storms frequently produced high winds and lightning. Many times storms that produce flash flooding are associated with an atmosphere that possesses very weak winds aloft. In this case, however, winds were rather strong aloft, resulting in occasional downburst straight-line winds and tornadoes. Additionally, these storms were very electrically active, producing significant cloud-to-ground lightning.

GENERAL DESCRIPTION OF THE FLOOD

The following sections provide information about the damages resulting from the June 28–29 storms and floods and their areal extent. Flood information is also provided for selected sites, streams, and (or) communities where specific flood-related data were collected. Many more communities and streams were affected by flooding than are mentioned here and their omission is not meant to reflect on the severity of those floods or the impact on the communities.

Areal Distribution of the Flood

The June 1998 storms caused flooding and other damage in much of central, east-central, and southeastern Ohio and in parts of northwestern, north-central, and central West Virginia. Flood and storm damage was sufficient to make 23 counties in Ohio (Athens, Belmont, Coshocton, Franklin, Guernsey, Harrison, Holmes, Jackson, Jefferson, Knox, Meigs, Monroe, Morgan, Morrow, Muskingum, Noble, Ottawa[5], Perry, Pickaway, Richland, Sandusky[5], Tuscarawas, and Washington) and 21 counties in West Virginia (Braxton, Cabell, Calhoun, Clay, Doddridge, Gilmer, Harrison, Jackson, Kanawha, Lewis, Marion, Marshall, Ohio, Pleasants, Ritchie, Roane, Tyler, Webster, Wetzel, Wirt and Wood) eligible for Federal disaster assistance (fig. 3). Flooding was most severe in the Ohio counties of Guernsey, Noble, and Washington and the West Virginia counties of Jackson, Kanawha, and Wood. All six counties lie roughly along a single north-south line coincident with the band of heaviest rainfall.

Flood Stages, Streamflows, Recurrence Intervals and High-Water Elevations

Peak-stage and peak-streamflow data for the June 1998 floods are listed in table 1 for selected stream locations in Ohio. Also listed are the maximum known stages and streamflows at these same locations prior to 1998 and the estimated recurrence-interval ranges for the June 1998 floods. The estimated recurrence-interval range was determined by comparing the peak streamflows to tables of peak streamflows and associated recurrence intervals computed from either (1) all available peak-streamflow data for the location using the Interagency Advisory Committee on Water Data (1982) guidelines for determining flood frequency, or (2) a regional regression equation for estimating flood-frequency data, developed by Koltun and Roberts (1990).

Peak streamflows for the June 1998 floods were determined either by use of standard USGS techniques for streamflow data collection and processing (Rantz and others, 1982) or by indirect means. Indirect determinations of peak discharge were made at four locations by the USGS. The slope-area method of determining peak discharge (Dalrymple and others, 1967) was used at three of the locations and the contracted-opening method (Matthai, 1967) was used at the fourth location. Both the slope-area and contracted-opening methods for indirectly determining peak discharge require that high-water marks be located and surveyed. Data gathered for indirect determinations of peak discharge discussed in this report are on file in the USGS, Water Resources Division district office in Columbus, Ohio.

The ODNR, Division of Water, identified and surveyed high-water marks after the floods at selected locations in Athens, Guernsy, Knox, Morrow, Muskingum, Noble, Perry, Tuscarawas, and Washington counties. Third-order-accuracy surveys were run to determine the elevations of the high-water marks reported in table 2.

Significant effort was expended during and after the floods to document peak streamflows on selected streams in the flood-affected areas. Details of some of those efforts are presented below for Duck Creek, Federal Creek, Hellbranch Run, the Little Muskingum River, and Wills Creek.

Duck Creek (Washington County) — Many communities that border Duck Creek and its tributary streams (such as Belle Valley, Caldwell, Elba, Lower Salem, Macksburg, and Whipple) experienced severe flooding during June, 1998, resulting in fatalities and extensive property damage. The USGS indirectly determined the peak discharge for Duck Creek by means of the slope-area method at a location approximately 7.7 mi downstream from the confluence of the East and West Forks of Duck Creek, in the community of Whipple (fig. 4). The slope-area calculations were based on data collected for about a 1,700-ft-long stream segment whose upstream end was approximately 200 ft downstream from the confluence of Whipple Run and Duck Creek. The peak streamflow calculated for Duck Creek is 41,600 ft^3/s (table 1). No streamflow data have been collected on Duck Creek from which to make a direct estimate of the flood recurrence interval; however, an estimate derived from the most current regional regression equations for estimating flood magnitude and frequency (Koltun and Roberts, 1990) indicates that the recurrence interval for the 1998 flood was greater than 100 years.

[5]Damages to Ottawa and Sandusky Counties occurred on June 24–25, 1998, primarily as a result of high winds and a tornado.

Figure 3. Ohio and West Virginia counties that received Federal disaster declarations as a result of storms and flooding in late June 1998.

Federal Creek (Athens County) — The Village of Amesville (figs. 4 and 5) has experienced several large floods this century including three large floods since 1963. Mayo and Webber (1969) stated that in March 1963, water was 7 ft deep on the main street (presumably the present State Route 550) and that a flood of similar magnitude occurred in the early 1920’s. Severe flooding occurred again in March 1997. Flood levels in 1997 were reported to be about 6 ft lower than those in 1998 (Federal Emergency Management Agency, 1998), indicating that the flood of 1997 reached levels somewhat higher than the 1963 flood. The flood of 1998 is the flood of record, with peak flood levels in the Village of Amesville exceeding 1963 levels by about 7-8 ft.

The USGS indirectly determined the peak discharge for Federal Creek by means of the slope-area method. The slope-area calculations were based on data collected for a stream segment beginning about 1,500 ft downstream from the confluence of Federal Creek and McDougal Branch and extending downstream approximately 9,800 ft. The peak streamflow calculated for the Federal Creek stream segment described above is 31,800 ft^3/s (table 1). No streamflow data have been collected on Federal Creek from which to make a direct estimate of the flood recurrence interval; however, an estimate derived from the most current regional regression equations for estimating flood magnitude and frequency (Koltun and Roberts, 1990) indicates that 1998 flood was considerably in excess of a 100-year flood.

Table 1. Peak stages and streamflows at selected locations in Ohio, June 1998

[Abbreviations: mi^2, square miles; ft, feet above an arbitrary datum; ft^3/s, cubic feet per second; Cr., creek; R., river; pr, present; —, not determined or not applicable; <, less than; >, greater than; ≈, approximately. Source: Recurrence intervals calculated from U.S. Geological Survey data. Other data from U.S. Geological Survey reports or data bases]

Permanent station no.	Stream and place of determination	Drainage area (mi^2)	Gage datum (feet above sea level)	Period of systematic record (water years)[1]	Maximum prior to 1998			Maximum in 1998			Estimated recurrence-interval range for June 1998 (years)
					Year	Stage (ft)	Discharge (ft^3/s)	Date	Stage (ft)	Discharge (ft^3/s)	
03111500	Short Cr. at Dillonvale	123	675.10	1941-pr	1990	12.27	8,200	6/29/98	6.74	1,950	<2
03111548	Wheeling Cr. below Blaine	97.7	699.11	1983-87 1989-pr	1994	7.93	5,110	6/28/98	8.21	5,470	≈10
03114000	Captina Cr. at Armstrong Mills	134	739.53	1927-35 1959-pr	1980	17.48	21,900	6/28/98	12.50	10,500	5-10
03115400	Little Muskingum R. at Bloomfield	210	645.99	1959-81 1996-pr	1963	28.08	21,200	6/28/98	30.78	32,300[2]	>100
03136500	Kokosing R. at Mt. Vernon	202	981.16	1953-pr	1959	18.19	38,000	6/29/98	14.82	10,000	10-25
03142000	Wills Cr. at Cambridge[3]	406	772.34	1926-28 1937-pr	1963 1980	22.55 24.51[4]	8,500 7,860	6/29/98	26.91	11,400	50-100[5]
03144000	Wakatomika Cr. nr Frazeysburg	140	748.12	1936-pr	1979	14.07	16,800	6/27/98	12.44	10,500	10-25
03146500	Licking R. near Newark	537	779.02	1940-pr	1959	20.30	45,000	6/29/98	11.69	10,800	<2
03159500	Hocking R. at Athens	943	611.26	1915-pr	1907[6]	27.00	50,000	6/29/98	15.46	8,430	<2
03159540	Shade R. near Chester	156	576.91	1965-pr	1997	31.44	15,600	6/28/98	20.56	3,850	2-5
03223000	Olentangy R. at Claridon	157	961.72	1947-pr	1959	16.77	14,900	6/30/98	12.82	5,000	5-10
03223425	Whetstone Cr. at Mt. Gilead	37.9	1074.00	1997-pr	1997	8.00	1,460	6/27/98	13.64	5,650	—
03228300	Big Walnut Cr. at Sunbury	101	≈945	1989-pr	1997	11.20	6,700	6/29/98	11.05	5,850	5-10
03230310	Little Darby Cr. at West Jefferson	162	≈785	1993-pr	1997	15.53	6,240	6/29/98	11.93	2,790	<2[7]
03230450	Hellbranch Run near Harrisburg	37.0	≈785	1993-pr	1996	9.80	1,300	6/29/98	14.19	3,180[2]	10-25[7]

Table 1. Peak stages and streamflows at selected locations in Ohio, June 1998—Continued

[Abbreviations: mi^2, square miles; ft, feet above an arbitrary datum; ft^3/s, cubic feet per second; Cr., creek; R., river; pr, present; —, not determined or not applicable; <, less than; >, greater than; ≈, approximately. Source: Recurrence intervals calculated from U.S. Geological Survey data. Other data from U.S. Geological Survey reports or data bases]

Permanent station no.	Stream and place of determination	Drainage area (mi^2)	Gage datum (feet above sea level)	Period of systematic record (water years)[1]	Maximum prior to 1998			Maximum in 1998			Estimated recurrence-interval range for June 1998 (years)
					Year	Stage (ft)	Discharge (ft^3/s)	Date	Stage (ft)	Discharge (ft^3/s)	
03230500	Big Darby Cr. at Darbyville	534	713.69	1922-35 1938-pr	1959	17.94	49,000	6/29/98	14.77	17,100	≈10
03230800	Deer Cr. at Mt. Sterling	228	836.25	1967-81 1996-pr	1968	11.87	11,600	6/29/98	11.95	11,200	10-25
—	Duck Cr. at Whipple	258	—	—	—	—	—	6/28/98	—	41,600[2]	>100[7]
—	Federal Cr. at Amesville	69.6	—	—	—	—	—	6/29/98	—	31,800[2]	>100[7]

[1]A water year is the 12-month period from October 1 through September 30 and is designated by the calendar year in which it ends.
[2]Peak discharge determined indirectly.
[3]Streamflow at this site has been regulated since 1937. Maximums reported for this site are for the regulated period.
[4]Peak stage affected by backwater.
[5]Streamflow affected by regulation. Recurrence-interval information obtained from Federal Emergency Management Agency, Flood Insurance Study (1989).
[6]Peak occurred before period of systematic record.
[7]Estimate based on regional regression equations developed by Koltun and Roberts (1990).

Table 2. Elevation of high-water marks at selected locations in Ohio for June 1998 flooding

[Data collected and compiled by the Ohio Department of Natural Resources, Division of Water]

Community	County	Stream	Latitude	Longitude	Elevation[1] (feet)	Description and location of high-water mark
Unincorporated Area	Guernsey	Leatherwood Creek	40°01′40″	81°33′54″	800.2	Mud line on front door of former Hunan Restaurant[2]
Unincorporated Area	Guernsey	Leatherwood Creek	40°01′28″	81°33′59″	799.9	Mud line on garage door of Decorator's Outlet store
City of Cambridge	Guernsey	Wills Creek	39°59′57″	81°34′26″	792.4	Mud line on side of Budgethost Motel building
Unincorporated Area	Guernsey	Wills Creek	39°59′55″	81°34′23″	801.1	Mud line on upstream side of levee gate for railroad
Unincorporated Area	Guernsey	Chapman Run	39°58′58″	81°34′26″	801.2	Mud line on front door of Suburban Tractor Company
Village of Byesville	Guernsey	Wills Creek	39°58′58″	81°32′43″	801.6	Mud line on storage tank at wastewater plant
Village of Byesville	Guernsey	Wills Creek	39°58′37″	81°32′37″	801.6	Mud line on garage door at 103 Tenth Street
Unincorporated Area (Derwent)	Guernsey	Wills Creek	39°55′17″	81°32′22″	804.8	Mud line on front door of house along State Route 313
Unincorporated Area (Fairview)	Guernsey	Buffalo Creek	39°54′10″	81°33′05″	808.9	Mud line on front door of Cross Road Tavern
Unincorporated Area (Fairview)	Guernsey	Buffalo Creek	39°54′09″	81°33′04″	808.9	Mud line on display case inside Trading Station
Village of Belle Valley	Noble	West Fork Duck Creek	39°47′22″	81°33′23″	751.8	Mud line on front door of American Legion building
Village of Belle Valley	Noble	West Fork Duck Creek	39°47′22″	81°33′13″	750.8	Mud line on wall of municipal building
Village of Belle Valley	Noble	West Fork Duck Creek	39°47′07″	81°33′04″	748.2	Mud line on window of U.S. Post Office building
Village of Belle Valley	Noble	West Fork Duck Creek	39°47′13″	81°32′58″	748.2	Mud line on front door of Belle Valley School building
Village of Caldwell	Noble	West Fork Duck Creek	39°44′43″	81°31′02″	729.0	Mud line on front door of municipal building
Village of Caldwell	Noble	West Fork Duck Creek	39°44′40″	81°30′58″	729.2	Mud line on front door of K of C Church building
Village of Dexter City	Noble	West Fork Duck Creek	39°39′44″	81°28′26″	692.7	Mud line on office door at Dexter Hardwood Company
Village of Dexter City	Noble	West Fork Duck Creek	39°39′22″	81°28′18″	688.2	Mud line on front door of Dexter town hall building
Village of Dexter City	Noble	West Fork Duck Creek	39°39′05″	81°28′27″	687.9	Mud line on office door at B & N Coal Company

Table 2. Elevation of high-water marks at selected locations in Ohio for June 1998 flooding—Continued

[Data collected and compiled by the Ohio Department of Natural Resources, Division of Water]

Community	County	Stream	Latitude	Longitude	Elevation[1] (feet)	Description and location of high-water mark
Village of Macksburg	Washington	West Fork Duck Creek	39°37′52″	81°27′44″	682.2	Mud line on back door of house at Broad Street and State Route 821
Village of Macksburg	Washington	West Fork Duck Creek	39°37′45″	81°27′21″	680.6	Mud line on front door of house at 151 Main Street
Unincorporated Area (Elba)	Washington	West Fork Duck Creek	39°36′29″	81°24′54″	672.1	Mud line on window of building next to Elba Community Church
Unincorporated Area (Elba)	Washington	West Fork Duck Creek	39°36′27″	81°24′43″	671.9	Mud line on front of Castle Hall building
Village of Lower Salem	Washington	East Fork Duck Creek	39°33′40″	81°23′46″	665.3	Mud line on window of red brick building at corner of Main Street and Whipple Road
Unincorporated Area (Whipple)	Washington	Duck Creek	39°31′16″	81°24′50″	644.0	Mud line on wall of Whipple Baptist Church
City of New Lexington	Perry	Little Rush Creek	39°43′03″	82°12′29″	863.9	Mud line on garage at 311 Water Street
City of New Lexington	Perry	Little Rush Creek	39°43′04″	82°12′45″	862.5	Mud line on manufactured home at 129 Union Street
Village of Corning	Perry	Sunday Creek	39°36′15″	82°05′21″	734.8	Mud line on door of recreation center building
Village of Corning	Perry	Sunday Creek	39°36′08″	82°05′20″	733.6	Mud line on door of American Legion Post 327 building
Village of Corning	Perry	Sunday Creek	39°36′09″	82°05′15″	733.3	Mud line on door of John’s Place store
Village of Corning	Perry	Sunday Creek	39°35′59″	82°05′23″	732.0	Mud line on side of Monroe Township Garage
Village of Corning	Perry	Sunday Creek	39°35′51″	82°05′26″	731.9	Mud line on door of storage building at 156 Lenert St.
Village of Glouster	Athens	Sunday Creek	39°30′11″	82°04′57″	685.9	Mud line on side of Kroger Store building
Village of Glouster	Athens	Sunday Creek	39°29′45″	82°05′10″	682.8	Mud line on door of Boy Scout building
Village of Trimble	Athens	Sunday Creek	39°29′04″	82°04′47″	681.6	Mud line on services sign at Trimble Christian Church
Village of Trimble	Athens	Sunday Creek	39°29′05″	82°04′39″	681.3	Mud line on inside of village hall office
Village of Amesville	Athens	Federal Creek	39°24′04″	81°57′26″	644.8	Mud line on inside of county highway building
Village of Amesville	Athens	Federal Creek	39°24′01″	81°57′20″	644.8	Mud line on outside of municipal building
Village of Amesville	Athens	Federal Creek	39°23′58″	81°57′15″	644.7	Mud line on house at corner of Liberty & Monroe Streets

Table 2. Elevation of high-water marks at selected locations in Ohio for June 1998 flooding—Continued

[Data collected and compiled by the Ohio Department of Natural Resources, Division of Water]

Community	County	Stream	Latitude	Longi-tude	Eleva-tion[1] (feet)	Description and location of high-water mark
Village of Frazeysburg	Muskingum	Wakatomika Creek	40°06′29″	82°07′38″	751.4	Observation by village officials of peak stage at top of County Road 8 bridge pier
Village of Mount Gilead	Morrow	Whetstone Creek	40°32′39″	82°49′45″	1073.2	Mud line on side of manufactured home at 22 North Court Drive
Village of Mount Gilead	Morrow	Whetstone Creek	40°32′40″	82°49′56″	1068.9	Mud line on foundation block of Morrow County fairground building
Unincorporated Area	Morrow	Whetstone Creek	40°32′34″	82°50′26″	1060.8	Mud line on side of electric box at Thistlewood Apartments
City of Mount Vernon	Knox	Kokosing River	40°23′04″	82°28′06″	974.0	Mud line on wood fence at 123 Quarry Street
City of Uhrichsville	Tuscarawas	Stillwater Creek	40°24′30″	81°20′39″	845.5	Observation by homeowner at 515 Morris Street of peak stage at top of creek bank
City of Uhrichsville	Tuscarawas	Stillwater Creek	40°24′10″	81°20′50″	846.4	Mud line on front door of house at 207 Lynn Street
City of Uhrichsville	Tuscarawas	Stillwater Creek	40°23′22″	81°20′52″	849.8	Mud line on side door to auto parts store at corner of Jay and Second Streets

[1]All elevations are referenced to sea level (National Geodetic Vertical Datum of 1929).

[2]Use of trade, brand, or firm names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

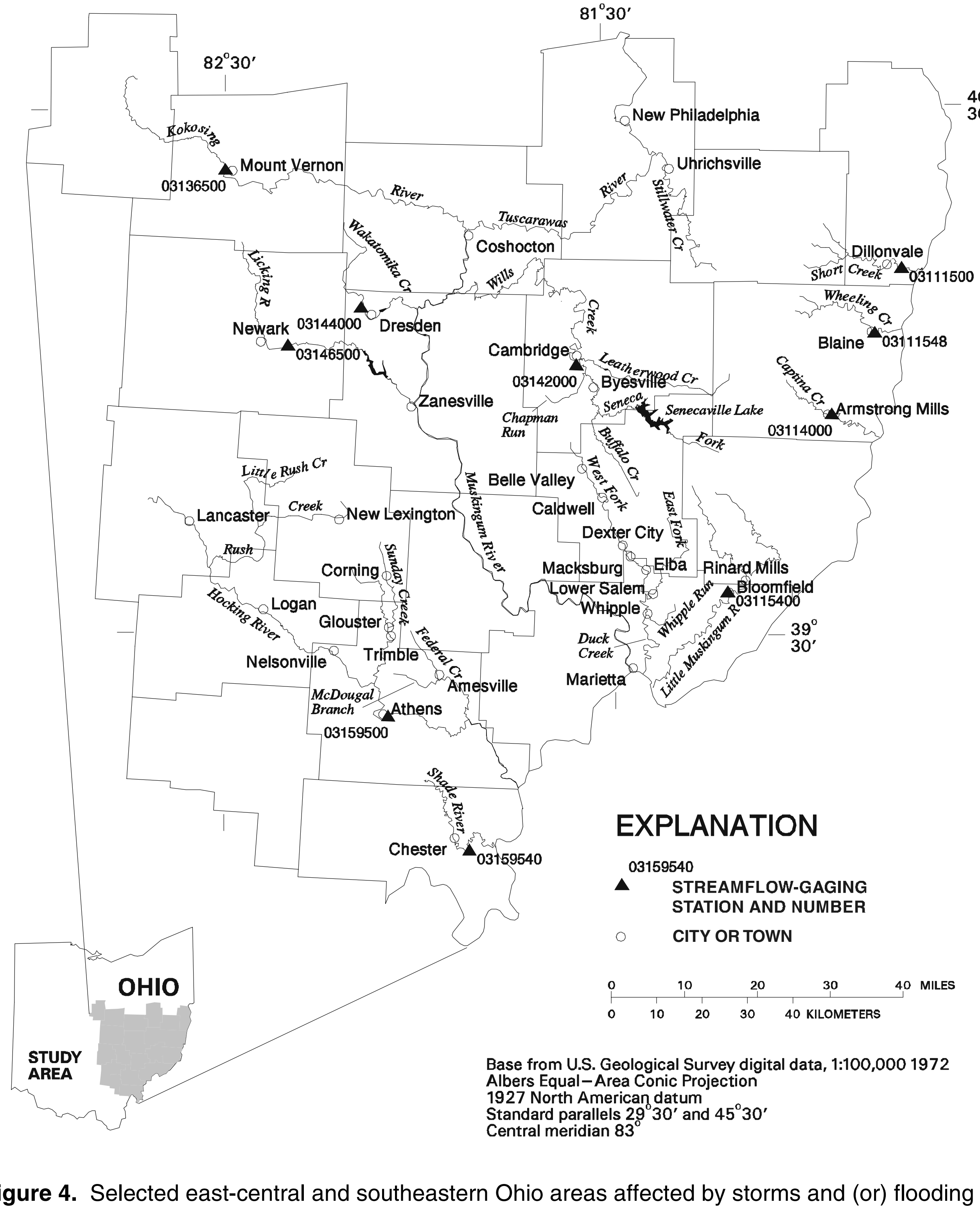

Figure 4. Selected east-central and southeastern Ohio areas affected by storms and (or) flooding in late June 1998.

Photograph by Demitrios Prokos (reproduced with permission)

Figure 5. Aerial view of flood waters at the confluence of McDougal Branch and Federal Creek in the Village of Amesville, Ohio (view looking northeast).

Hellbranch Run (Franklin County) — Hellbranch Run, a tributary to Big Darby Creek, drains about 37.7 mi^2 in southern Franklin County (fig. 6). The USGS has operated a streamflow-gaging station on Hellbranch Run near Harrisburg, Ohio (station number 03230450), since October, 1992. Floodwaters prevented USGS crews from reaching the gage during the peak of the flood on June 29, 1998. The apparent magnitude of the flood relative to previously measured streamflows required that the peak discharge be determined indirectly.

Conditions at the streamflow-gaging station were not suitable for an indirect determination of discharge. Consequently, the peak discharge was determined indirectly by means of the contracted-opening method (Matthai, 1967) at the Beatty Road bridge, approximately 2.1 mi north of the gaging-station site. The peak discharge determined for the Beatty Road site was transferred to the streamflow-gaging station site by means of a drainage-area-ratio-based function. The peak streamflow calculated for Hellbranch Run near Harrisburg is 3,180 ft^3/s (table 1). The streamflow-gaging station on Hellbranch Run has not been in operation long enough for reliable computation of flood-frequency information; however, estimates based on regional regression equations developed for Ohio (Koltun and Roberts, 1990) indicate that a flood of that magnitude would have a recurrence interval of between 10 and 25 years.

Daily suspended-sediment discharge has been determined for Hellbranch Run near Harrisburg since October, 1992. The streamflow-gaging station is equipped with a pumping sampler controlled so as to collect water samples at every 0.5 ft of rise in the water surface and at every 1.0 ft of fall in the water surface. Samples collected by the pumping sampler were augmented by samples collected by USGS personnel (once they could reach the site). The suspended-sediment load for June 29, 1998 is estimated to have been 4,420 tons and represented more than half of the suspended-sediment load passing that site during the entire 1998 water year.

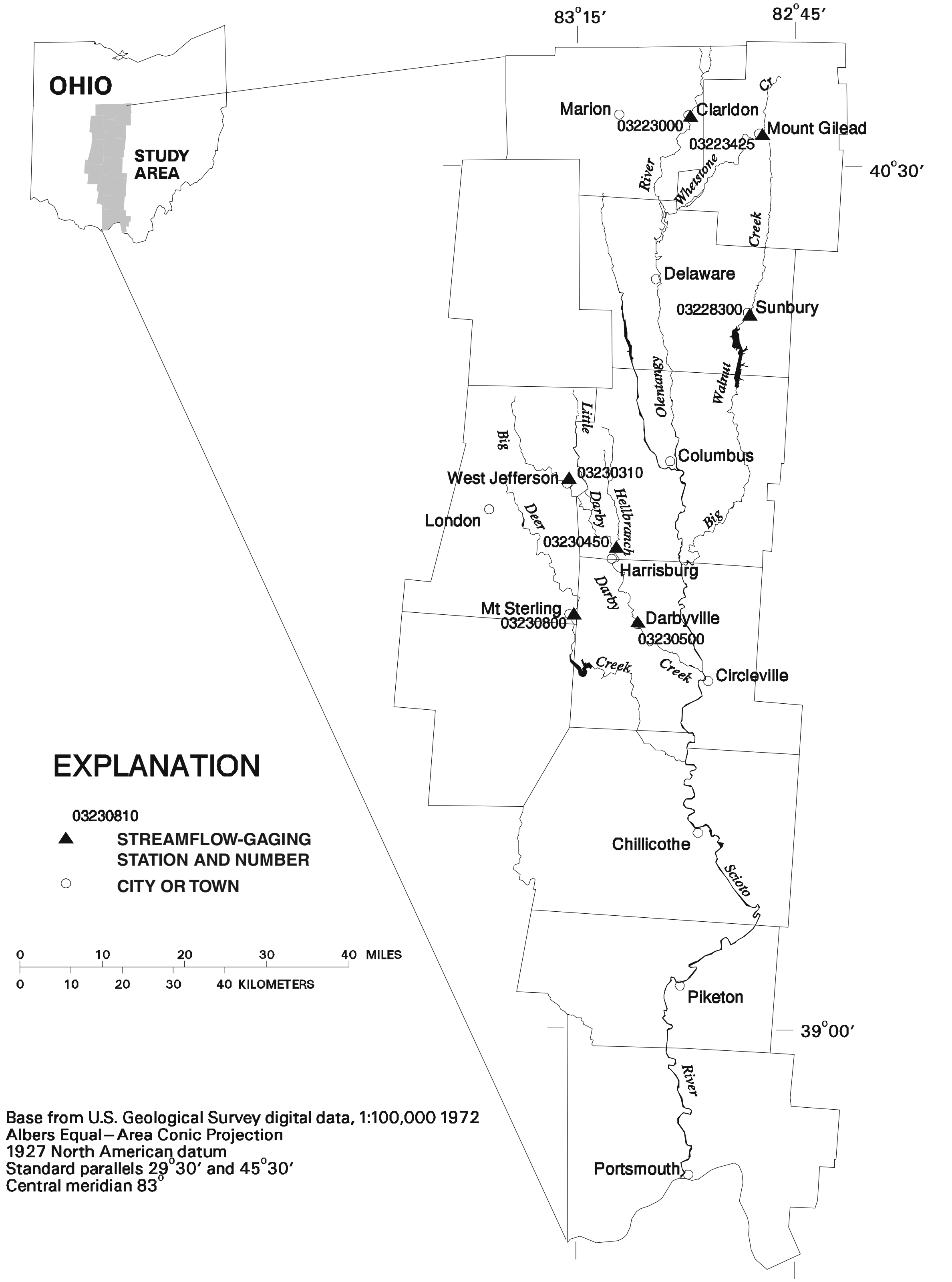

Figure 6. Selected central and south-central Ohio areas affected by storms and (or) flooding in late June 1998.

Figure 7. Flooding from Wills Creek along State Route 209 in Cambridge, Ohio (view looking northwest).

Little Muskingum River (Washington County) — Peak-stage and peak-streamflow for the June 1998 flood were the largest recorded during systematic operation of the streamflow-gaging station on the Little Muskingum River at Bloomfield (fig. 4 and table 1) and may have been the largest to have occurred this century. Prior to the 1998 flood, the March 1963 flood was considered to have been the largest since 1913. Data are insufficient to ascertain whether the 1998 flood magnitude was greater than the 1913 flood magnitude at this site.

The streamflow-gaging station on the Little Muskingum River at Bloomfield, Ohio (station number 03115400), was unreachable during the flooding; consequently, the USGS indirectly determined the peak discharge for the Little Muskingum River at Bloomfield by means of the slope-area method. The slope-area calculations were based on data collected for a 2,353-ft-long stream segment whose downstream end was approximately 28,200 ft upstream from the gage in the community of Rinard Mills (fig. 4). The peak discharge determined for the Rinard Mills site was transferred to the streamflow-gaging station site by means of a drainage-area-ratio-based function. The peak streamflow calculated for the Little Muskingum River at Bloomfield is 32,300 ft^3/s (table 1).On the basis of an analysis of peak streamflows using the Interagency Advisory Committee on Water Data (1982) guidelines for determining flood frequency, the recurrence interval for the June 1998 flood is estimated to be greater than 100 years.

Wills Creek (Guernsey County) — The City of Cambridge and the Village of Byesville were severely impacted by flooding from Wills Creek (figs. 4 and 7). The USGS has operated a streamflow-gaging station on Wills Creek at Cambridge, Ohio (station number 03142000) (fig. 4), since May 1937. A gage was also operated during the period June 1926 to September 1928. Senecaville Lake, located on Seneca Fork, a tributary of Wills Creek, has regulated streamflow in Wills Creek at both Cambridge and Byesville since about 1937. The U.S. Army Corps of Engineers operates the dam on Senecaville Lake principally for flood control and was not releasing water from the dam during the peak of the flood. However, on June 29, 1998, water levels in Senecaville Lake came within less than 1 ft of the spillway crest and eventually reached a record peak level of 842.39 ft above sea level (0.17 ft lower than the spillway crest) on July 3, 1998 (Gary Mankin, U.S. Army Corps of Engineers, written commun., 1999).

On June 29, 1998, the streamflow-gaging station on Wills Creek at Cambridge recorded a record peak stage of 26.91 ft with a corresponding streamflow of 11,400 ft^3/s. The peak stage of 26.91 ft, which corresponds to an elevation of 799.25 ft above sea level, is larger than any historically documented peak stage at that site (including pre-regulation peaks dating to as early as 1913). A USGS crew measured a streamflow of 9,490 ft^3/s (at a stage of 25.30 ft) on June 30, once floodwaters had receded sufficiently to gain access to the gage. Water levels on Wills Creek at Cambridge, Ohio, exceeded the NWS flood stage of 15 ft for a period of approximately 130 hours, spanning 7 calendar days.

Flood and Storm Damages in Ohio

By David H. Cashell[6]

The impact of the June 1998 storms and floods to Ohio's citizens was considerable on both a personal and public level. An estimated 9,000 people were evacuated during the flooding. Twelve deaths were related to the storms and floods in Ohio: eight by drowning and one each due to lightning, heart attack, electrocution, and injuries sustained during a tornado. The fatalities occurred in Belmont (2), Fairfield (1), Guernsey (1), Meigs (1), Noble (6), and Washington (1) Counties. Information compiled and reported by the Ohio Emergency Management Agency (OEMA) indicates that access to the flood-stricken areas was hampered by impassable roads. More than 100 road closures occurred throughout the area, including periodic closings of I–70 and I–77. During the peak of the disaster, more than 24,000 residences were without electricity and in excess of 5,800 were without telephone service. At one point during the flooding, five public water-supply systems were not operating and at least 24 others were operating under boil-water advisories because of potential contamination of source supplies, treatment facilities, or distribution systems by floodwaters.

Estimates of the damages associated with the June 1998 storms and floods, prepared by the OEMA, indicate that the economic impact to Ohio's citizens, communities, and businesses may approach $178 million. These estimates include individual assistance and temporary housing, $14.9 million (includes cost of purchased trailers); public assistance, $33.6 million; Small Business Administration (SBA) loans (businesses, homes, and churches), $24.1 million; insured losses, $47 million; agriculture-related assistance, $3.2 million; Federal highways, $28.5 million; Natural Resources Conservation Service (streambank stabilization/repair and erosion control), $17 million; and other State and Federal agency and volunteer organization expenditures, $9.6 million. OEMA also estimates that fourteen mitigation projects costing $18 million will be undertaken.

[6]Hydrologist, Ohio Department of Natural Resources, Division of Water

Effect of Storms and Floods on Public Infrastructure

The June 1998 storms and floods resulted in more than $36 million damage to public infrastructure (which includes roads, bridges, water-control facilities, public buildings, public utilities, and parks and recreation facilities) in north-central and eastern Ohio. Categorized infrastructure damage, listed by county and state agency, is summarized in table 3 (at back of report).

Effect of Storms and Floods on Private Property

The June 1998 storms and floods affected many residences and businesses throughout north-central and eastern Ohio. More than 7,000 homes were affected; temporary-housing applications approved totaled 4,160. At least 1,050 structures were completely destroyed or declared uninhabitable. The SBA's records indicate that at least 292 business or commercial structures incurred some damage during the storms and floods. The effects of the June 1998 storms and floods on residential and commercial structures and other personal property are reflected by the number of applications for assistance and by the approved loan and grant amounts. These disaster-recovery statistics for individual and other private-sector assistance are summarized in table 4 (at back of report).

SUMMARY

Storms during June 26–30, 1998, resulted in flooding and widespread damage throughout much of central, east-central, and southeastern Ohio (flood and storm damage also occurred throughout parts of northwestern, north-central, and central West Virginia). The largest rainfall amounts occurred in Ohio between June 27 and June 29, with more rainfall occurring earlier in the period for areas in the northwest and later in the period for areas in the southeast. More than 10 in. of rain fell during a 4-day period in parts of Guernsy, Morgan, Noble, and Washington Counties and more than 9 in. of rain fell during the same period in a small part of southern Franklin and northern Pickaway Counties.

Twenty-three Ohio counties were declared Federal disaster areas as a result of the storms and flooding with an estimated economic impact of nearly $178 million. Twelve storm or flood-related fatalities were reported. More than 100 road closures resulted from flooding, including periodic closings of I–70 and I–77. During the peak of the disaster, more than 24,000 residences were without electricity and in excess of 5,800 residences were without telephone service.

Peak streamflows were determined for several streamflow-gaging stations in the flood affected areas as well as for some ungaged stream locations. Estimated recurrence intervals associated with those flood peaks were quite variable as might be expected given the areal variability in rainfall amounts. Streams draining areas with the largest rainfall accumulations generally experienced the more severe floods, as indicated by larger recurrence intervals. At least three streams had floods with associated recurrence intervals estimated to be greater than 100 years.

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Table 3. Infrastructure-damage estimates related to the June 1998 storms and flooding in Ohio

[All figures in dollars; Damage estimates provided by the Ohio Emergency Management Agency unless stated otherwise, Department of Public Safety. Abbreviations: ODOT, Ohio Department of Transportation; ODNR, Ohio Department of Natural Resources: ONG, Ohio National Guard]

County or State of Ohio Agency	Debris Removal	Emergency Protective measures	Roads and bridges	Water-control facilities	Public buildings, facilities,	Public utilities	Parks and recreation	Other	Total dollars
Athens	10,800	0	723,850	0	0	0	0	0	734,650
Belmont	0	0	2,782,500	0	0	0	0	0	2,782,500
Coshocton	31,000	0	75,000	0	0	0	0	0	106,000
Franklin[1]	2,000	2,000	34,300	0	40,000	0	0	0	78,300
Guernsey	335,000	0	1,258,000	20,000	34,000	1,240,000	0	0	2,887,000
Harrison	5,900	0	102,000	0	0	0	0	0	107,900
Holmes	55,000	5,000	76,000	0	0	0	0	0	136,000
Jackson	80,000	2,000	735,000	0	0	0	0	0	817,000
Jefferson	103,600	0	109,700	0	455,760	0	0	0	669,060
Knox	0	150,000	675,000	0	0	0	100,000	0	925,000
Meigs	395,000	75,000	2,612,000	0	0	0	0	0	3,082,000
Monroe	16,000	0	1,495,100	35,000	0	0	0	0	1,546,100
Morgan	315,000	0	316,000	11,000	26,000	4,000	16,000	100,000	788,000
Morrow	38,000	5,000	570,000	13,000	15,000	11,000	0	0	652,000
Muskingum	170,000	0	735,000	0	0	678,000	0	0	1,583,000
Noble	1,790,000	0	1,270,000	0	2,310,000	450,000	140,000	0	5,960,000
Ottawa	330,000	178,500	0	0	0	0	0	0	508,500
Perry	150,810	12,300	670,810	12,000	136,022	0	8,700	0	990,642
Pickaway	15,000	10,000	77,371	0	4,500	0	0	0	106,871
Richland	10,000	0	536,000	0	0	50,000	0	0	596,000

Table 3. Infrastructure-damage estimates related to the June 1998 storms and flooding in Ohio—Continued

[All figures in dollars; Damage estimates provided by the Ohio Emergency Management Agency unless stated otherwise, Department of Public Safety. Abbreviations: ODOT, Ohio Department of Transportation; ODNR, Ohio Department of Natural Resources: ONG, Ohio National Guard]

County or State of Ohio Agency	Debris Removal	Emergency Protective measures	Roads and bridges	Water-control facilities	Public buildings, facilities,	Public utilities	Parks and recreation	Other	Total dollars
Sandusky[2]	136,000	0	0	0	0	0	0	0	136,000
Tuscarawas	8,100	0	153,300	0	0	0	0	0	161,400
Washington	476,500	187,600	2,757,200	3,000	307,000	800,200	68,500	2,000,000	6,600,000
ODOT	3,500	0	819,689	0	10,355	0	0	0	833,544
ODNR	91,497	33,542	28,947	76,448	35,109	2,535	117,720	0	385,798
ONG	0	0	0	0	3,677,920	0	43,500	0	3,721,420
Total dollars	4,568,707	660,942	18,612,767	170,448	7,051,666	3,235,735	494,420	2,100,000	36,894,685

[1]Damage estimates provided by the Franklin County Emergency Management Agency (Vernon Poe, written commun., 1999).

[2]Damage estimates provided by the Sandusky County Emergency Management Agency (Bernadine Parrish, oral communication, 1999), the Ottawa-Sandusky-Seneca Joint Solid Waste Management District (Tim Wasserman, oral communication, 1999), and the Sandusky County Engineer's Office (Kris Burdette, oral communication, 1999)

Table 4. Private and personal property damage recovery estimates for the June 1998 storms and flooding in Ohio

[All grant and loan figures are in dollars; Disaster recovery estimates provided by the Ohio Emergency Management Agency unless stated otherwise, Department of Public Safety. FEMA, Federal Emergency Management Agency; SBA, Small Business Administration]

County	FEMA temporary housing grants		SBA home and personal property loans		SBA Business and economic injury loans		State of Ohio individual and/or family grants		Total
	Number of applica-tions	Amount approved	Number of applica-tions	Amount approved	Number of applica-tions	Amount approved	Number of applica-tions approved	Amount approved	
Athens	328	747,811	61	1,690,300	20	576,700	122	542,181	3,556,992
Belmont	204	374,617	35	653,200	3	44,500	47	71,536	1,143,853
Coshocton	22	23,944	3	19,200	0	0	5	16,523	59,667
Franklin	196	331,547	48	633,100	11	157,900	83	162,105	1,284,652
Guernsey	1,033	1,745,621	191	2,530,400	100	2,734,900	355	1,172,695	8,183,616
Harrison	12	14,210	1	3,800	0	0	5	7,856	25,866
Holmes[1]	0	0	0	0	0	0	0	0	0
Jackson	73	117,711	13	347,000	3	72,500	24	70,719	607,930
Jefferson	98	307,926	27	493,400	2	1,500	38	144,575	947,401
Knox	192	315,649	39	427,600	5	17,300	37	66,815	827,364
Meigs	120	198,327	17	487,600	6	72,300	35	234,143	992,370
Monroe	134	200,020	17	188,500	2	10,000	28	142,750	541,270
Morgan	87	143,632	9	175,300	11	166,200	26	80,603	565,735
Morrow	10	16,998	2	31,600	0	0	2	2,330	50,928
Muskingum	303	386,350	56	587,100	11	127,200	78	149,192	1,249,842
Noble	374	964,316	119	3,017,200	47	1,888,000	145	739,270	6,608,786
Ottawa	37	48,018	16	322,000	5	64,000	15	63,117	497,135
Perry	146	343,723	19	403,500	8	141,800	54	244,524	1,133,547

Table 4. Private and personal property damage recovery estimates for the June 1998 storms and flooding in Ohio—Continued

[All grant and loan figures are in dollars; Disaster recovery estimates provided by the Ohio Emergency Management Agency unless stated otherwise, Department of Public Safety. FEMA, Federal Emergency Management Agency; SBA, Small Business Administration]

County	FEMA temporary housing grants		SBA home and personal property loans		SBA Business and economic injury loans		State of Ohio individual and/or family grants		Total
	Number of applica-tions	Amount approved	Number of applica-tions	Amount approved	Number of applica-tions	Amount approved	Number of applica-tions approved	Amount approved	
Pickaway	23	38,257	3	42,300	0	0	5	9,759	90,316
Richland	30	30,120	10	141,100	9	320,600	4	6,177	497,997
Sandusky	4	2,012	2	51,300	0	0	3	1,338	54,650
Tuscarawas	261	430,875	51	675,000	18	177,400	78	182,219	1,465,494
Washington	473	936,334	129	3,541,900	31	1,029,300	147	641,175	6,148,709
Total	4,160	7,718,018	868	16,462,400	292	7,602,100	1,336	4,751,602	36,534,120

[1]Damage recovery estimates provided by the Holmes County Emergency Management Agency (Dennis Fitzpatric, oral communication, 1999)