# FINAL REPORT ON LANDSLIDES OF JULY 9, 1973 IN KANAWHA CITY AREA OF CHARLESTON, WEST VIRGINIA


By

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WEST VIRGINIA GEOLOGICAL AND ECONOMIC SURVEY

ROBERT B. ERWIN, DIRECTOR AND STATE GEOLOGIST

OF1

September 7, 1973

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# Final Report on Landslides of July 9, 1973 in Kanawha City Area of Charleston, West Virginia

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## SUMMARY

The factors initiating the landslides of July 9, 1973, in the Kanawha City area included a combination of geologic, topographic, surface-water, and ground-water conditions. The storm of that day added an extremely intense rainfall to what was apparently an existing, naturally unstable situation. The slides resulted from the liquefaction of the upper 1 to 3 feet of soil after complete saturation with water. This mixture of water and soil then cascaded rapidly down-slope. No evidence of any coal mining was observed in or around the scarps of the landslides investigated.

The probability of small slides recurring in the area is very likely. This type of slide is mainly a nuisance that causes minor damage that poses little or no threat to public safety. The larger slides started primarily as a result of an intense summer thunderstorm. Since the probability is very low that this storm intensity will happen again, it follows that the probability also is low that these large slides will recur. However, it is quite possible that a less intense rainfall could produce other disastrous landslides in the future.

Listed at the end of this report are eight recommendations to reduce the likelihood of future landslides and to minimize damage from any that may occur. Included in these recommendations is the drilling

of a 300-foot core hole on the mountain top above the Right Fork of Upper Donnally Branch; results of this drill hole can be used to more clearly define the probability of recurrence of large slides at this location. Another recommendation is to study the feasibility of regulatory zoning for houses at the bases of mountain slopes.

## INTRODUCTION

Between 4 and 6 a.m. on Monday, July 9, 1973, a severe, isolated thunderstorm occurred in the Kanawha City area of Charleston, West Virginia. The following unofficial rainfall measurements were made: greater than 4 inches in Lower Donnally Branch (marked as D on Figure 1); 5 inches at 50th and Kanawha Avenue (marked as E on Figure 1); and 5 to 6 inches in Upper Donnally Branch (marked as F on Figure 1). The intense rainfall caused local flashflooding, the overtopping of several small dams, the failure of one siltation dam, and numerous landslides. These effects are located on Figure 2, where slides F, G, H, I, and K caused minor local damage from soil and debris and slides B, C, D, E, and J caused little or no damage. Slide A totally destroyed three houses on Upper Donnally Road and killed three children. Several sections of Chappell Hollow have artificial dams across the creek with small culverts for normal flow only. These dams backed up the creek and were overtopped during the storm, causing much siltation and flooding, although none failed. A siltation dam on the Right Fork of Rush Creek (marked as N on Figure 2) did fail during the storm, although downstream damage was only minor.

As of this date, numerous agencies have been involved with the investigations of this storm including: the West Virginia Department

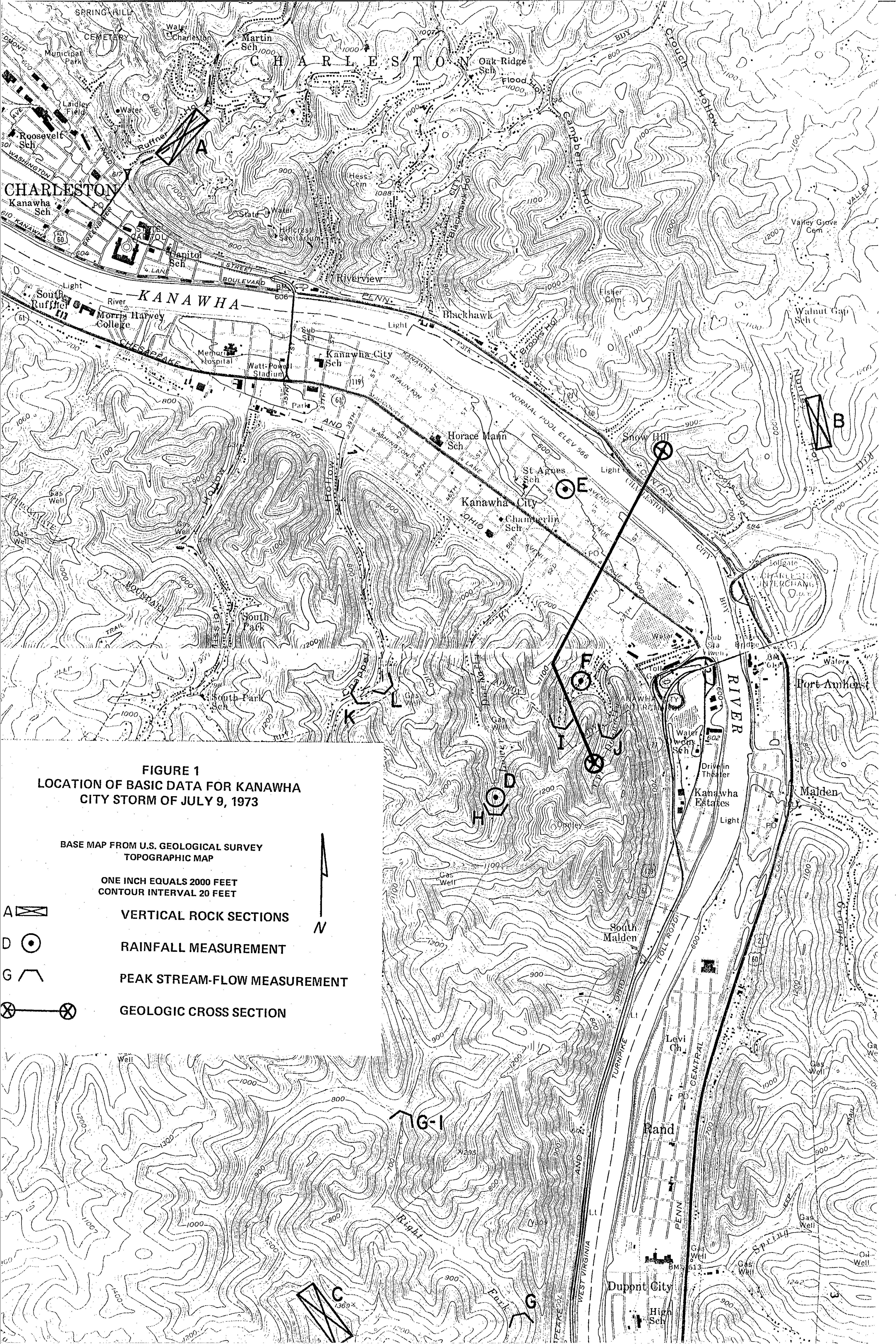



FIGURE 1
LOCATION OF BASIC DATA FOR KANAWHA CITY STORM OF JULY 9, 1973

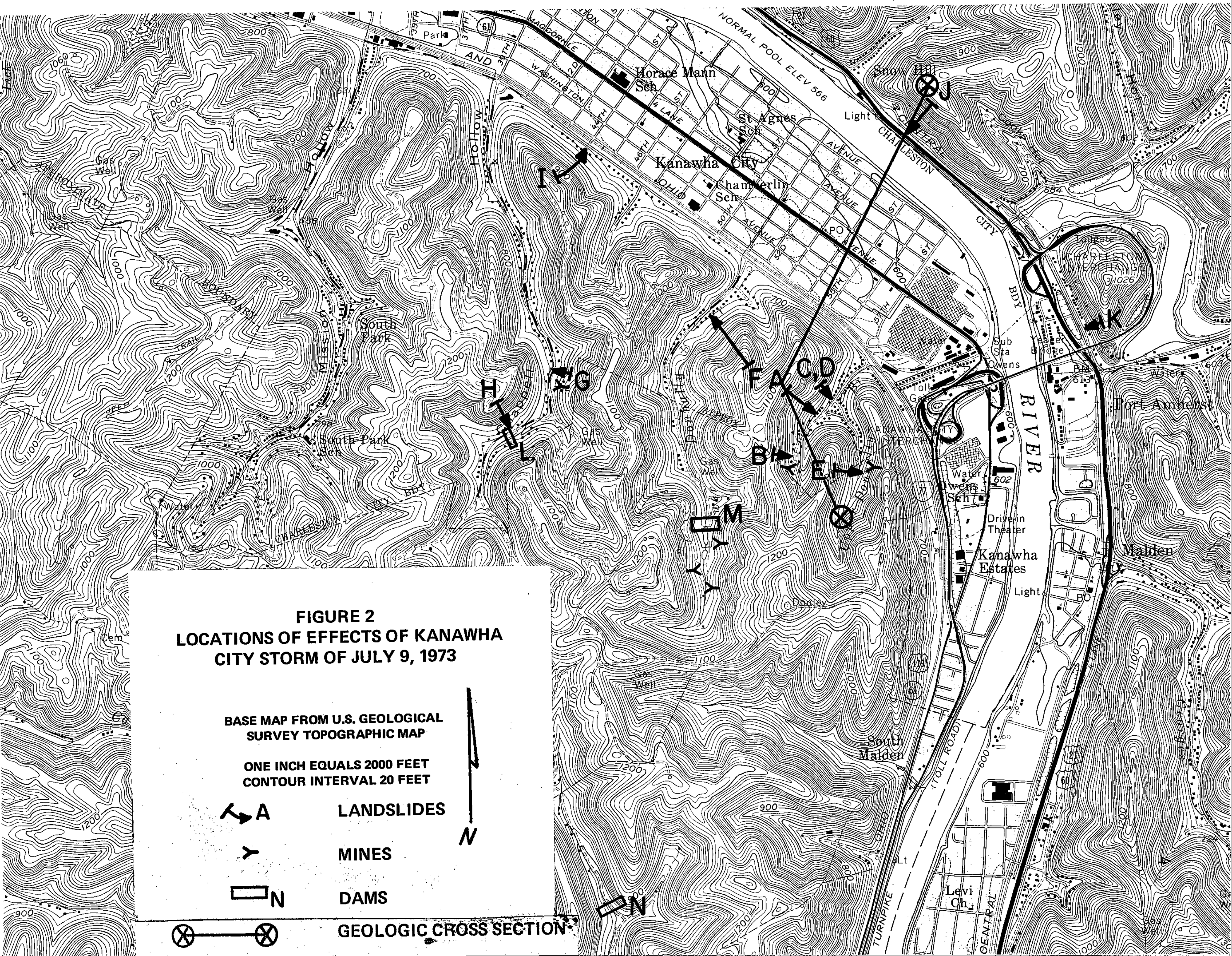



**FIGURE 2**
**LOCATIONS OF EFFECTS OF KANAWHA CITY STORM OF JULY 9, 1973**

of Natural Resources, the West Virginia Department of Mines, the U. S. Geological Survey, the U. S. Bureau of Mines, the U. S. Soil Conservation Service, and the U. S. Weather Service. The results of the U. S. Geological Survey study of streamflows during the storm are incorporated into a later section of this report titled "Hydrology." Our investigation of the storm began on July 23 and included carefully examining all the landslides reported in the area and assembling known geologic and hydrologic data.

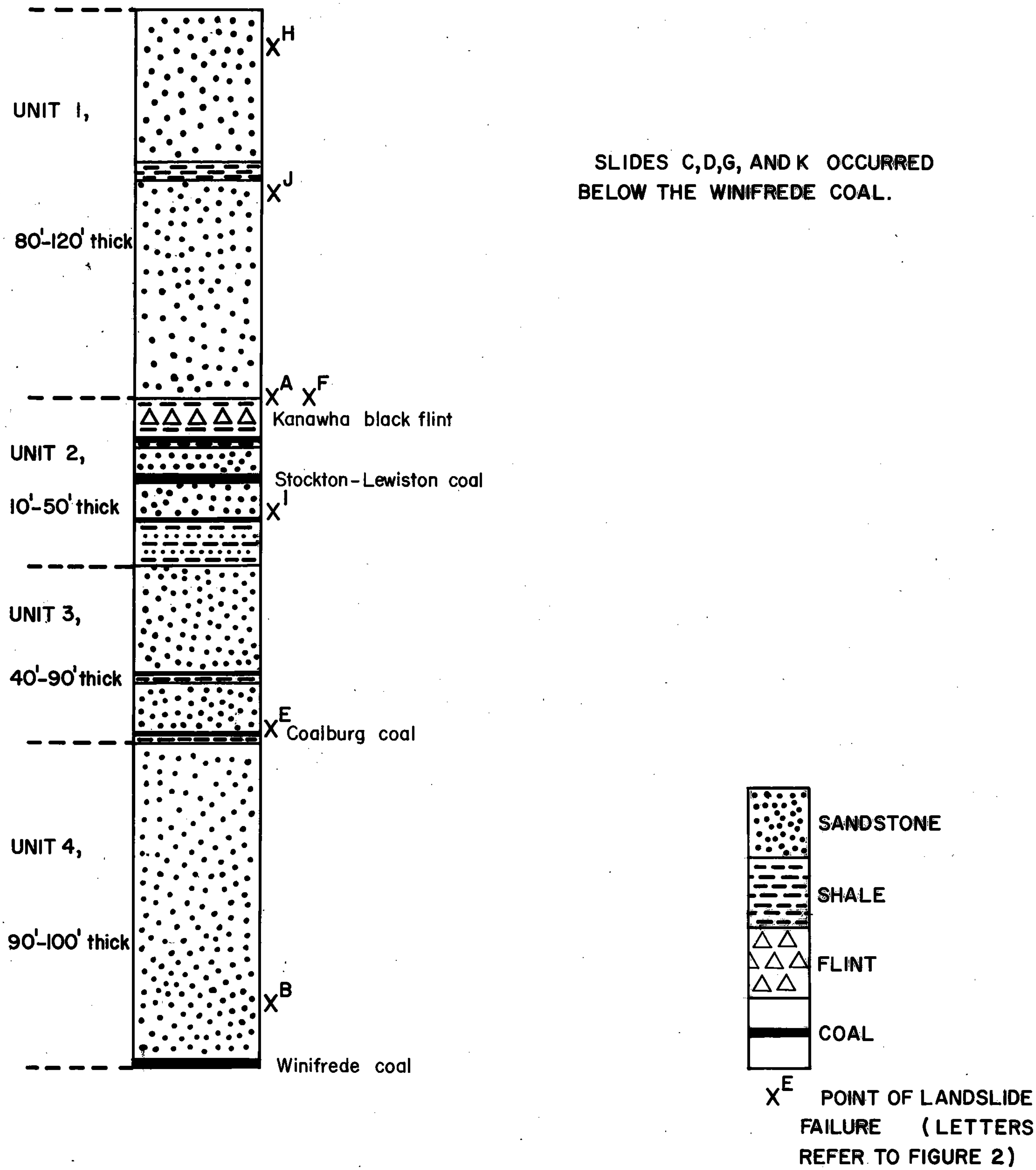
## GEOLOGY

### Bedrock Geology

The bedrock geology--i.e. the nature of the solid rock underlying the soil cover--is described below and is illustrated with a generalized rock sequence (Figure 3) and a cross section (Figure 4). The rock interval of interest beneath the hills of Kanawha City is 250 to 320 feet thick and, for the purpose of this report, has been subdivided into four rock units.

Unit 1 at the top (see Figure 3) is composed of a massive, slightly fractured sandstone, 80 to 120 feet thick, which caps many of the hills. At a few locations, small sections of the sandstone are exposed as very steep cliffs, but the entire unit is generally covered by soil and vegetation. Near the middle is a thin, shaly sequence. Unit 2 varies from 10 to 50 feet in thickness, but most often is between 30 and 50 feet thick. Although this interval is predominantly alternating sandstone and shale, it also contains: (1) the Stockton-Lewiston coal, 2 to 3 feet thick (strip mined on Rush Creek to the south); (2) one or two other minor coal seams; and (3) the Kanawha black flint. Unit 3 con-

FIGURE 3. GENERALIZED ROCK SEQUENCE IN KANAWHA CITY AND ITS RELATIONSHIP TO LANDSLIDES OF JULY 9, 1973



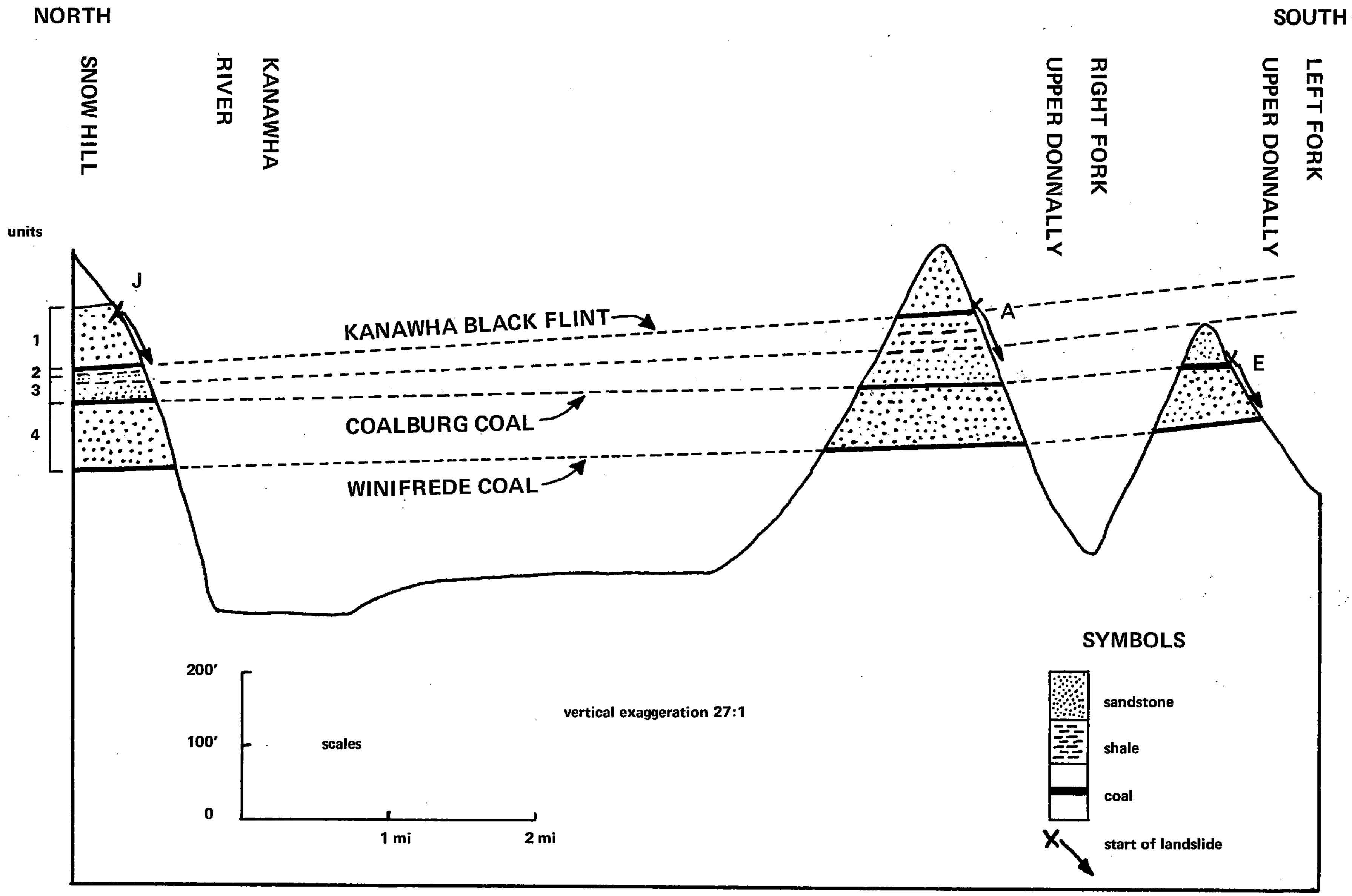



**Figure 4. GEOLOGIC CROSS SECTION OF KANAWHA CITY AREA**

sists of massive sandstone with the 30-inch-thick Coalburg coal at its base. Up to three minor coals with underclays are associated with the Coalburg. This unit varies in thickness from 40 to 90 feet. Unit 4 is a thick sandstone overlying the Winifrede coal. The sandstone is 90 to 100 feet thick and the Winifrede coal is approximately 2 to 3 feet thick.

Much of this rock section is concealed in the Kanawha City area. Therefore, the above descriptions are composites of four nearby outcrops: (1) Ruffner Hollow, north of the State Capitol (A on Fig. 1); (2) Nunley Hollow, north of the Charleston interchange of the West Virginia Turnpike (B on Fig. 1); (3) Rush Creek, northwest of Marmet (C on Fig. 1); and (4) Kanawha State Forest, 3 miles southwest of Kanawha City (not shown on Fig. 1).

## Soils

Two types of soil cover the hillsides in the area where these landslides developed. A colluvial soil, developed on the debris of older landslides and slumps, is sandy to pebbly with very little clay. It is 60 to 80 or more inches thick. A low-permeability layer is generally encountered at 20 to 50 inches beneath the surface. This layer is up to 40 inches thick and causes seasonally-high water tables and wet-weather springs. This soil type occurs on the lower slopes of the mountains and is very prone to slumping. A residual soil formed on the sandstone bedrock. This soil occurs on steep slopes and ridge tops and is usually 20 to 40 inches thick. Generally, this soil type is silty to sandy with abundant coarse rock fragments. This material has a high potential for erosion and slumping because of its location on very steep slopes.

### Coal Mining

In the immediate vicinity of Upper Donnally Branch, but not associated with the landslides, evidence of former coal mining was discovered. In the Right Fork of Upper Donnally Branch, an airhole to an abandoned mine is located behind the Henderson house (839 Upper Donnally Road) at an elevation of approximately 830 feet. In Lower Donnally Branch, at least three mine openings exist at an elevation of approximately 820 feet. In Chappell Hollow, an old mine opening was observed behind the Peak house (866 Chappell Road) at an elevation of approximately 800 feet. The coal that was mined at all of these locations was probably the Winifrede. The vertical position of the Winifrede coal with respect to several landslides is illustrated in Figures 3 and 4.

In the Left Fork of Upper Donnally Branch, a mine shaft was seen in the creek at an elevation of approximately 720 feet. This mine shaft lies 150 feet below the Winifrede.

## HYDROLOGY*

Upper Donnally and Lower Donnally Branches were particularly hard hit by this thunderstorm, which caused severe flooding and landslides. Chappell and Mission Hollows also were subjected to considerable runoff. Flooding was extensive on the Right Fork of Rush Creek, a tributary to Kanawha River and about 3 1/2 miles upstream from Kanawha City; however, owing to sparse development, damage was slight. Characteristic of summer thunderstorms, precipitation appears to have occurred over a small area.

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*This section was compiled by the U. S. Geological Survey, Water Resources Division, Charleston, W. Va.

Peak-flow determinations of the July 9 flood were made by the U. S. Geological Survey (USGS) on Upper Donnally Branch, Lower Donnally Branch, Chappell Hollow, and the Right Fork of Rush Creek (see Figure 1). The results of these determinations are shown in Table 1. Flood peaks range from 96 cfs (cubic feet per second) on the Left Fork of Chappell Hollow to 657 cfs on the Right Fork of Rush Creek. For a better comparison, these discharges were converted to cubic feet per second per square mile (cfsm). This is called "unit runoff" and compares the "yield" from each of the basins by adjusting for the size of each drainage area. As indicated by the runoff data, the highest yield occurred in Upper Donnally Branch with each fork contributing about 2,500 cfsm. To the south and west, Lower Donnally and the headwaters of the Right Fork of Rush Creek yielded 1,280 and 1,060 cfsm, respectively. Farther west, the Left Fork of Chappell Hollow had 640 cfsm and the Right Fork had 310 cfsm. The runoff pattern indicates that the storm centered over Upper Donnally Branch and Donley Mountain. Although 2,500 cfsm is an extremely high unit runoff, it is possible to obtain this amount of flow under certain conditions, particularly from such small drainage areas.

*Table 1. Peak Discharges and Drainage Areas of Kanawha City Floods, July 9, 1973*

| Location (See Fig. 1) | Discharge (cfs) | Drainage Area (sq. mi.) | cfs per sq. mi. (cfsm) |
|---|---|---|---|
| K. Chappell Hollow (Right Fork) | 118 | 0.38 | 310 |
| L. Chappell Hollow (Left Fork) | 96 | 0.15 | 640 |
| H. Lower Donnally | 192 | 0.15 | 1,280 |
| I. Upper Donnally (Right Fork) | 108 | 0.042 | 2,570 |
| J. Upper Donnally (Left Fork) | 290 | 0.12 | 2,420 |
| G-1. Right Fork, Rush Creek | 657 | 0.62* | 1,060 |

*Survey site located near mouth; however, most of the flow was contributed from the upper watershed.

## DESCRIPTION OF LANDSLIDES

The locations of the landslides that occurred on July 9 that were examined during the study are shown on Figure 2. The following is a detailed description of the slides, each designated by a letter on Figure 2. In each case, to determine the cause of the slide, the description concentrates on the top of the slide, the point of failure. Table 2 gives some of the dimensions for each slide.

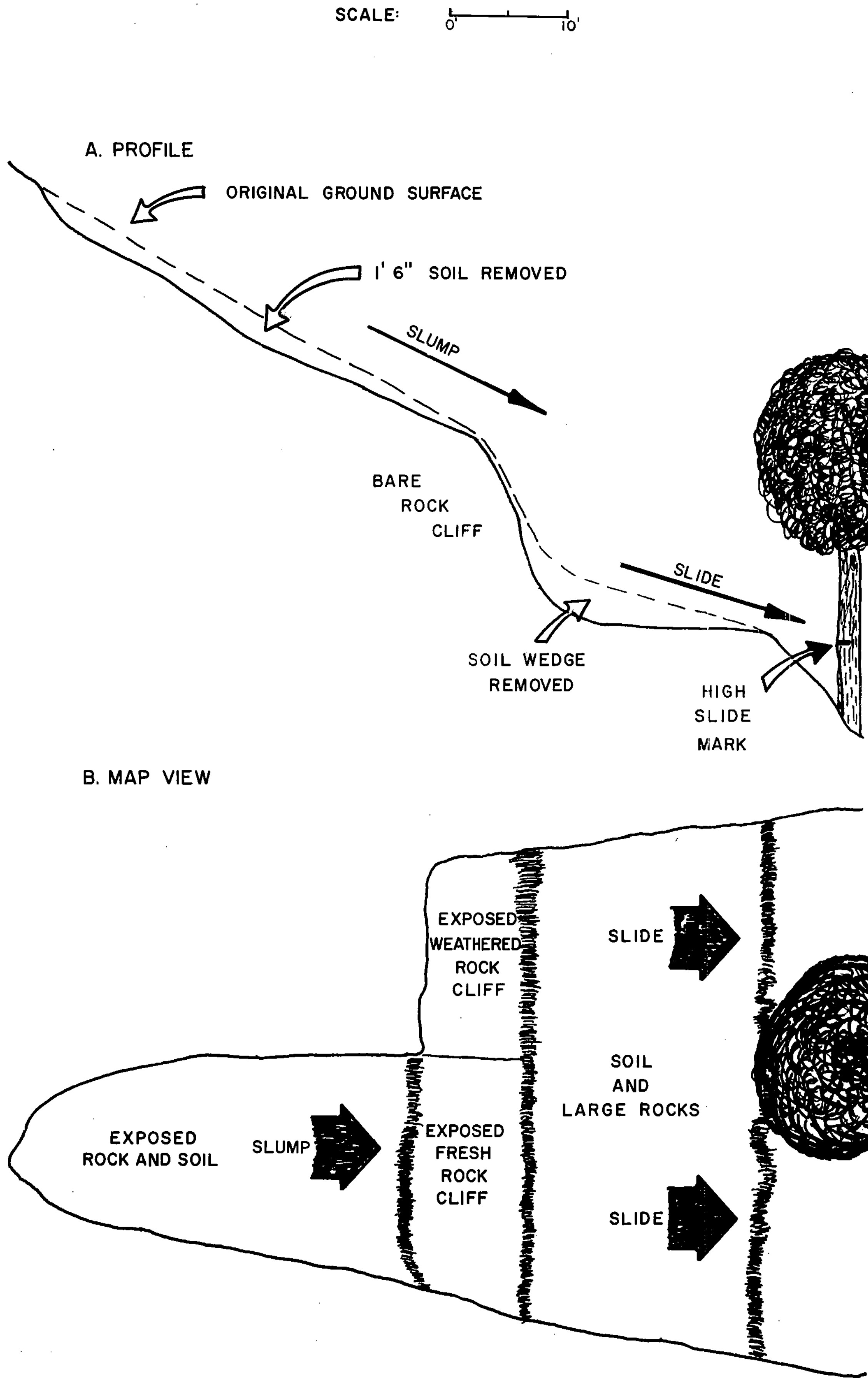
Slide A was by far the most destructive event associated with the storm. This slide, unlike the others studied, apparently involved the movement of a wedge-shaped mass of soil (see Figure 5) from the base of the rock cliff, accompanied or followed by the slumping of a thin sheet of soil from higher up the slope. The bedrock underlying the scarp (i.e., the head of the slide) consists of thinly bedded sandstone above the cliff. The cliff itself is thickly bedded sandstone with some vertical fractures. This rock interval is within unit 2 of the generalized rock sequence and is just above the Kanawha black flint and Stockton-Lewiston coal, although these layers are not exposed here. Slopes on either side of slide A are of approximately the same magnitude as the slide area itself; therefore, the slide's starting point was not controlled by a topographic depression. In the area where slide A began, no evidence was found of coal mining--that is, no openings, access roads, or coal debris--although the slide debris may be covering such evidence.

Slide B (Figure 2) occurred behind the house of Woodroe Henderson at 839 Upper Donnally Road. The area where the slide began shows that a semicircular region of 2 feet of soil was removed and slid 50 feet downhill. No evidence of coal or coal mining was found at the point of failure, although the top of a vertical mine airvent is located 35

*Table 2. Dimensions of Landslides of July 9, 1973, Kanawha County, West Virginia (in feet unless noted)*

| SLIDE (FIG.2) | TOP OF SLIDE | | | ROUTE OF SLIDE | | | BOTTOM OF SLIDE | |
|---|---|---|---|---|---|---|---|---|
| | ELEVATION ABOVE SEA LEVEL | DISTANCE BELOW HILLTOP | WIDTH | VERTICAL DROP | DISTANCE OF MOVEMENT ON SLOPE | AVERAGE SLOPE, DEGREES | ELEVATION ABOVE SEA LEVEL | WIDTH |
| A | 1060 | 60 | 45 | 330 | 800 | 22 | 730 | 100 |
| B | 892 | 220 | 20 | 52 | 250 | 12 | 840 | 35 |
| C&D | 750 | 350 | 10-20 | 70 | 180 | 15 | 680 | 40 |
| E | 970 | 50 | 30 | 320 | 600 | 34 | 700 | 60 |
| F | 1050 | 70 | 15 | 416 | 1100 | 22 | 634 | 15 |
| G | 780 | 320 | 50 | 10 | 10 | 30 | 770 | 50 |
| H | 1100 | 70 | 20 | 250 | 600 | 30 | 850 | 20 |
| I | 1020 | 30 | 40 | 400 | 900 | 25 | 620 | 10-15 |
| J | 1000 | 75 | 30 | 385 | 800 | 30 | 615 | 50 |
| K | 670 | 355 | 22 | 50 | 65 | 30 | 620 | 30 |

FIGURE 5. SKETCH OF THE TOP OF SLIDE A



feet below the top of the scarp. Neither the presence of this vent nor the underlying mine had any effect upon this slide. Slides C and D (Figure 2) are identical to B (50 feet high, occurring at the base of the mountain), except that they began at a lower elevation. Two very similar slides, 15 to 20 feet high, occurred between C and D.

Slide E occurred in the valley of the Left Fork of Upper Donnally Branch. About 3 feet of sandy, rocky soil was removed from above a sandstone ledge in the area where the slide began. The rocks in the immediate vicinity include a massive sandstone that overlies 30 inches of coal, which, in turn, overlies 15 feet of thickly bedded sandstone. This coal is probably the Coalburg coal at the base of geologic unit 3 (Figures 3 and 4).

Slide F (Figure 2) occurred behind the house of Mr. E. Bailey of 722 Lower Donnally Road. In the area where the slide began, apparently a wedge of rocky soil 3 to 4 feet deep by 13 feet wide was removed. This exposed a 15-foot rock cliff. Sandmarks on trees 12 feet out from the base of this wedge showed that the slide was about 12 feet deep, or splashed 12 feet high, at this point. The exposed cliff consists of the same medium-bedded sandstone within geologic unit 2 as noted at the point of failure of Slide A. Approximately 50 feet in front of the base of the removed soil wedge is a rectangular depression, with vertical soil sides, about 7 feet by 4 feet, and covered by at least 1 foot of soil. This may be some type of man-made feature, although no evidence was found for any coal or coal mining in the area.

Slide G occurred behind 866 Chappell Road. The slide is unique in this area because the failure was a rotational slump and occurred along a bowl-shaped curved surface. The slide took place behind a house that had been built on an excavation into the base of the steep slope. The excavation of this material to make room for the house apparently removed the support of the hillside, i.e., "cut the toe of the slope." There is evidence of some past coal mining well above the slides, but there seems to be no apparent connection between the two.

Slide H occurred behind 909 Chappell Road. The point of failure was one of the very few cases in which a slide began where definite human activity had taken place. In this case, the slide originated in the fill beneath a jeep trail. The road itself was saturated with water, which may have contributed to the slide. Bedrock in the cliffs above the road is thickly bedded sandstone with much vertical fracturing and with some shale. The scarp is located near the top of geologic unit 1 (see Figures 3 and 4). Moderately large sandstone boulders were carried down the mountain.

Slide I occurred behind 4405 Chesterfield Road. Halfway down the slope, this slide moved into a pre-existing drainage depression that channelled its direction. Where the slide began, a uniform thickness of about 1 1/2 feet of soil was removed to expose broken sandstone below. There is evidence for much water movement on both sides of the slide scar down the hill. Bedrock in this vicinity consists of thinly bedded sandstone with some shale of unit 2.

Slide J occurred on Snow Hill in eastern Charleston. It is very near, and very similar to, many older slides. At the scarp, about 2 feet of soil was removed. The slide began in sandstone of unit 1 about 60 feet above the level of the Kanawha black flint. The Winifrede coal is exposed about halfway up the slide.

Slide K occurred behind 3420 East Piedmont Road. At the point of failure, about 2 1/2 feet of rocky soil was removed, but this did not expose any bedrock.

Table 2 summarizes the physical dimensions of these slides. All of the large landslides (A, E, F, H, I, and J) have several common attributes. They all originate at an elevation of about 1,000 feet and less than 100 feet from the top of the hills, and they all began at about the same geologic horizon, the shale of unit 2. The estimated slopes for all these slides are greater than 22°.

## CONCLUSIONS

### Causes of Landslides

The factors involved in the initiation of the landslides include a combination of geologic, topographic, surface-runoff, and ground-water conditions. The topography in this area is very steep, and the potential for soil and rock erosion and slumping on such terrain is great under normal conditions. The intense storm of July 9, 1973, added an extremely rare amount of rainfall to an existing, naturally-unstable situation. The role of ground water in causing these slides is not completely clear. In the case of slide A, ground water may have been responsible for saturating the wedge of soil before the intense rain.

The generalized regional rock sequence in this area consists of a thick sandstone capping a shale and sandstone sequence. For example, at slide A approximately 100 feet of sandstone (unit 1) overlies a 50-foot sequence of alternating sandstone and shale (unit 2). The low permeability of the shale units prohibited any water that may have percolated down through the soil and the overlying sandstone from continuing downward to the water table. Instead, this water accumulated and remained in the soil zone. Underground water, moving downward through pores and fractures in the sandstone and laterally along the top of the shale sequence, may have aided in saturating the soil prior to the storm. Measurements of rock permeability near the level of the water table in these hills will be required to further evaluate the role ground water played in causing these landslides.

The topography of the hills is a direct consequence of the bedrock. The more resistant sandstone resists erosion and stands out as near-vertical cliffs, whereas the less resistant shales are easily eroded to form benches. Soil and rock debris accumulate on these benches--the soil wedges involved in the landslides.

In reconstructing the events leading up to the development of the larger slides (A, E, F, H, I, and J), the following picture emerges. Early during the rainfall, water soaked into the soil, both directly from rainfall and from water flowing over the surface. Perhaps the soil was already saturated from underground water. Water accumulated in the thin soil and in soil wedges until the soil was completely saturated. The upper 1 to 3 feet of soil then liquefied--this was the time of failure and the start of the slide. This mixture of soil and water cascaded very rapidly as a thick liquid down the steep slopes. At slide F, the mixture left a mark 12 feet above ground level on trees at the base of the scarp. Boulders up to 7 feet in diameter, part of the residual soil, were carried down the hill. Trees with 2- to 3-foot diameters were uprooted. The soil and water mixture "snowballed" as it moved down hill, incorporating 1 to 2 feet of soil (also saturated and at the point of liquefaction) along most of its path. The slide's movement can best be described as sheet wash of the soil and water.

Reconstruction of the smaller slides (B, C, D, G, and K) gives much the same picture. These slides, however, generally were not more than 50 feet high, and they occurred in colluvial soil at the base of mountain slopes. In these cases, the low-permeability layer within the soil prevented water from percolating downward into the rocks. In all other respects, except elevation, these smaller slides resemble the larger ones. The small slide at 866 Chappell Road (slide G) was unusual in that it was a rotational slide. The scarp face was 7 to 10 feet high, which is about the thickness of the soil zone. The surface of rotation was, in part, the soil-bedrock contact.

There is no evidence of any "blow-out" of water under high pressure from the side of these hills. The soil-flow marks high on trees below the points of failure could lead to this hypothesis; however, a rapidly liquefied mass of soil and rock could move with sufficient speed simply under the influence of gravity to make such marks. There is at present no evidence that coal mining was in any way connected with, or responsible for, these landslides. The abandoned mines in the Winifrede coal are at least 200 feet below the landslide scarps. No evidence of mining was found in or around any of the slide scarps investigated. At the top of slide E, the Coalburg coal is exposed, but there is no evidence of mining. There is a possibility that the Stockton-Lewiston coal occurs near the top of slides A, F, and I, but the natural soil and landslide debris have completely covered the interval. Although not related to coal mining, a jeep trail at slide H may have had a relationship to the slide, but only in localizing the point of failure at that particular elevation, rather than somewhat higher or lower.

## Future Landslides in the Kanawha City Area

The probability of small slides recurring in the Kanawha City area is very likely. This type of slide is mainly a nuisance, generally causing minor damage and posing little or no threat to public safety.

Large slides, such as the one that took place at point A on Figure 2 and took the lives of the three Hunter children, were initiated by the intense rainfall of July 9 more than any other single factor. Since the probability is very low that this storm intensity will happen again, it follows that the probability also is low that these large landslides will recur. However, the other factors contributing to landslides continue to exist, namely unfavorable geologic conditions, very steep slopes, some ground-water discharge, and man's activity. Therefore, it is quite possible that a less-intense rainfall could produce disastrous landslides at some time in the future. With present knowledge, no prediction can be made of the exact location or timing of future slides. Suggesting methods to prevent future landslides and to minimize damage are the best that can be done.

## Recommendations

To reduce the likelihood of major landslides and to minimize damage from any slide that may occur, the following recommendations are made:

1. No blasting should be done near the tops of these mountains for any reason.

2. Bare slopes should be seeded with fast-growing, deep-rooted ground cover as soon as possible.

3. Slopes should not be overloaded with buildings or roads, and the base of slopes should not be excavated without detailed on-site evaluations. The excavation of this material can often remove the support for the slope and cause slides. Although overloaded slopes and excavated slope bases played no part in

most of the landslides of July 9, this recommendation is made as a precautionary measure.

4. The natural surface-water drainage of the hillsides should not be altered. For example, small dams can cause an increase in soil water content and hence in hillside instability.

5. In areas where soils are often saturated, subdrains may be installed into hillsides to reduce the danger of slides.

6. Regulatory zoning for houses at the base of mountain slopes should be considered. These types of regulations could prevent excessive cutting into the base of slopes or even regulate the distance of construction from the bases of the hills. The Hunter house and adjacent houses are much closer to the base of the hill than the houses beneath slides F and H.

7. Impoundments in Lower Donally Branch and the several dams across Chappell Hollow should be inspected and upgraded. Spillways should be installed and existing culverts should be enlarged. Had any of these dams broken during the floods, a still greater disaster may have occurred.

8. A core hole should be made at the top of the hill above the Right Fork of Upper Donnally Branch to determine:

    a. The exact sequence of rock underlying the hill and the nature of the fractures in these rocks.

    b. The level of the water table.

    c. The permeability of the rock in place.

    d. The positions and thickness of any coals that may now be concealed by landslide debris.

    This boring should penetrate at least to the level of the Winifrede coal, a depth of approximately 300 feet. The information gained by core drilling can then be used to further assess the problem of large slides at this location. Costs for a drilling contractor for this type of core-hole is in the range of $5 to $8 per foot plus setup fees, or about $2,000 to $4,000 total costs.