

FLOODS IN THE FAJARDO-LUQUILLO AREA,  
NORTHEASTERN PUERTO RICO

This report provides factual and interpretive information on major floods in the Fajardo-Luquillo area. The information provides a technical basis on which the planner, engineer, administrator, or other interested persons can make decisions relative to land use and development compatible with the degree of flood risk. Among the data presented are tabulations of flood discharge and flood stage, flood profiles, and a map of the area inundated by the floods of 1960 in the Rio Fajardo basin, the floods of 1970 in the Rio Sabana, Rio Pitahaya and Rio Juan Martin basins; and the flood of 1972 in the Rio Manayes basin. The areas of inundation are specifically for conditions that existed at the time of the floods. A tabulation of flood-frequency data is presented for selected sites. This study is based principally on floodmarks obtained immediately after the floods of 1960, 1970, and 1972 by personnel of the U.S. Geological Survey. Information was also obtained from interviews with residents who live or work in the study area.

A dual system of metric, "The International System of units (SI)", and English units are used in this publication. English units followed by SI units in parentheses are used throughout the report except in tables. Tables are in English units and a conversion table is included. The following abbreviations are used:

inches	.....	ft
feet	.....	mi
square mile	.....	mi <sup>2</sup>
cubic feet per second	.....	ft <sup>3</sup> /s
cubic feet per second per square mile	.....	ft <sup>3</sup> /s-mi <sup>2</sup>
millimeter	.....	mm
meter	.....	m
kilometer	.....	km
square kilometer	.....	km <sup>2</sup>
cubic meter per second	.....	m <sup>3</sup> /s
cubic meters per second per square kilometer	.....	m <sup>3</sup> /s-km <sup>2</sup>

**Drainage Basins**—The Fajardo-Luquillo study area (fig. 1) lies in the northeastern part of Puerto Rico and encompasses about 75 mi<sup>2</sup> (194 km<sup>2</sup>) of the coastal plain bordering the Océano Atlántico and the mountains El Yunque area which is the eastern terminus of the Sierra de Luquillo.

The coastal plain is covered by large areas of mangrove forest and lowlying land which are partly drained by networks of canals discharging to the streams. Higher ground is mostly used for raising sugarcane with some dairy farming. Highways, urbanization, and industries are causing swift and drastic cultural changes in the area.

The mountains area is largely in timber and lies in the Caribbean National Forest which is renowned for its rain forest where rainfall exceeds 500 in (12,800 mm) annually. The five rivers that contribute to flooding in the study area have their origins on the northern or eastern slope of the Sierra de Luquillo and discharge to the Océano Atlántico. The combined drainage of the streams is about 60 mi<sup>2</sup> (155 km<sup>2</sup>). The peaks and the main escarpment of the Sierra de Luquillo range between 2,500 and 4,000 ft (760 and 1,200 m) above mean sea level. The maximum distance from stream origin to the Océano Atlántico (Rio Fajardo) is 15 mi (24 km). Channel slopes are very steep and stream velocities are extremely high in the mountains. The slopes become less steep from the foothills to the ocean.

Rio Manayes, the westernmost stream in the study area flows in a northerly direction and passes to the east of the town of Manayes before emptying into the Océano Atlántico. The drainage area at the mouth is 17.2 mi<sup>2</sup> (44.5 km<sup>2</sup>). At the U.S. Geological Survey gaging station near Sabana (site 1 in fig. 1) the drainage area is 6.9 mi<sup>2</sup> (17.9 km<sup>2</sup>). Rio Sabana also flows northward discharging to the ocean at the town of Luquillo. Rio Pitahaya, its major tributary, joins the Rio Sabana about 0.3 mi (0.5 km) from the ocean. The drainage area of Rio Sabana at the mouth, including Rio Pitahaya, is 18.6 mi<sup>2</sup> (48.3 km<sup>2</sup>). At the U.S. Geological Survey gaging station at Luquillo (site 2 in fig. 1) the drainage area of Rio Sabana is 7.0 mi<sup>2</sup> (18.1 km<sup>2</sup>). Rio Juan Martin heads on the foothills of the Sierra de Luquillo and flows northward through mangrove forest on the coastal plain and empties into the sea. The drainage area at the mouth is about 2.8 mi<sup>2</sup> (7.3 km<sup>2</sup>).

Rio Fajardo, the largest stream in the study area, flows in a northeasterly direction, passing to the south of the town of Fajardo and reaches the sea about 0.2 mi (0.3 km) south of Punta Fajardo. The drainage area at the mouth is about 26.4 mi<sup>2</sup> (68.4 km<sup>2</sup>); at the U.S. Geological Survey gaging station near Fajardo (site 3 in fig. 1) it is 14.3 mi<sup>2</sup> (36.8 km<sup>2</sup>), and at the U.S. Geological Survey gaging station at Fajardo (site 4 in fig. 1), it is 21.6 mi<sup>2</sup> (55.9 km<sup>2</sup>).

**Flood Frequency**—It is not possible to predict when a flood of a specific magnitude will occur. However, the probable number of floods with a specific magnitude that will occur over a long period of time can be estimated. The frequency of occurrence (recurrence interval) is the average interval of time within which a given flood will be exceeded once. For example, a flood with a 25-year recurrence interval would have a 4 percent chance of being exceeded in any given year, or a flood with a 50-year recurrence interval would have a 2 percent chance of being exceeded in any given year.

The frequency of occurrence for the peak discharges of the floods of 1960, 1969, 1970, and 1972 at 4 sites (fig. 1) are shown in table 1. These recurrence intervals were computed on the basis of data and method reported by Lopes and Fields (1970). Because records are of insufficient length to support computation of recurrence intervals greater than 50 years, the ratio of the peak discharge to the 50-year flood has been shown as an indication of magnitude.

**Flooded Areas**—The areas inundated by the 1960 flood on Rio Fajardo; the 1970 flood on Rio Juan Martin, Rio Pitahaya and Rio Sabana; and the 1972 flood on Rio Manayes have been delineated on the topographic map on the basis of flood-stage information furnished by local residents and observations in the field by U.S. Geological Survey personnel immediately after the floods.

Flood boundaries were determined from water-surface profiles based on elevations of floodmarks, which were obtained from field surveys. The boundaries are well defined in densely populated areas and fairly well defined in agricultural and forest lands.

The flood boundaries shown on the topographic map reflect channel and flood-plain conditions existing when the 1960, 1970, and 1972 floods occurred. The inundation pattern of future floods may be affected by changes in channel conditions, alteration of waterway openings at highways, changes in runoff characteristics of the stream caused by increased urbanization, and other cultural developments. Protective works built after the floods may reduce the frequency of flooding in the protected area but will not necessarily eliminate future floods. By reducing the area subject to flooding, however, protective works may increase the depth of inundation in unprotected areas.

In the Rio Fajardo basin, floodmarks indicate that the flood of September 6, 1960, was about 0.3 ft (0.1 m) higher than the flood of May 21, 1969. However, areas inundated by these two floods are so nearly the same that a difference in flood boundaries cannot be shown. On the topographic map the flood boundary shown on Rio Fajardo actually delineates both of these floods.

**Water-Surface Contours**—Water-surface contours based on floodmark elevations are imaginary lines representing equal elevations of water surface. Generally they are at right angles to the direction of flow. (Exceptions to flow, either natural or manmade, and variations in valley width cause irregularities in the contours. The water surface contours shown on the flood map are for the flood of October 21, 1972, on Rio Manayes; for the flood of October 9, 1970, on Rio Sabana; Rio Pitahaya and Rio Juan Martin; and for the flood of September 6, 1960, on Rio Fajardo.

**Depth of Flooding**—Depth of flooding at any point can be determined by subtracting the ground elevation at the point from the flood elevation indicated by the profile or by water-surface contour lines. The approximate ground elevation can be determined from ground contours shown on the map. Elevation of the ground and of the water surface at any point can be estimated by interpolation between contours. More accurate elevations can be obtained by leveling to nearby reference marks. The elevations and locations of these reference marks are given in table 3.

**Cooperation and Acknowledgments**—This report was initiated as part of the floods investigation authorized by a cooperative agreement between the Department of Public Works, Commonwealth of Puerto Rico and the U.S. Geological Survey. Administration of the cooperative program was placed under the Puerto Rico Department of Natural Resources in January 1972, and this report was completed under their auspices.

**Additional Information**—Additional information relating to floods in the Fajardo-Luquillo area can be obtained from the U.S. Geological Survey, San Juan, Puerto Rico.

SELECTED REFERENCES

Barnes, H. H., Jr., and Bogart, D. B., 1961. Floods of September 6, 1960 in eastern Puerto Rico. U.S. Geol. Survey Circ. 431, 12 p.

Haire, W. J., 1972. Floods of October 5-10, 1970: U.S. Geol. Survey open-file report, 29 p., 1 pl.

Lopes, M. A., and Fields, F. K., 1970. A proposed stream-flow data program for Puerto Rico: U.S. Geol. Survey open-file report, 42 p.



TO CONVERT ENGLISH UNITS TO METRIC UNITS, MULTIPLY:

in	x	25.4	=	mm
ft	x	0.305	=	m
mi	x	1.609	=	km
ft <sup>3</sup>	x	0.028	=	m <sup>3</sup>
mi <sup>3</sup>	x	2.590	=	km <sup>3</sup>
ft <sup>3</sup> /s	x	0.011	=	m <sup>3</sup> /s

Table 2.—Elevation of bridges in flooded areas

Map symbol	Stationing along base line, kilometers	Location of bridge	Elevation, in meters above mean sea level
A	2.08	Rio Manayes, Highway 3	11.6
B	2.35	Rio Sabana, old railroad	1.8
C	.90	do Highway 3	4.1
D	1.00	do old Highway 3	1.8
E	1.40	do old railroad	3.0
F	3.70	do Highway 991	18.1
G	.45	Rio Pitahaya, old railroad	1.8
H	1.65	do dirt road	2.6
I	2.42	do Highway 983	11.4
J	2.70	do Highway 940	8.2
K	1.42	do Highway 983	11.4
L	4.24	do Highway 983	16.5
M	.30	Rio Juan Martin, old railroad	2.3
N	.30	do old railroad	1.1
P	2.00	do Highway 3 (culvert)	20.4
R	2.15	do Highway 940	18.4
S	2.65	do Highway 984	23.3
T	3.12	do Highway 984	31.2
U	1.96	Rio Fajardo, old railroad	1.3
W	2.32	do Highway 195	6.9
X	2.85	do Highway 3	10.9

Table 3.—Reference marks established by the U.S. Geological Survey in the Fajardo-Luquillo area. (See flood map)

Reference mark number	Elevation above mean sea level, meters	Description
1	1.68	At Custom House in Playa de Fajardo. A brass disk stamped "U.S. Geological Survey" set in concrete on first-story stairs facing the Océano Atlántico.
2	5.56	At Central Fajardo. A brass disk stamped "U.S. Geological Survey" set in concrete on base of warehouse next to the Traffic Office of the Central.
3	11.01	At bridge on Highway 3 at kilometer 47.3. A brass disk stamped "U.S. Geological Survey" set in concrete on right upstream side of abutment of bridge over Rio Fajardo.
4	31.35	At bridge on Highway 984 at kilometer 1.6. A brass disk stamped "U.S. Geological Survey" set in concrete on right upstream side of abutment of bridge over Rio Juan Martin.
5	11.64	At bridge on Highway 980 at kilometer 0.7. A brass disk stamped "U.S. Geological Survey" set in concrete on left upstream side of bridge abutment over Rio Pitahaya.
6	19.21	At culvert on Highway 980 at kilometer 3.5 and at entrance to Segunda Unidad de Sabana school. A brass disk stamped "U.S. Geological Survey" set in concrete on downstream side of culvert over Rio Sabana.
7	4.39	At bridge on Highway 3. A brass disk stamped "U.S. Geological Survey" set in concrete on right upstream abutment of bridge over Rio Sabana.
8	2.97	At entrance to Finca San Miguel about 1.5 kilometers northeast of Luquillo. A brass disk stamped "U.S. Geological Survey" set in concrete base on northeast corner of abandoned gas concrete tank.
9	3.11	At entrance to condominium Playa Azul, in Luquillo. A brass disk stamped "U.S. Geological Survey" set in concrete base by fire hydrant.
10	35.48	At culvert on Highway 196 at kilometer 4.3 and at Vajpor. A brass disk stamped "U.S. Geological Survey" set in concrete base on downstream side of culvert over tributary to Rio Pitahaya.
11	15.86	At bridge on Highway 3 at kilometer 1.4. A brass disk stamped "U.S. Geological Survey" set in concrete base on downstream left abutment of bridge over Rio Manayes.
12	9.54	At bridge on Highway 3 at kilometer 31.6. A brass disk stamped "U.S. Geological Survey" set in concrete on left downstream corner of bridge over tributary to Rio Manayes.

Table 1.—Summary of flood stages and discharges

No	Stream and place of determination	Drainage area (mi <sup>2</sup> )	Date of flood	Water-surface elevation (meters above mean sea level)	Discharge (ft <sup>3</sup> /s)	Ratio of peak discharge to 50-year flood	Recurrence interval (years)
1	Rio Manayes at Hwy 191 at Manayes (06071)	11.8	January 26, 1969	12.89	22,200	1.880	1.19
			May 6, 1969	12.84	17,800	1.440	.49
			October 9, 1970	12.49	18,400	1.560	.49
			October 21, 1972	12.81	22,400	1.900	1.22
2	Rio Sabana at Luquillo (0680)	7.08	September 6, 1960	94.5	8,500	1.200	1.5
			May 6, 1969	90.6	13,400	1.960	1.07
3	Rio Fajardo near Fajardo (0710)	14.9	September 6, 1960	47.21	14,500	970	18
			May 6, 1969	47.06	13,400	890	11
			October 9, 1970	48.51	9,200	617	9
4	Rio Fajardo at Fajardo (0720)	21.6	May 21, 1969	8.29	73,800	836	17.5
			October 9, 1970	7.83	73,800	825	9

\* Number refers to station location in figure 1.  
† U.S. Geological Survey downstream order number for site identification.  
‡ Ratio of peak discharge to that of a 50-year flood; long-term records are not available to support frequent greater than the 50-year flood. A ratio of the peak discharge to the 50-year flood in given year as an indication of the magnitude of the flood in relation to the computed recurrence interval of 50 years.

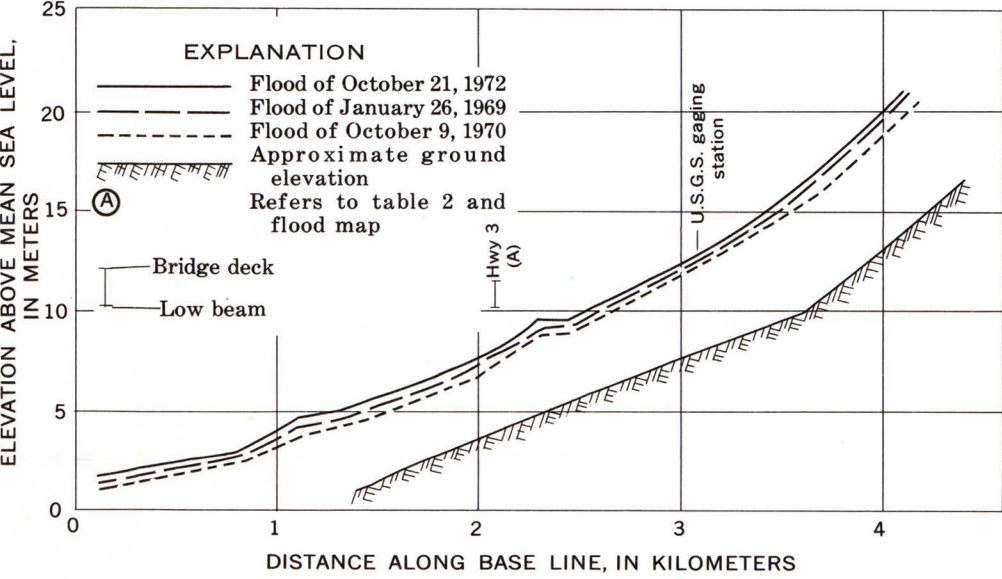


FIGURE 2.—Profile of Rio Manayes, floods of January 26, 1969; October 9, 1970; and October 21, 1972.

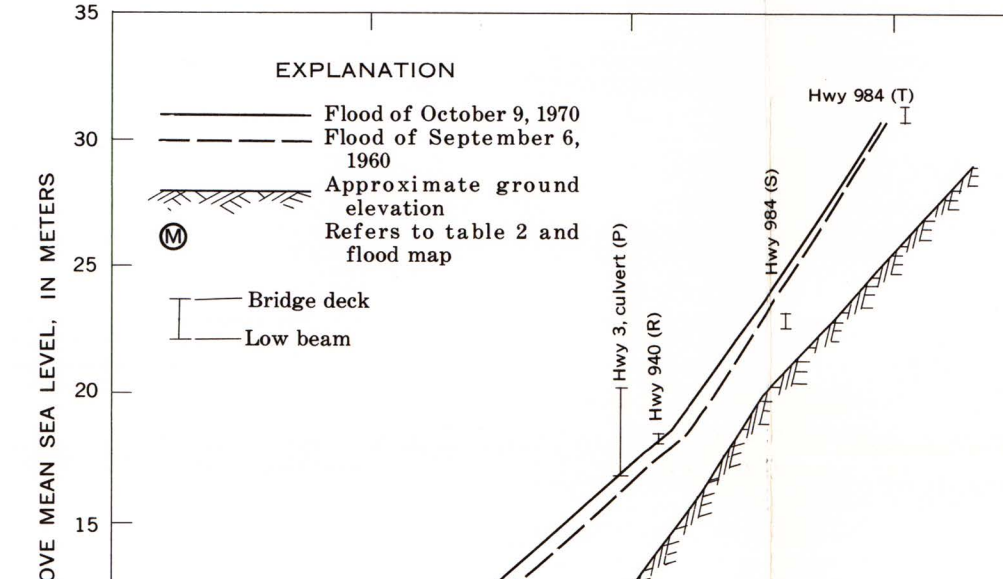


FIGURE 5.—Profile of Rio Juan Martin, floods of September 6, 1960, and October 9, 1970.

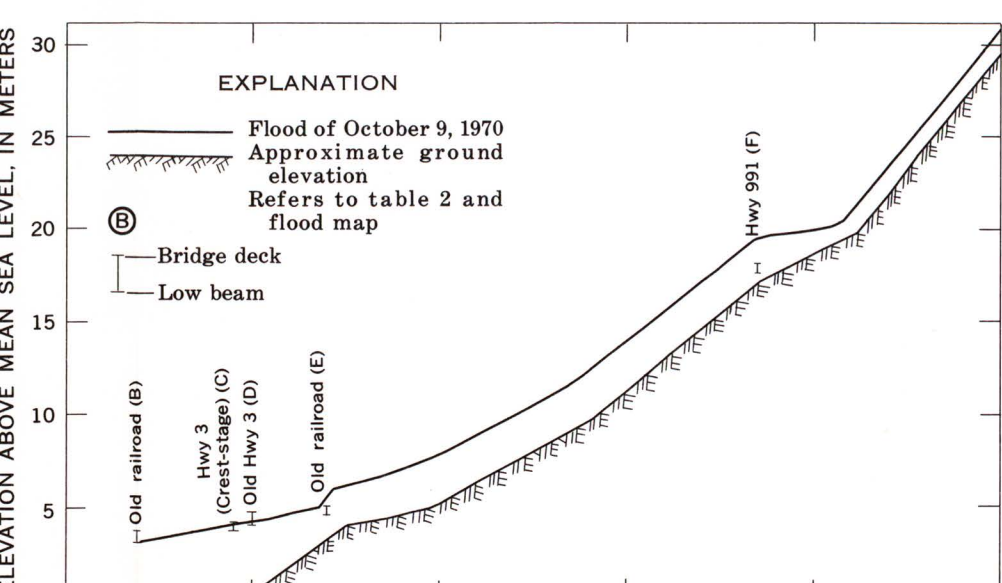


FIGURE 3.—Profile of Rio Sabana, flood of October 9, 1970.

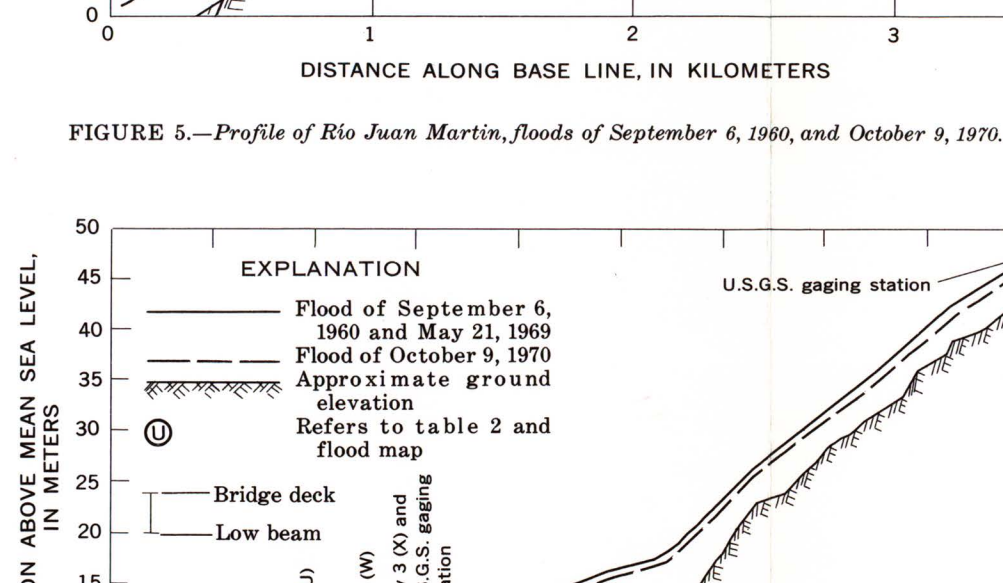


FIGURE 6.—Profile of Rio Fajardo, floods of September 6, 1960; May 6, 1969, and October 9, 1970.

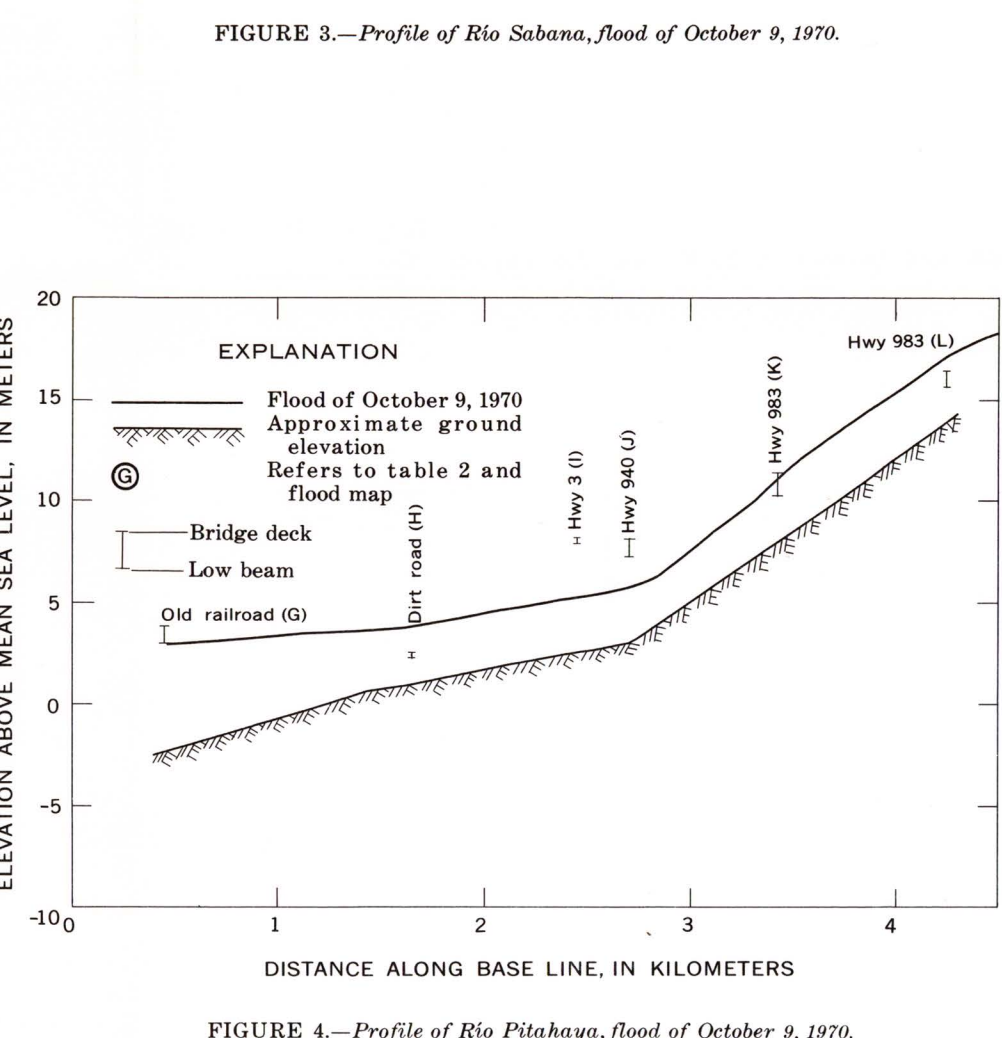


FIGURE 4.—Profile of Rio Pitahaya, flood of October 9, 1970.

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1975