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Comparison of Peak Discharges among Sites with and without Valley Fills for the July 8–9, 2001, Flood in the Headwaters of Clear Fork, Coal River Basin, Mountaintop Coal-Mining Region, Southern West Virginia

By JEFFREY B. WILEY and FREDDIE D. BROGAN

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CONVERSION FACTORS

Multiply	By	To Obtain
acre	4,047	square meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
square mile (mi^2)	2.590	square kilometer

VERTICAL DATUM

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

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ABSTRACT

The effects of mountaintop-removal mining practices on the peak discharges of streams were investigated in six small drainage basins within a 7-square-mile area in southern West Virginia. Two of the small basins had reclaimed valley fills, one basin had reclaimed and unreclaimed valley fills, and three basins did not have valley fills.

Indirect measurements of peak discharge for the flood of July 8-9, 2001, were made at six sites on streams draining the small basins. The sites without valley fills had peak discharges with 10- to 25-year recurrence intervals, indicating that rainfall intensities and totals varied among the study basins. The flood-recurrence intervals for the three basins with valley fills were determined as though the peak discharges were those from rural streams without the influence of valley fills, and ranged from less than 2 years to more than 100 years.

INTRODUCTION

Increased mechanization of coal mining in West Virginia in recent decades has led to extensive use of mountaintop-removal mining to reach coal seams. Excess overburden from mountaintop removal is placed in adjacent headwater valleys, creating what are known as “valley fills.” Mountaintop mining and valley filling in the coal-mining region of southern West Virginia have changed forested landscapes with layered sedimentary rocks into grass-covered landscapes underlain by poorly sorted rock fragments. The U.S. Geological Survey (USGS), in cooperation with the Office of Surface Mining Reclamation and Enforcement, investigated the effects of valley fills on the peak discharges for the flood of July 8-9, 2001, in the headwaters of Clear Fork in the Coal River Basin. The study area included six sites on streams draining small basins (drainage areas ranging from 0.189 to 1.17 mi^2) within an area of about 7 mi^2 in the headwaters of Clear Fork of the Coal River in the Appalachian Plateaus Physiographic Province in the southern coalfields of West Virginia. Peak discharges after the flood were determined indirectly at the six sites by surveying high-water marks and cross sections, and applying open-channel-flow equations. Peak discharges were compared among basins with and without valley fills.

This study resulted from investigations used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (EIS). The EIS assesses the policies, guidance, and decision-making processes of regulatory agencies in order to minimize any adverse environmental effects from this mining practice. Preparation of the EIS was a voluntary effort among the Office of Surface Mining, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and the West Virginia Department of Environmental Protection (U.S. Environmental Protection Agency, 2000). Some of the data-collection sites for this study are at or near data-collection sites used in preparation of the EIS.

DESCRIPTION OF STUDY AREA

Six sites on streams draining the small basins in the headwaters of Clear Fork of the Coal River in southern West Virginia were selected for investigation after the flood of July 8–9, 2001 (figs. 1*A*–*C*). The six site identifications are: USGS1, Unnamed Tributary to Lick Run; USGS2, Unnamed Tributary to Clear Fork; MT65C, Unnamed Tributary to Buffalo Fork; MT66, Buffalo Fork; USGS3 (near MT69), Ewing Fork; and MT76, Reeds Branch. The “USGS” prefix indicates that the site was selected by the USGS for this study, and the “MT” prefix indicates that the site had already been used for preparation of the Mountaintop Mining/Valley Fill EIS.

Three sites are on streams that drain basins without a valley fill and without active surface mining (USGS1, USGS2, and USGS3) and three sites are on streams that drain basins with valley fills (MT65C, MT66, and MT76). MT65C is in a basin that has one reclaimed and one unreclaimed valley fill, and there is active surface mining in the basin. A reclaimed valley fill has a configuration and vegetation cover that meets the plan that has been permitted. An unreclaimed valley fill has a configuration that is still under construction or lacks the vegetation cover necessary to meet the requirements of the permit. MT66 has two reclaimed valley fills, and there is active surface mining on the southern ridge of the basin. MT76 has one reclaimed valley fill and there is no active surface mining in the basin. The three sites associated with valley fills are downstream from sediment ponds at the toes of the fills. The surface areas of the individual valley fills, except for the area of the valley fill near MT76, were available from the West Virginia Department of Environmental Protection (2002). The surface area of the valley fill near MT76 was estimated as 0.3 mi^2 (180 acres) from an orthophotograph (the largest valley fill in the study basins). The valley fills range between about 0.02 and 0.3 mi^2 (12 and 180 acres), which is equal to or greater than the average valley-fill surface area of about 0.02 mi^2 (12 acres) in West Virginia (West Virginia Department of Environmental Protection, 2002).

The study area is underlain by consolidated, mostly noncarbonate sedimentary rocks that dip gently to the northwest. The erosion of rocks by streams has formed steep hills with deeply incised valleys that follow a dendritic pattern, and plateaus capped by resistant layers of sandstone and shale (Fenneman, 1938; Fenneman and Johnson, 1946; and U.S. Geological Survey, 1970). Ground water flows primarily in bedding-plane separations beneath valley floors and in slump fractures along the valley walls (Wyrick and Borchers, 1981). Generally, ground-water flow is greater laterally than vertically and decreases with increasing depth with little flow below 100 ft, except in coal seams, where ground water can flow at depths greater than 200 ft (Harlow and LeCain, 1993). The climate is primarily continental, with mild summers and cold winters (U.S. Geological Survey, 1991). Mean annual precipitation is about 44 in. (U.S. Department of Commerce, 1960), and precipitation with a 24-hour intensity of 2.75 in. falls on the average of once every 2 years (U.S. Department of Commerce, 1961).

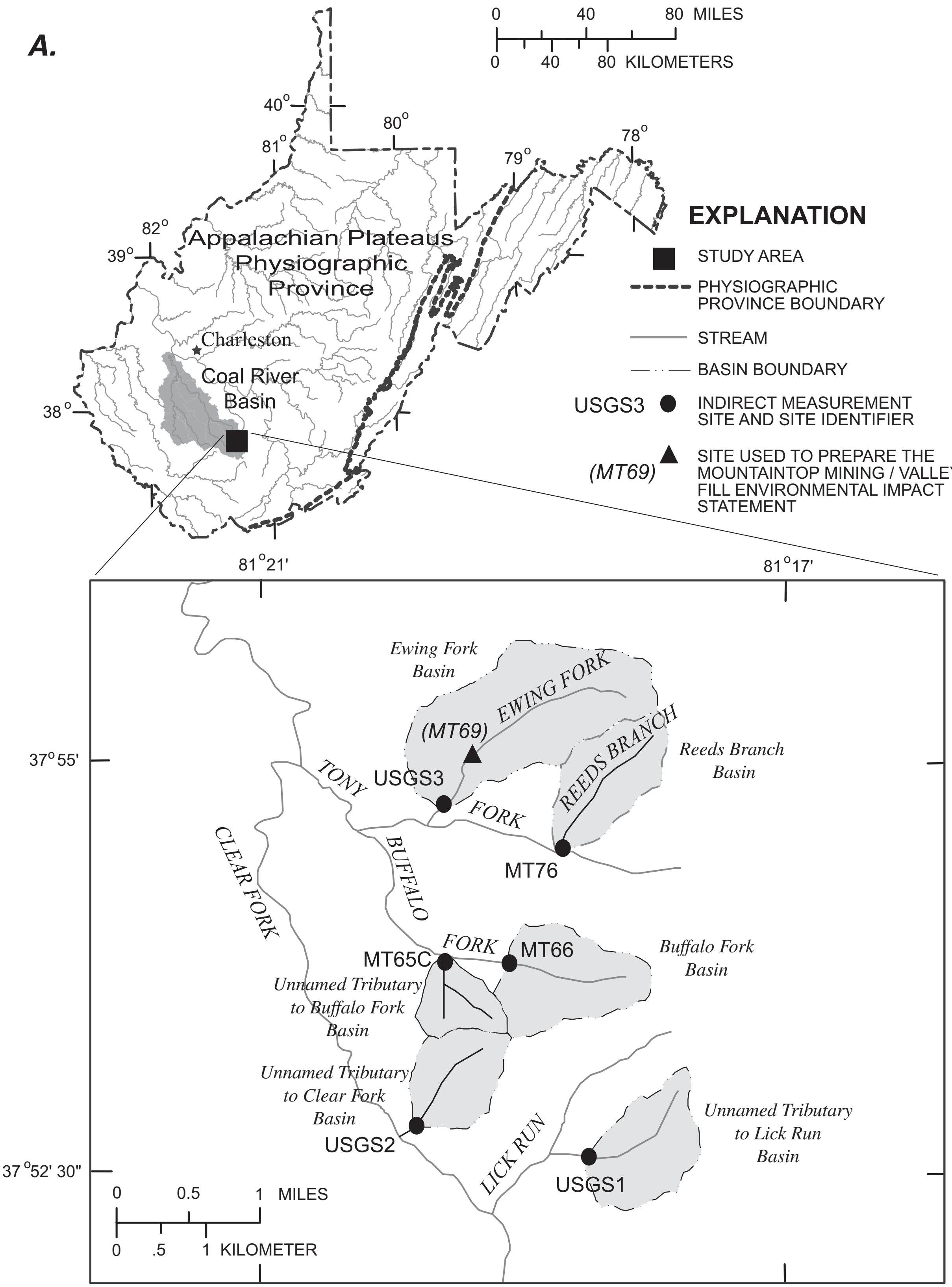

Figure 1. Study-area location of the (*A*) Coal River Basin, including (*B*) Ewing Fork and Reeds Branch (the northern basins), and (*C*) Unnamed Tributary to Lick Run, Unnamed Tributary to Clear Fork, Unnamed Tributary to Buffalo Fork, and Buffalo Fork (the southern basins), Coal River Basin, mountaintop coal-mining region, southern West Virginia.

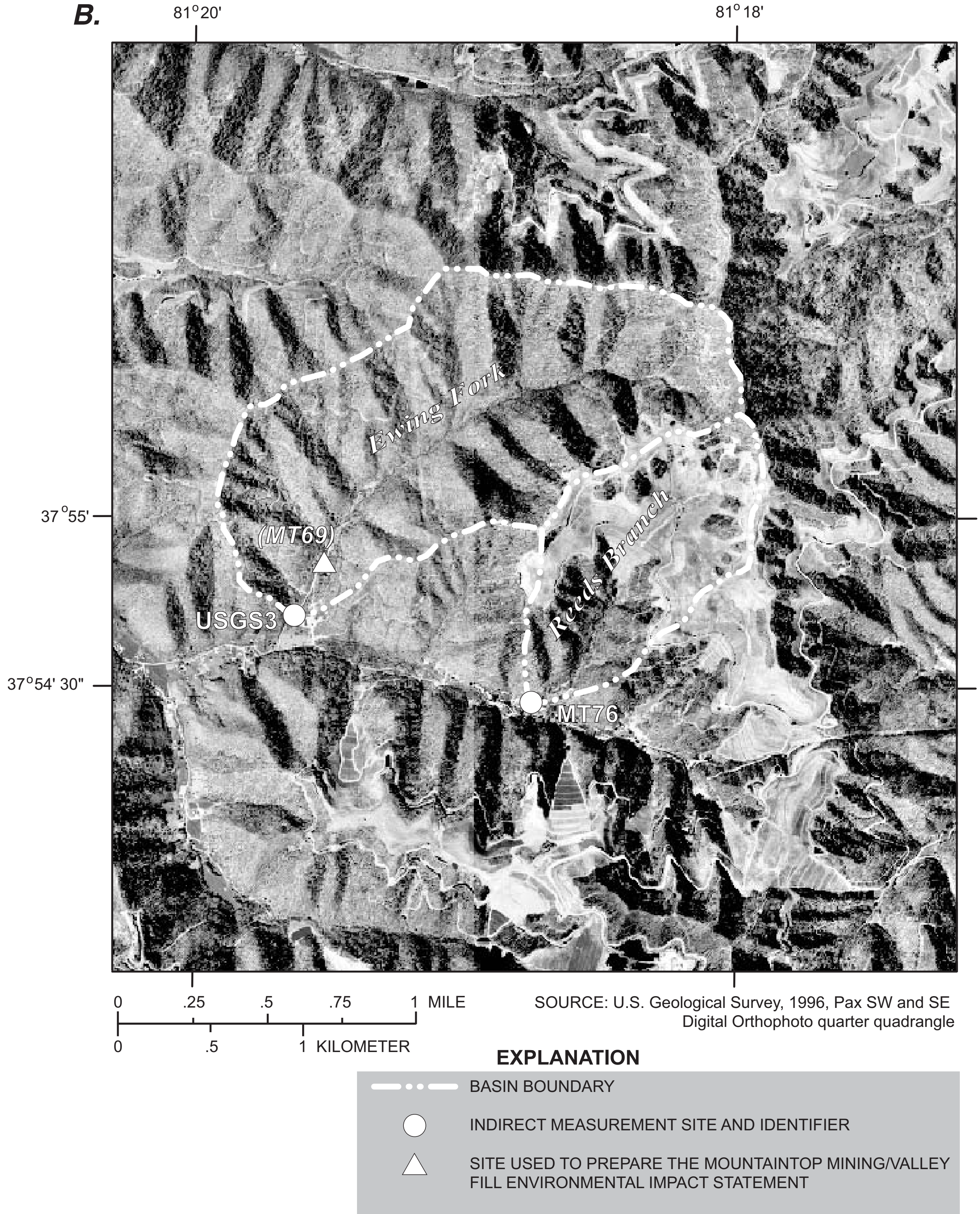

Figure 1. Study-area location of the (*A*) Coal River Basin, including (*B*) Ewing Fork and Reeds Branch (the northern basins), and (*C*) Unnamed Tributary to Lick Run, Unnamed Tributary to Clear Fork, Unnamed Tributary to Buffalo Fork, and Buffalo Fork (the southern basins), Coal River Basin, mountaintop coal-mining region, southern West Virginia—*Continued.*

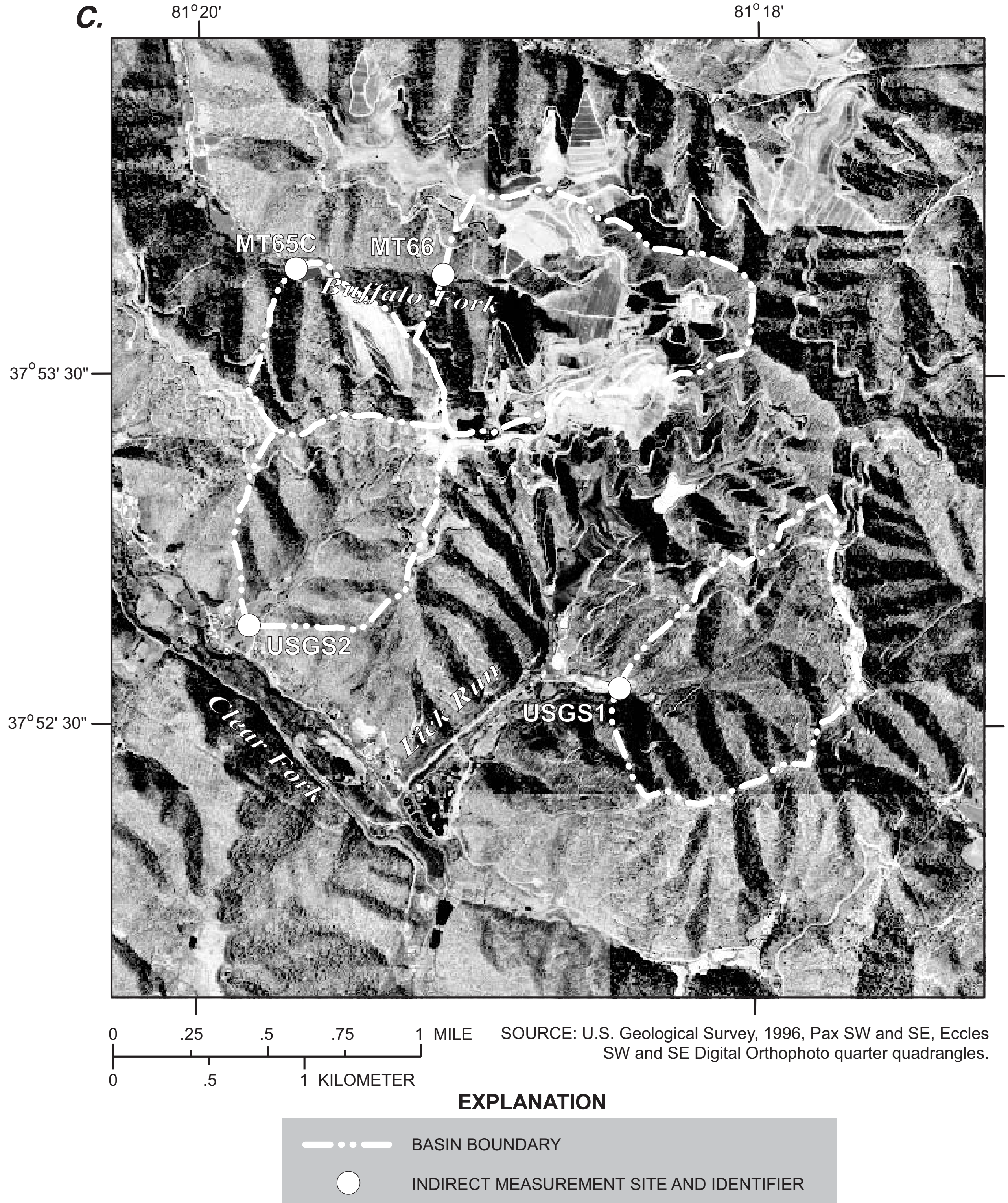

Figure 1. Study-area location of the (*A*) Coal River Basin, including (*B*) Ewing Fork and Reeds Branch (the northern basins), and (*C*) Unnamed Tributary to Lick Run, Unnamed Tributary to Clear Fork, Unnamed Tributary to Buffalo Fork, and Buffalo Fork (the southern basins), Coal River Basin, mountaintop coal-mining region, southern West Virginia—*Continued*.

FLOOD OF JULY 8–9, 2001

In the early morning of July 8, 2001, a thunderstorm complex formed in central West Virginia from outflow winds of an earlier group of thunderstorms that moved across northern West Virginia. The thunderstorm complex then moved into southeastern West Virginia by late morning on July 8, and by early afternoon, 3 to 6 in. of rainfall had fallen in 5 to 6 hours. The hydrologic service area of the National Weather Service office in Charleston, West Virginia, used radar images and field-observer reports to prepare a map showing the total rainfall from the morning of July 8 through the morning of July 9. Figure 2 is a sub-area of the map prepared by the National Weather Service with the addition of streams, basin boundaries, one town, and one gaging station. Figure 2 shows that the total rainfall in the study area was between 4 and 5 in. (John Sikora, National Weather Service, written commun., 2001).

Flooding from the thunderstorm complex was caused primarily by intense rainfall on dry ground. Rainfall totals for the storm were nearly equal to the monthly average of about 5 in. (John Sikora, written commun., 2001). The most severe flooding occurred in the headwaters of the Coal, Guyandotte, and Tug Fork Rivers, where recurrence intervals of peak discharges (the average time between floods that equal or exceed a particular peak discharge) at some locations were at or greater than 100 years. The gaging station Clear Fork at Whitesville (USGS station number 03198350, drainage area 62.8 mi^2) is downstream from the study area (fig. 2), and the indirectly-measured peak discharge (calculated by means of the same techniques as the peak discharges given in this study) at this station during this storm was determined to have a recurrence interval of more than 100 years.

INDIRECT MEASUREMENT OF PEAK DISCHARGES

Indirect measurements of peak discharges for the July 8–9, 2001, flood at the six study sites were based on the techniques described by Benson and Dalrymple (1967), and were calculated by the computer program developed by Fulford (1994). Generally, high-water marks are identified along the stream banks, a land survey of high-water marks and stream cross sections is conducted, estimates of channel roughness are made with Manning's roughness coefficients, and a computer program is used to apply open-channel-flow equations to determine discharge. This indirect method of measuring peak discharges is commonly referred to as the "slope-area method." Data on rainfall totals and intensities are not necessary to compute peak discharges. Indirectly measured peak discharges at the six study sites ranged from 45 to 228 ft^3/s (table 1).

Benson and Dalrymple (1967) discuss the errors associated with the slope-area method of computing peak discharges by comparing the computed discharges to known discharges. Slope-area measurements of peak discharges during the May–June 1948 floods in the Columbia River Basin were made at 22 locations where the discharges were known. There was a 25-percent difference at one location. There was a maximum difference of 15.6 percent and an average of 6.7 percent at the remaining 21 locations. Errors associated with the slope-area measurements made for this study probably have similar magnitudes.

The site MT65C is at the outflow of a sediment pond downstream from two valley fills. The drainage area above MT65C, 0.189 mi^2 (121 acres) is a revised value from the 0.102 mi^2 (65 acres) previously published by Wiley and others (2001). The omission of one of the two valley fills resulted in the incorrect previously published drainage area.

Manning's roughness coefficients are the only values used in the discharge calculation that are not directly measured, except for the interpretation of high-water marks. Manning's roughness coefficients were estimated by comparison of field observations and photographs of the stream channels at the sites to photographs taken at locations with measured roughness coefficients (Barnes, 1967).

The sensitivity of calculated discharge values to 10-percent increases and decreases in the roughness coefficients was evaluated (table 2). The magnitude of 10 percent was selected because most experienced surface-water hydrologists could probably estimate Manning's roughness coefficient within 10 percent of the actual value. The largest change in discharge was that calculated at site MT66, Buffalo Fork, where a 10-percent decrease in roughness increased discharge by about 12 percent (peak discharge was calculated to increase from 224 to 251 ft^3/s). No sensitivity tests were performed based on the interpretation of high-water marks.

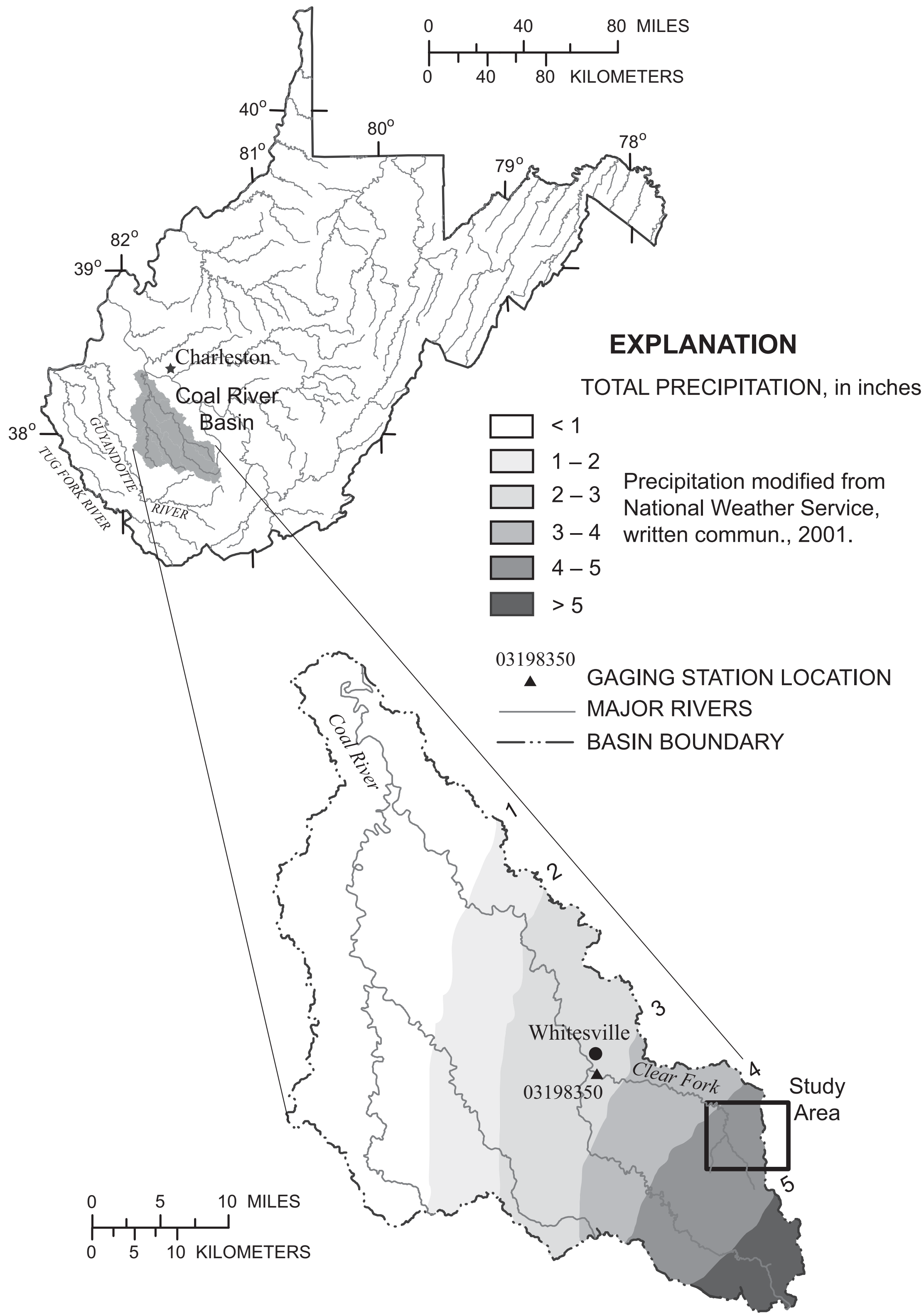

Figure 2. Total rainfall from the morning of July 8 through the morning of July 9, 2001, in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia.

Table 1. Indirectly measured peak discharges and estimated recurrence intervals for the flood of July 8–9, 2001, at the six study sites in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia

[USGS(n) identifies a site selected by the U.S. Geological Survey for this study; MT(n) indicates that the site being used in this study was part of the Mountaintop Mining/Valley Fill Environmental Impact Statement study, where (n) is a unique numeric or alphanumeric identifier. Flood-recurrence interval was determined by using Wiley and others (2000) and the sensitivity of calculated discharges to Manning's roughness coefficients]

Basin name	Site identifier	Latitude ° ′ ″	Longitude ° ′ ″	Drainage area, in square miles	Indirectly measured peak discharge, in cubic feet per second	Estimated flood recurrence interval, in years
Basins without valley fills						
Unnamed Tributary to Lick Run	USGS1	37 52 36	81 18 31	0.461	140	25
Unnamed Tributary to Clear Fork	USGS2	37 52 42	81 19 50	.360	90	10
Ewing Fork[a]	USGS3	37 54 45	81 19 34	1.17	228	10
Basins with valley fills						
Unnamed Tributary to Buffalo Fork	MT65C	37 53 48	81 19 38	[b].189	113	[c]>100
Buffalo Fork	MT66	37 53 47	81 19 09	.583	224	[c]50–100
Reeds Branch	MT76	37 54 28	81 18 46	.462	45	[c]<2

[a]Site is near MT69, which was used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (Wiley and others, 2001).

[b] Drainage area was revised from the 65 acres (0.102 square miles) used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement and is the value published by Wiley and others (2001).

[c]Flood-recurrence interval of indirectly measured peak discharge was computed as though the peak discharge was that from a rural stream without the influence of valley fills.

Table 2. Sensitivity of indirectly measured peak discharges to Manning's roughness coefficients for the flood of July 8–9, 2001, at the six study sites in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia

[USGS(n) identifies a site selected by the U.S. Geological Survey for this study; MT(n) indicates that the site being used in this study was selected by group of agencies for preparation of the Mountaintop Mining/Valley Fill Environmental Impact Statement, where (n) is a unique alphanumeric identifier]

Basin name	Site identifier	Indirectly measured peak discharge, in cubic feet per second	Range of Manning's roughness coefficient	Discharge calculated with a 10 percent decrease in Manning's roughness, in cubic feet per second	Discharge calculated with a 10 percent increase in Manning's roughness, in cubic feet per second
Basins without valley fills					
Unnamed Tributary to Lick Run	USGS1	140	0.065–0.068	154	127
Unnamed Tributary to Clear Fork	USGS2	90	0.050–0.060	100	81
Ewing Fork[a]	USGS3	228	0.055–0.060	253	207
Basins with valley fills					
Unnamed Tributary to Buffalo Fork	MT65C	113	0.070–0.080	124	103
Buffalo Fork	MT66	224	0.055–0.080	251	201
Reeds Branch	MT76	45	0.060–0.062	49	41

[a]Site is near MT69, which was used to prepare the Mountaintop Mining/Valley Fill Environmental Impact Statement (Wiley and others, 2001).

Estimates of flood-recurrence intervals (table 1) at the sites in basins without a valley fill (USGS1, USGS2, and USGS3) were made by comparing the indirectly measured peak discharges to estimated peak discharges determined from published flood-frequency estimating equations (Wiley and others, 2000) (fig. 3). Consideration was given to the sensitivity of calculated discharges to Manning's roughness coefficients (table 2). Flood-recurrence intervals were calculated for the sites in the basins with valley fills (MT65C, MT66, and MT76) as though the peak discharges were those from rural streams without the influence of valley fills (table 1 and fig. 3). Estimates of recurrence intervals of peak discharges for the six study sites were between less than 2 years and more than 100 years.

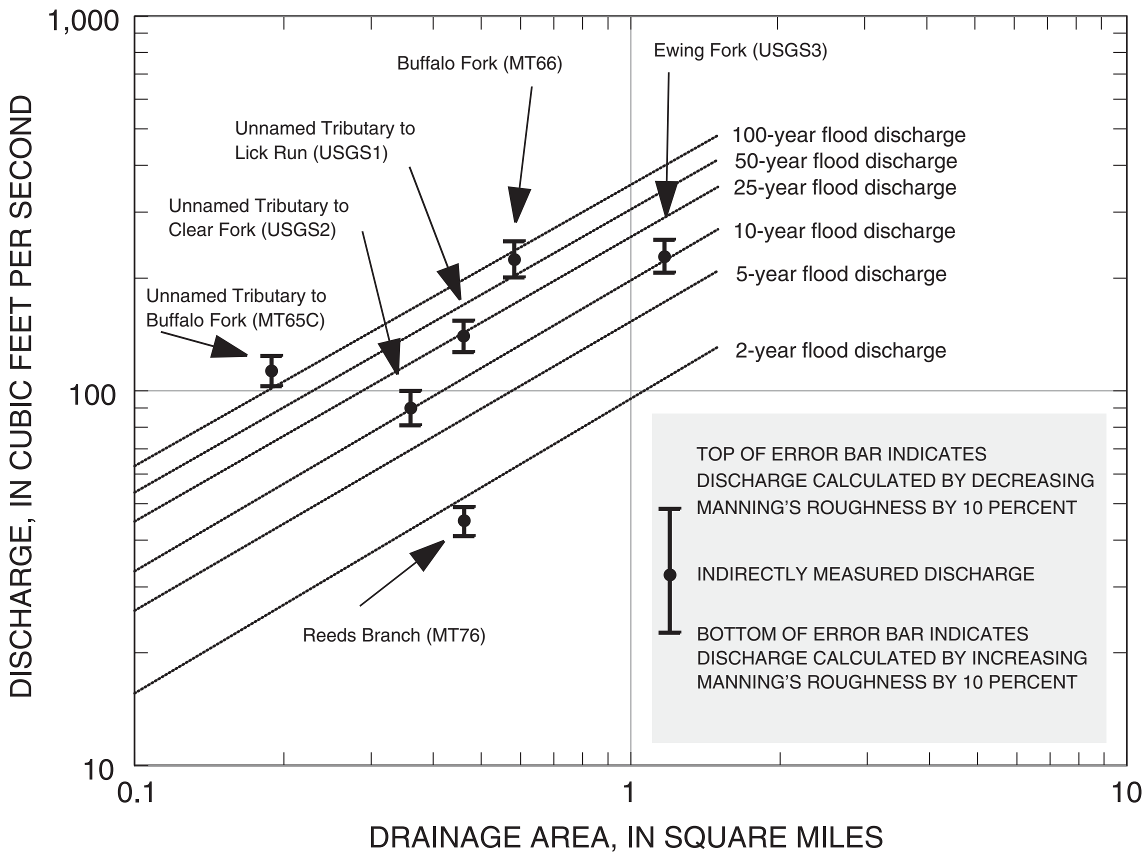

Figure 3. Comparison among indirectly measured discharges and selected recurrence-interval flood discharges at the six study sites in the headwaters of Clear Fork, Coal River Basin, mountaintop coal-mining region, southern West Virginia. Recurrence-interval flood discharges are those for rural streams without the influence of valley fills (Wiley and others, 2000).

COMPARISON OF PEAK DISCHARGES AMONG SITES IN BASINS WITH AND WITHOUT VALLEY FILLS

Flood peaks in small headwater basins with valley fills constructed from mountaintop-removal mining are affected by changes in surface slopes and permeability, deforestation, and the construction of sediment ponds downstream from the toe of the fill. The lower surface slope of the valley fill compared to that of the original mountainside tends to increase the travel time of overland runoff and facilitate infiltration. Reclaimed surfaces (and previous grades of the valley fill and surrounding spoil areas, particularly previous grades resulting from lift-construction techniques used to build the valley fill) commonly are formed of small particles compacted by equipment traffic and the sorting of materials due to gravity, and the resulting lower permeability tends to decrease the travel time of overland runoff (Wunsch and others, 1996). The valley fill and adjacent spoil areas are recharged where boulders exposed to the surface facilitate infiltration, where streams and springs run directly into the fill, at the contact point between the edge of the fill and highwalls or near-surface tectonically induced fractures, at active mining areas, and where specially designed ponds collect overland runoff and direct the flow deep into the fill (Kipp and Dinger, 1991; Wunsch and others, 1992; and Wunsch and others, 1996). Deforestation from logging generally results in increases in peak discharges during the growing season and fall recharge period, and has minimal impact on peak discharges during the dormant season if management practices are implemented to decrease runoff from roads and skid trails. Snow, antecedent soil moisture, and probably other factors also affect the peak discharge from deforested areas (Reinhart and others, 1963). Generally, the greatest peak discharges from small drainage areas result from intense, local thunderstorms during the growing season, rather than from frontal systems and tropical cyclones normally associated with the greatest peak discharges for large drainage areas (Doll and others, 1963). Ponds constructed at the bases of valley fills can collect and retain runoff, and thus cause a decrease in peak discharges (Curtis, 1979). The magnitude of the decrease in peak discharge depends on the flood-storage volume and the design for the outfall of the pond.

The study plan was based on the assumption that the six study basins were within an area (7 mi^2) small enough that rainfall intensities and totals would be approximately equal, but this assumption was determined invalid. The flood-recurrence intervals for the three basins without valley fills should be approximately equal if the assumption was correct. Table 1 shows that the flood-recurrence intervals for the three basins without valley fills (USGS1, USGS2, and USGS3) are not equal. The flood frequencies were between 10 and 25 years with the greatest flood frequency at the southernmost basin, USGS1.

The flood-recurrence intervals for the three basins with valley fills (peak discharges were treated in the computation like those from rural streams without the regulation of valley fills) were between less than 2 years and more than 100 years (table 1). The smallest recurrence interval was at MT76, the site in the northernmost basin with no active surface mining and a reclaimed valley fill, which was the largest valley fill in this study. The greatest recurrence interval was at MT65C, the site in a basin with active surface mining and one reclaimed and one unreclaimed valley fill, which was the only unreclaimed valley fill in this study.

Changes in hydrologic conditions and responses resulting from changes in surface slopes and permeability, deforestation, the construction of sediment ponds, other reclamation practices, and basin and climate conditions (such as basin orientation, size and composition of the valley fill, local geology, antecedent soil moisture, and precipitation intensities and totals) in basins with valley fills are not adequately understood.

SUMMARY

The U.S. Geological Survey, in cooperation with the Office of Surface Mining Reclamation and Enforcement, investigated the effects of mountaintop-removal mining with valley fills on the peak discharges for the flood of July 8–9, 2001. The study area included six small basins (drainage areas ranging from 0.189 to 1.17 mi^2) within an area of about 7 mi^2 in the headwaters of Clear Fork of the Coal River in the Appalachian Plateaus Physiographic Province of southern West Virginia.

In the early morning of July 8, 2001, a thunderstorm complex formed in central West Virginia from outflow winds of an earlier group of thunderstorms that had moved across northern West Virginia. Flooding from the thunderstorm complex was primarily caused by intense rainfall on dry ground, and rainfall totals were nearly equal to the monthly average of about 5 in.

Indirect peak-discharge measurements were made at three sites in basins with valley fills and three sites in basins without valley fills. Flood-recurrence intervals were estimated by comparing the indirectly measured peak discharges to peak discharges determined from equations for estimating magnitudes of floods for different recurrence intervals in rural, unregulated streams of West Virginia. The sites without valley fills had peak discharges with about 10- to 25-year recurrence intervals; this result indicates that rainfall intensities and totals varied among the study basins. The flood-recurrence intervals for the three basins with valley fills were determined as though the peak discharges were those from rural streams without the influence of valley fills, and were between less than 2 years and greater than 100 years.

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