

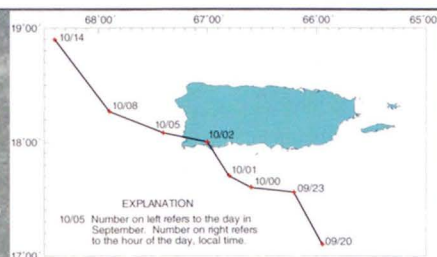
HURRICANE HORTENSE

Impact on Surface Water in Puerto Rico



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

Late Monday night, September 9, and into the early morning hours of Tuesday, September 10, 1996, Hurricane Hortense passed over the southwestern part of Puerto Rico (inset). Hurricane Hortense made landfall as a Category One Hurricane (74 to 95 miles per hour) on the Saffir-Simpson Scale, with maximum sustained winds of nearly 80 miles per hour. The eye of Hurricane Hortense moved over the towns of Guayanilla, Yauco, Guánica, Lajas, San Germán, Cabo Rojo, Hormigueros, and Mayagüez (fig. 1).



Source: NASA—Goddard Space Flight Center

FLOODING

During September 10, 1996, most of the mountainous interior, and several areas along the northern, eastern, and southern coasts of Puerto Rico experienced moderate to severe floods. Almost half of the island's 76 towns were affected by these floods. The most severe flooding occurred within the basins north of the insular hydrologic divide: the Río Grande de Manatí (at the towns of Orocovis, Morovis, Ciales, Manatí, and Barceloneta), the Río de la Plata (at the towns of Cayey, Comerío, Toa Alta, Toa Baja, and Dorado), the Río de Bayamón (at the town of Bayamón), the Río Piedras (at Hato Rey), and the Río Grande de Loíza (at the towns of San Lorenzo, Gurabo, Caguas, Trujillo Alto, Carolina, Canóvanas, Loíza, and Río Grande) (fig. 1). Significant flooding also occurred at Jayuya, Arecibo, and Salinas.

RAINFALL

Hortense produced heavy rains over Puerto Rico, especially in the eastern half of the island. The USGS raingage network reported 24-hour rainfall totals that ranged from less than 4 inches in most of western Puerto Rico to nearly 24 inches on the peaks of the Sierra de Luquillo and Sierra de Cayey. For some raingage stations, notably those in the eastern interior, the rainfall exceeded the 100-year, 24-hour recorded maximum values. Extremely heavy rainfall was reported in the towns of Cayey, Caguas, Comerío, Gurabo, Orocovis, and San Lorenzo.

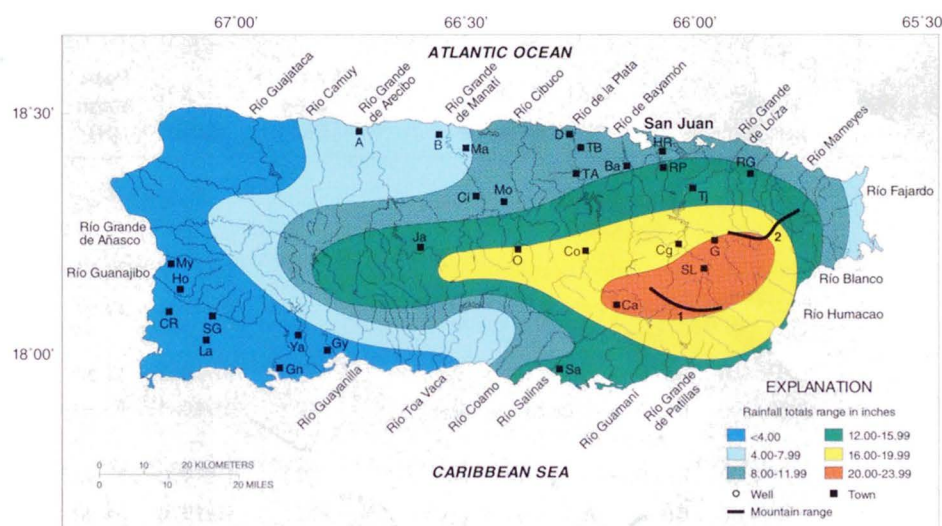


Figure 1. National Weather Service 24-hour rainfall distribution in Puerto Rico for Hurricane Hortense, September 9-10, 1996. Town names in alphabetical order are: A, Arecibo; B, Barceloneta; Ba, Bayamón; Cg, Caguas; Ca, Cayey; Ci, Ciales; Co, Comerío; CR, Cabo Rojo; D, Dorado; Gn, Guánica; G, Gurabo; Gy, Guayanilla; Ho, Hormigueros; HR, Hato Rey; Ja, Jayuya; La, Lajas; Ma, Manatí; Mo, Morovis; My, Mayagüez; O, Orocovis; RG, Río Grande; RP, Río Piedras; Sa, Salinas; SG, San Germán; SL, San Lorenzo; TA, Toa Alta; TB, Toa Baja; Tj, Trujillo Alto; Ya, Yauco. Mountain ranges are: 1, Sierra de Cayey, and; 2, Sierra de Luquillo.

SUMMARY OF FLOOD STAGES AND DISCHARGES

information from gaging stations throughout Puerto Rico (fig. 2). High-water marks were surveyed shortly after the event to determine the peak stages at sites where recording instruments failed or were damaged during the flood.

Indirect measurements are being conducted at sites where the historical maximum stages and discharges were exceeded significantly.

Hydrologic information indicates that floods of moderate to severe intensity

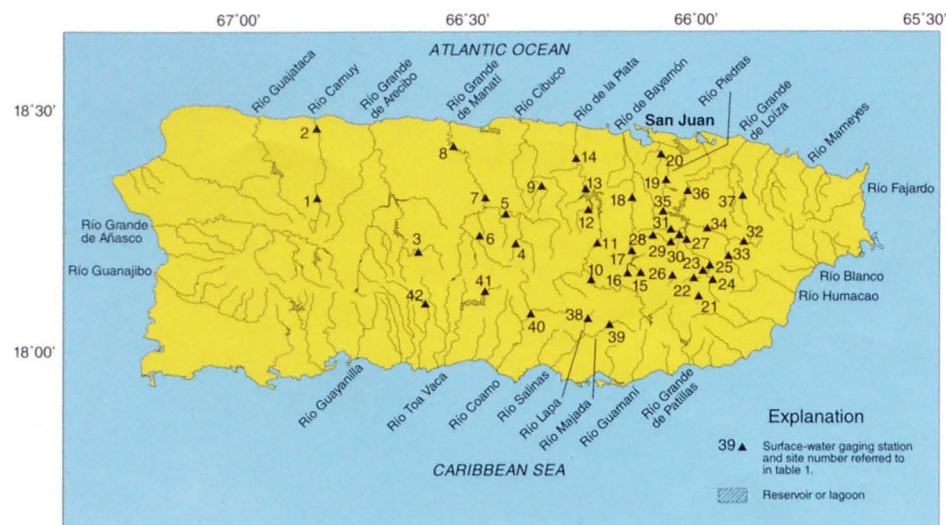


Figure 2. Location of U.S. Geological Survey surface-water gaging stations in Puerto Rico summarized in table 1.

Table 1. Summary of peak stages and discharges prior to and during September 10, 1996, at selected U.S. Geological Survey streamflow-gaging stations in Puerto Rico

[mi², square miles; ft, feet above an arbitrary datum; ft³/s, cubic feet per second; Hwy, highway; no., number; --, not determined; >, greater than]

Site no.	Station number	Station name	Drainage area (mi ²)	Previous maximum discharge			Flood of September 10, 1996		
				Date	Peak stage (ft)	Maximum discharge (ft ³ /s)	Peak stage (ft)	¹ Peak discharge (ft ³ /s)	Recurrence interval (years)
1	50014600	² Río Camuy at Tres Pueblos Sinkhole	--	10/1991	12.42	1,030	19.58	3,650	--
2	50015700	Río Camuy near Hatillo	--	10/1985	24.75	10,500	24.58	10,400	10
3	50025155	² Río Saliente at Coabey near Jayuya	9.25	06/1994	13.92	5,900	19.29	14,500	--
4	50030460	Río Orocovis at Orocovis	5.03	01/1992	11.53	2,320	16.85	8,070	30
5	50031200	Río Grande de Manatí near Morovis	55.2	05/1985	17.89	48,000	18.83	53,000	30
6	50034000	Río Bauta near Orocovis	16.7	10/1970	21.90	17,800	25.14	25,900	40
7	50035000	Río Grande de Manatí at Ciales	128	10/1970	24.00	125,000	25.20	128,000	40
8	50038100	Río Grande de Manatí at Hwy 2 near Manatí	197	10/1985	33.79	97,500	36.36	>140,000	>30
9	50038320	Río Cibuco below Corozal	15.1	11/1979	19.80	13,600	20.30	13,800	10
10	50043000	Río de la Plata at Proyecto La Plata	54.8	01/1992	36.39	73,600	34.10	63,000	20
11	50043800	² Río de la Plata at Comerío	109	01/1992	29.22	127,000	28.41	118,000	--

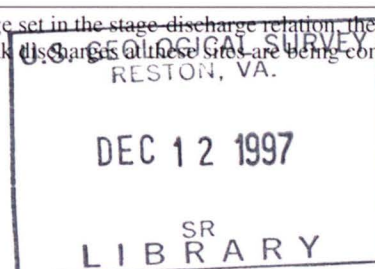
Table 1. Summary of peak stages and discharges prior to and during September 10, 1996, at selected U.S. Geological Survey streamflow-gaging stations in Puerto Rico--Continued

Site no.	Station number	Station name	Drainage area (mi ²)	Date	Previous maximum discharge		Flood of September 10, 1996		
					Peak stage (ft)	Maximum discharge (ft ³ /s)	Peak stage (ft)	¹ Peak discharge (ft ³ /s)	Recurrence interval (years)
12	50044830	² Río Guadiana at Guadiana	9.19	01/1992	13.36	6,670	16.58	11,200	--
13	50045010	² Río de la Plata below La Plata Dam	173	01/1992	34.76	127,000	42.26	197,000	--
14	50046000	Río de la Plata at Hwy 2 near Toa Alta	208	01/1992	26.39	118,000	27.40	>118,000	>25
15	50047535	² Río de Bayamón at Arenas	0.45	05/1993	5.40	255	7.34	885	--
16	50047540	² Río Sabana at Vista Monte	0.80	09/1993	4.63	296	12.02	2,380	--
17	50047560	² Río de Bayamón below Lago Cidra	8.32	07/1993	16.56	2,090	27.34	15,000	--
18	50047850	Río de Bayamón near Bayamón	41.8	10/1970	20.20	28,000	29.07	65,000	50
19	50048770	² Río Piedras at El Señorial	7.49	08/1988	16.08	4,680	15.46	5,400	--
20	50049100	Río Piedras at Hato Rey	15.2	12/1975	20.56	8,660	22.11	10,500	20
21	50050900	Río Grande de Loíza at Quebrada Arenas	6.00	01/1992	17.52	18,200	25.93	>20,000	>35
22	50051150	Quebrada Blanca at El Jagual	3.25	05/1985	14.58	7,400	14.64	7,610	12
23	50051180	Quebrada Salvatierra near San Lorenzo	3.74	05/1985	17.20	9,320	20.87	15,000	20
24	50051310	Río Cayaguas at Cerro Gordo	10.2	08/1979	³ 9.44	13,200	23.26	12,600	9
25	50051800	² Río Grande de Loíza at Hwy 183 near San Lorenzo	25.0	01/1992	31.37	40,700	35.62	56,800	15
26	50053025	² Río Turabo above Borinquen	7.14	01/1992	21.07	12,000	22.60	15,200	30
27	50055000	Río Grande de Loíza at Caguas	89.8	09/1960	31.17	71,500	32.32	83,000	50
28	50055100	² Río Cagüitas near Aguas Buenas	5.30	09/1993	18.28	2,990	21.23	5,000	--
29	50055170	² Río Cagüitas near Caguas	8.27	09/1993	26.10	3,010	31.60	9,040	--
30	50055225	² Río Cagüitas at Villa Blanca at Caguas	16.9	01/1992	19.91	13,400	23.89	25,000	--
31	50055390	² Río Bairoa at Bairoa	5.08	01/1992	12.32	1,580	18.16	7,200	--
32	50055750	² Río Gurabo below El Mango	22.3	11/1991	17.38	5,870	24.12	19,100	--
33	50056400	Río Valenciano near Juncos	16.4	12/1987	25.63	40,000	22.95	25,000	12
34	50057000	Río Gurabo at Gurabo	60.2	09/1960	³ 27.70	74,600	31.44	62,100	11
35	50058350	² Río Cañas at Río Cañas	7.53	10/1990	20.55	3,830	24.60	7,500	--
36	50059050	² Río Grande de Loíza below Damsite	209	11/1987	39.57	124,000	49.31	223,000	--
37	50061800	Río Canóvanas near Campo Rico	9.84	09/1982	13.10	15,000	13.58	10,100	10
38	50100200	Río Lapa near Rabo del Buey	9.92	01/1992	17.82	15,700	18.65	18,100	25
39	50100450	² Río Majada at La Plena	16.7	01/1992	17.19	15,200	18.69	17,700	20
40	50106100	² Río Coamo at Coamo	43.5	05/1992	13.49	9,290	19.94	26,300	--
41	50110900	² Río Toa Vaca above Lago Toa Vaca	7.64	01/1992	13.24	8,700	18.65	>15,000	--
42	50113800	² Río Cerrillos above Lago Cerrillos near Ponce	15.4	01/1992	9.65	8,140	10.62	10,600	--

¹ In the gaging stations where the flood stage exceeded the highest stage set in the stage-discharge relation, the peak discharge is reported as greater than (>) the highest discharge set in the discharge rating. Peak discharges at these sites are being computed using indirect measurement methods.

² Gaging station with less than 10 years of record.

³ Gage at different site and datum.





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Figure 3. Sediment-laden streamflow over the Carraízo Dam, September 10, 1996, at 2 p.m., during the peak discharge of Hurricane Hortense, in excess of 200,000 cubic feet per second. The narrow, sinuous lake behaves hydraulically like a river during peak flows. Discharge events of this magnitude commonly transport a sediment load equal to the annual yield. Photograph taken by Richard Webb.

occurred in the basins of the Río Grande de Arecibo, the Río Grande de Manatí, the Río Cibuco, the Río de la Plata, the Río de Bayamón, the Río Piedras, the Río Grande de Loíza, the Río Lapa, and the Río Majada (see figs. 3, 4, and 5). Flood stages, discharges, recurrence intervals, and other information pertinent to selected gaging stations within these basins are summarized in table 1. For purposes of comparison, the table also includes the

recorded stage, discharge, and recurrence interval of the highest recorded peak discharges prior to September 10, 1996.

Recurrence intervals for peak discharges were determined at gaging stations that have more than 10 years of record as recommended by the U.S. Interagency Advisory Committee on Water Data (1982). Recurrence intervals for peak discharges at gaging stations with less than 10 years of record will be estimated using



Figure 4. Streamflow on the Río Grande de Loíza, (Station 50055000) September 10, 1996, 12:30 p.m., at peak stage during hurricane. Photograph taken by Matthew Larsen.



Figure 5. Same location as left photo, 24 hours later. River stage has fallen to near normal flow, leaving evidence of localized bank scour and associated channel widening, as well as deposition of fresh gravel bars. Photograph taken by Matthew Larsen.

the regional regression analysis for ungaged sites in Puerto Rico described in López and others (1979). In the gaging stations where the flood stage exceeded the highest stage set in the stage-discharge relation, indirect methods will be used to estimate the peak discharge and then the recurrence interval for each of the gaging stations.

Peak discharges were exceeded at 34 of 86 gaging stations. The peak discharge ranged from 885 cubic feet per second at the Río Bayamón at Arenas gaging station to more than 200,000 cubic feet per second at the Río Grande de Loíza below Damsite gaging station (fig. 3). Peak discharges in excess of 100,000 cubic feet per second were registered in six sites.

—Heriberto Torres-Sierra

References

- López, M.A., Colón-Dieppa, Eloy, and Cobb, E.D., 1979, Floods in Puerto Rico, Magnitude and frequency: U.S. Geological Survey Water-Resources Investigations Report 78-141, 68 p.
- U.S. Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Hydrology Subcommittee Bulletin 17B, 183 p.

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