Prepared in cooperation with the
Appalachian Regional Commission

Heavy storm precipitation and related mass movement, Allegheny County, Pennsylvania

Heavy storm precipitation in Allegheny County is derived from decaying stages of extratropical cyclonic storms entering the Ohio River basin, as well as from storms resulting from continental weather movements. The cyclonic storms have been classified as hurricanes by the National Weather Service. Although such storms generally have lost hurricane wind velocities by the time they enter the Ohio River basin, they bring with them or cause heavy rains (Relyea, 1969). So far as known, there is no standard criteria on expressing the rate of heavy precipitation; however, Blair (1944, p. 73) discussed rates of excessive rainfall.

"Rainfall is considered excessive when it falls at the rate of 0.25 inch in 5 minutes, 1 inch in 1 hour, or 2.50 inches in 24 hours." Rainfall at these rates have been commonly reported as heavy. The pattern of hurricane tracks in the Ohio River basin are shown on figure 1, and their resulting precipitation recorded at Pittsburgh is given in table 1. An analysis of 38 hurricanes (1872-1965) tracking the Ohio River basin indicates a 2.8 year recurrence (Relyea, 1969). Hurricanes Camille (August 1969) and Agnes (June 1972) have been included on figure 1 and their data given in table 1. The number of hurricanes tracking the Ohio River basin (1872-1972) is 40. A summary of selected data of historical interest on the 40 is listed in the following table.

Earliest date: June 17 (in 1934)
Latest date: October 26 (in 1872)
Average date: September 3
Maximum number in any one year: 3 (in 1915, and in 1916)
Number of hurricane storms affecting western part: 23
Number of hurricane storms affecting middle part: 15
Number of hurricane storms affecting eastern part, which includes Allegheny County: 21
Total number of hurricanes (1872-1972): 40 (12 affected more than 1 - part of the basin)
Highest recorded Ohio River stage from hurricanes at Pittsburgh: 35.8 feet in 1972 (Flood stage at Pittsburgh 25 feet)
Number of floods from hurricanes at Pittsburgh: 3 (1888, 1954, and 1972)

Three floods at Pittsburgh have been associated with precipitation from hurricanes; however, the flood of record at Pittsburgh (March 1936) resulted from the combined effect of precipitation and snow-melt runoff. The combination created a river stage on the Ohio River at Pittsburgh of 46 feet (14.0 m)--21 feet (6.4 m) above flood stage. High intensity precipitation not of hurricane origin occurs in the region and produces disastrous floods. One very severe cloudburst over much of Allegheny County on the evening of July 26, 1874, caused the deaths of more than 150 persons and destroyed a great deal of property. An article in the Pittsburgh Gazette of the time described it as an "Appaling Disaster, Fearful Record of a July Sabboth." Local flash flooding occurred in tributary stream valleys of the Ohio River Basin, notably in McLaughlin and Painters Runs in the vicinity of Bridgeville, south of Pittsburgh. Precipitation from this storm recorded at Pittsburgh during July 26 and the early morning of July 27, 1874, totaled 3.40 inches (86.4 mm), of which 3.26 inches (82.8 mm) occurred on July 26.

The impact of heavy-storm precipitation on the hydrogeologic regime and land use is generally related to intensity and duration. Impact is also affected by soil moisture at the time of precipitation, which, in turn, is influenced by other recent storms and by soil composition, structure, and thickness; slope; surface cover; and land use. The soil absorbs all the rain it can by infiltration; the excess then runs off to streams. Occasionally this runoff is of flood proportions. Floods resulting from precipitation of more than 5 inches (130 mm) in a 24-hour period will be little affected by soil moisture. The highest 24-hour record of precipitation at Pittsburgh is 3.57 inches (90.7 mm) from hurricane Hazel in 1954.

A sequence of several daily periods of light or moderate precipitation may have similar hydrologic results as those from a single period of heavy precipitation. The percolation of rain water through the soil, from either type of precipitation, is one of the important processes associated with mass movement. Water percolates from the soil zone into the joints in the underlying sandstone, siltstone, shale, and limestone beds, increasing the degree of saturation and adding to the fluid pressure within the rock mass. Joint planes and other planes of weakness fail under stress. These conditions may be considered chief factors affecting slope stability of unstable soils and bedrock materials of Allegheny County. The environmental characteristics of unstable soils in Allegheny County are given in table 2. The areal distribution of soils in the county is shown in U.S. Department of Agriculture-Soil Conservation Service (1973a). Joints and other structural characteristics of rock materials, as related to slope failure due to hydrogeologic and environmental stresses, are illustrated on a slide in Elizabeth Township on State Highway 51 half a mile (0.8 km) southeast of the Monongahela River bridge at Elizabeth. The slide has a horizontal dimension of about 1,000 feet (300 m) on a bedrock terrace above Fallen Timber Run. As reported by Jessee Craft[1/], the slide problem at this urban site is probably the result of slope failure involving three types of movement: 1) slump-type fill failure; 2) mud-slide failure of strip-mine refuse; and 3) joint-block failure.

Although variations of intensity of precipitation may result in similar types of mass movement, heavy-storm precipitation appears to have the more extensive affect in relation to the magnitude and distribution of landslides. A preliminary inventory up to June 1974 of the distribution of landslides in Allegheny County initiated or aggravated by heavy-storm precipitation of hurricane Agnes is shown in figure 2. The majority of these slides have occurred in fine-grained weathered clayey materials overlying rocks from the Ames Limestone Member of the Glanshaw Formation of the Conemaugh Group upward to the base of the Upper member of the Pittsburgh Formation (Benwood Limestone as used by Gallaher, 1973) of the Monongahela Group. The fine-grained weathered clayey materials have a high porosity--as much as 40 percent, but their permeability is low, ranging from 0.001 to 2 gpd/ft^2. As little as 1 to 5 percent of the pore water will drain by force of gravity. The pore water is rather largely retained in the interstices by forces of molecular attraction, adhesion, and cohesion. An increase of this pore-water pressure in such deposits tends to result in excessive hydrostatic pressure, which, in turn, decreases their component of shear resistance--reducing resistance to sliding. In many places surcharge conditions occur that can cause slope failure in poorly compacted and poorly drained landfill composed of soil and vegetal material, construction debris, strip-mine refuse, and waste piles of rock quarries. These may result in oversteepen slopes of unstable material readily subject to erosion, compaction, and slump movement. Other unstable conditions of mass movement in the county occur from soil creep and rock fall.

1/ Reported in "Upper St. Clair (Township, Allegheny County) as it was--A Documentary" by Margaret B. Gilfillan, Woman's Club of Upper St. Clair, undated. Spelling as quoted by Mrs. Gilfillan.

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Relyea, C. M., 1969, Hurricanes and the Ohio River: New York Academy of Sciences Trans., Ser. II, v. 31, n. 1, p. 42-55, January.

U.S. Department of Agriculture, Soil Conservation Service, 1973a, Volume 1 - Soil survey maps for Allegheny County, Pennsylvania: U.S. Dept. Agri., p. 1-7, 243.

U.S. Department of Agriculture, Soil Conservation Service, 1973b, Volume 2 - Soil survey interpretations for Allegheny County, Pennsylvania: U. S. Dept. Agri., p. 1-120, G1-G7.

Figure 1.--Tracks of extratropical storms entering Ohio River basin, 1871-1972. (Adapted from Relyea, 1969)

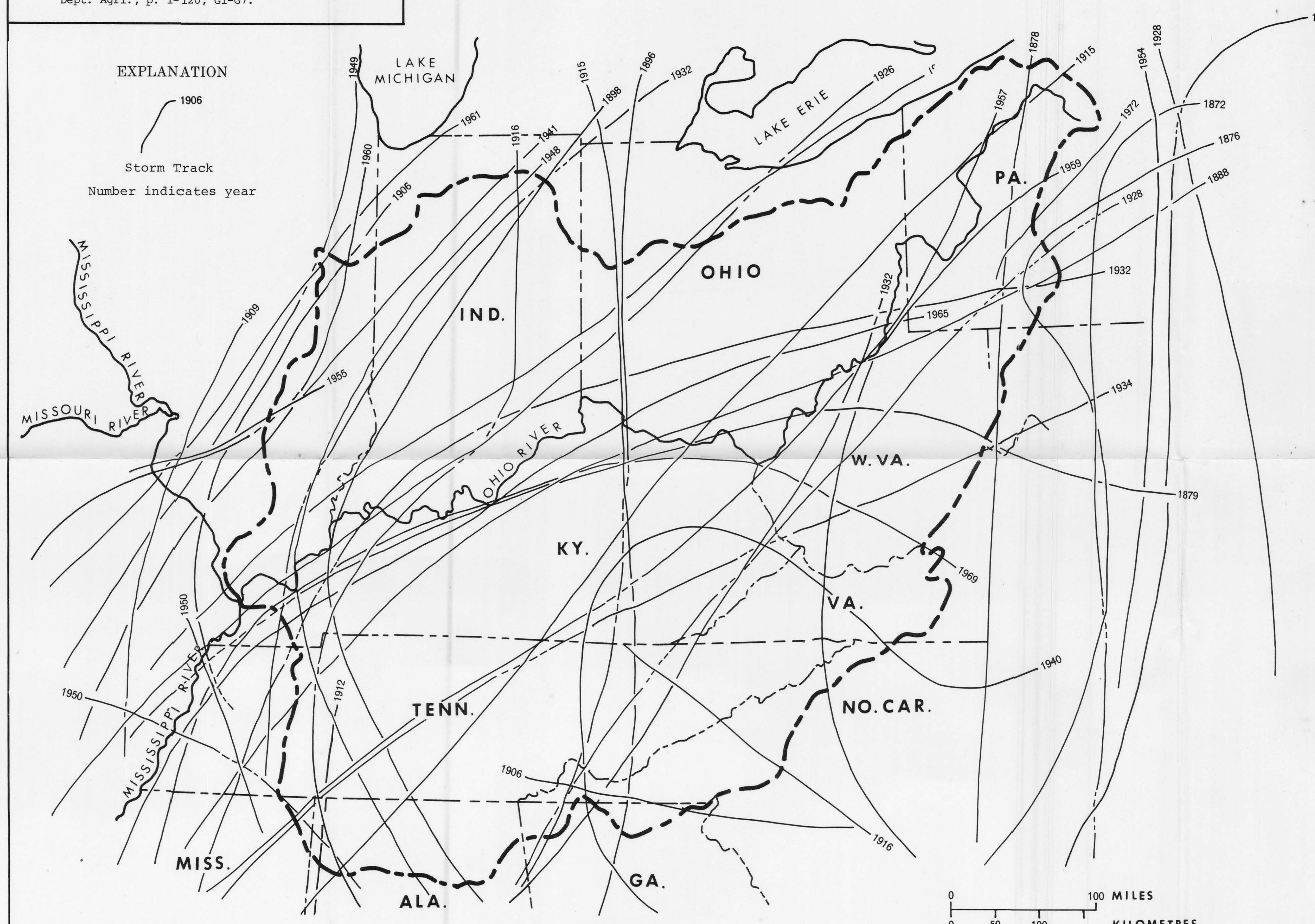


Table 1.--Precipitation (in inches) at Pittsburgh, Pa. associated with hurricane storms tracking the Ohio River basin (See fig. 1). Adapted from Relyea, 1969. (Precipitation data from National Weather Service.)

Year	Month	Day	Amt. (inches)	Track W	Track M	Track E
1872	Oct.	22	0.01			X
		23	.41			
		24	.03			
		25	1.90			
		26	.24			
		27	.04			
1876	Sept.	16	.30			X
		17	3.38			
		18	1.21			
1878	Sept.	11	.31			X
		12	3.24			
		13	.93			
1879	Aug.	23	1.01	X	X	X
		24	.28			
		25	2.59			
1879	Sept.	1	0			
		2	.06	X	X	
		3	.01			
1880	Sept.	1	0			
		2	0			
		3	.06	X		
1888	Aug.	17	2.42	X	X	X
		18	.14			
		19	0			
		20	0			
		21	3.57			
		22	.08			
1893	Oct.	12	0			
		13	1.01			X
		14	.33			
		15	.05			
1896	July	4	.34		X	
		5	.88			
		6	.06			
		7	.13			
		8	.07			
		9	.54			
1898	Oct.	2	0			
		3	0			
		4	.03	X	X	
		5	.14			
		6	0			
1906	Sept.	18	0			
		19	.01	X		X
		20	2.33			
		21	T			
		22	.10			
		28	0			

Year	Month	Day	Amt. (inches)	Track W	Track M	Track E
1906	Sept.	30	.10			
1909	Sept.	20	0			
		21	0			
		22	T	X		
		23	.34			
		24	0			
1912	Sept.	13	0			
		14	.03	X		
		15	.16			
		16	.01			
		17	0			
1915	Aug.	19	0			
		20	0.07	X	X	
		21	.14			
		22	.09			
		23	0			
	Sept.	3	T		X	
		4	T			
		5	.05			
		6	.04			
		7	T			
		30	T			
	Oct.	1	1.50		X	X
		2	T			
1916	July	9	0			
		10	T	X	X	
		11	0			
		13	.09			
		14	.51			
		15	T			
		16	.78			
		17	.01			
		18	.18			
	Oct.	15	.06	X		
		16	.06			
		17	.02			
		18	.07			
		19	1.56			
		20	.27			
1926	July	31	0			
	Aug.	1	.01	X	X	X
		2	T			
1928	Aug.	15	0			
		16	T			
		17	.08			
		18	.19			
		19	0			

Year	Month	Day	Amt. (inches)	Track W	Track M	Track E
1928	Sept.	18	0			
		19	.49			
		20	.39			
		21	T			
		22	0			
1932	Sept.	1	0			
		2	.07	X		
		3	0			
1934	June	17	0			
		18	1.56	X	X	X
		19	T			
1940	Aug.	13	0			
		14	.09			X
		15	0			
1941	Sept.	23-26	0			
1948	Sept.	5	0			
		6	.03	X		
		7	.11			
		8	.03			
		9	T			
1949	Aug.	27	0			
		28	0.42			X
		29	.12			
		30	0			
		31	.22			
	Oct.	3	0			
		4	.21	X		
		5	.03			
		6	.18			
		7	.40			
		8	0			
1950	Aug.	28	.04	X		
		29	.09			
		30	.98			
		31	.03			
	Sept.	1	.13	X		
		2	T			
		7-8	0			
		9	.01			
1954	Oct.	14	0			

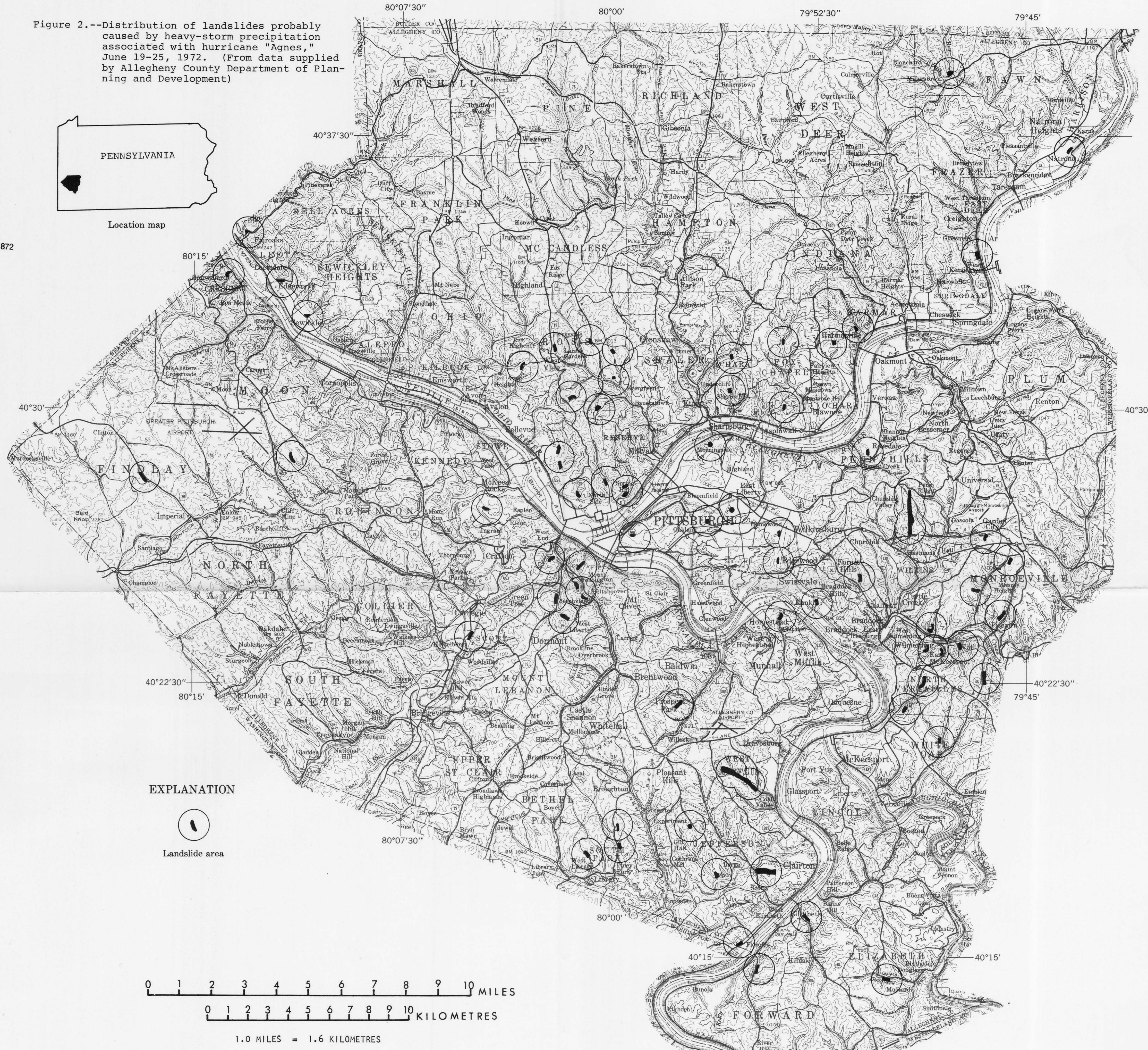
Year	Month	Day	Amt. (inches)	Track W	Track M	Track E
1954	Oct.	15	3.57			
"Hazel"		16	T			
		17	.12			
1955	Aug.	10	0			
		11	1.98			X
"Connie"		12	T			
		13	2.24			
		14	0			
1957	June	27	0			
		28	.90	X	X	X
"Audrey"		29	.09			
		30	.08			
1959	Sept.	29	0			
"Gracie"		30	1.68			X
	Oct.	1	.04			
		2	0			
1961	Sept.	12-13	0			
		14	.18	X		
"Carla"		15	0			
1965	Sept.	10	T	X	X	X
		11	.47			
"Betsey"		12	1.13			
		13	.20			
		14				
1969	Aug.	16	.02	X	X	X
		17	.02			
"Camille"		18	.05			
		19	1.40			
		20-22	0			
1972	June	19	0			
		20	1.66			X
		21	.27			
"Agnes"		22	1.23			
		23	.64			
		24	.34			
		25	.06			

Track, W - Western portion of basin
M - Middle portion of basin
E - Eastern portion of basin

T - Trace
X - Portion of basin affected by storm track

Conversion
1 Inch = 25.4 Millimetres

Figure 2.--Distribution of landslides probably caused by heavy-storm precipitation associated with hurricane "Agnes," June 19-25, 1972. (From data supplied by Allegheny County Department of Planning and Development)



CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

Base Map from U.S. Geological Survey 1972

Table 2.--Environmental characteristics of unstable soils, Allegheny County, Pa. (Adapted from U. S. Department of Agriculture - Soil Conservation Service, 1973b) Areal distribution of soils in Allegheny County shown in U. S. Department of Agriculture-Soil Conservation Service, 1973a.

Soil Series	Rock Type	Description 1/ 2/	Soil Cover: Percent of County	Soil Cover: Acres 2/
Ernest-Vandergrift	Colluvium	Deep, moderately well drained soils formed from relatively acid colluvial material. Occur as a complex of Ernest and Vandergrift soil textures on concave landscape slopes ranging from 3 to 25 percent at the base of steeper upland slopes. Depth to bedrock 5+ feet.	<1	1,500
Gilpin-Upshur	Shale	Moderately deep and deep, well drained soils formed from relatively acid shale and some sandstone interbedded with non-acid red clay shale. Occur as a complex of Gilpin and Upshur soil textures forming upland slopes ranging from 3 to 80 percent. Gilpin-Upshur depth to bedrock: Gilpin 1-1/2 to 3-1/2 feet; Upshur 5+ feet.	16	74,000
Guernsey, fine loamy variant	Shale and limestone	Deep, moderately well drained soils formed from interbedded shale and limestone bedrock up to a thickness of 5-feet. Depth to bedrock 4+ feet. They generally nave slow permeability of less than 0.2 inch per hour and occur on upland slopes ranging from 2 to 35 percent.	8	39,000
Guernsey	Shale and limestone	Deep moderately well drained soils formed from interbedded clay shale, shale and limestone bedrock up to a thickness of 4-feet. Depth to bedrock 4+ feet. Generally have slow permeability of less than 0.2 inch per hour and occur on upland slopes ranging from 2 to 25 percent.	3	14,500
Guernsey-Vandergrift	Colluvium	Deep, moderately well drained soils formed from interbedded shale, limestone, and red clay shale bedrock. Occurs as a complex of Guernsey and Vandergrift soil textures on upland slopes ranging from 3 to 25 percent. Depth to bedrock: Guernsey 4+ feet, Vandergrift 5+ feet.	3	12,000
Library	Shale and Limestone	Deep, somewhat poorly drained soils formed from limestone and some shale bedrock up to a thickness of 4-1/2 feet. Depth to bedrock 3-1/2 to 6 feet. Generally have slow permeability of less than 0.2 inch per hour and occurs on upland slopes ranging from 3 to 25 percent.	<1	3,100
Upshur	Shale	Deep, well drained soils formed from non-acid red clay shale up to a thickness of 5-feet. Depth to bedrock 5+ feet. Generally have slow permeability of less than 0.2 inch per hour and occur on slopes ranging from 3 to 15 percent.	<1	800

Hydrologic Characteristics 2/

Soil series suggested as unstable (landslide prone) make up about 30 percent of the 466,000 acres of soil cover of Allegheny County. These are characterized by a soil profile which consists chiefly of silty loam, blocky silty clay, and shaly silty clay matrix containing fragmental chips of shale, limestone, and sandstone. Such soils have slow permeability of less than 0.2 inch per hour, locally seasonal high water table as deep as 6 feet below ground surface, generally considered moderately well drained, and form upland slopes ranging from 2 to 80 percent. In turn, these characteristics may affect their moisture content and pore-water pressure as influenced by their response to the frequency, intensity, and duration of precipitation.

Other unstable soil series may be those associated with mine dumps, strip mines, and urban land which reflect varying hydrogeologic characteristics, generally of poor drainage, and require more extensive on-site investigations. These soil series are described as

Mine dumps - Variable land consisting of coal, shale, sandstone, and other acid materials which resulted from underground mining operations and most often occurring as very steep sided slopes.

Strip mines - Variable land consisting of rock, waste coal and soil material resulting from surface mining operations. It occurs chiefly in upland areas forming slopes ranging from 0 to 75 percent.

Urban land - This land consists of (1) fill material which was hauled and placed on flood plains and (2) highly disturbed land resulting from cut and fill operation; both of which are subsequent to coverage of land with urban structures.

1/ Permeability excludes A soil horizon, commonly less than 10 inches.
2/ 1 inch = 25.4 millimetres; 1 foot = 0.3048 metre; 1 acre = 0.4047 hectare.

Interior—Geological Survey, Reston, Va.—1976—L26068

Heavy storm precipitation and related mass movement, Allegheny County, Pennsylvania By Seymour Subitzky 1975