

FLOODS AT TOA ALTA, TOA BAJA, AND DORADO, PUERTO RICO

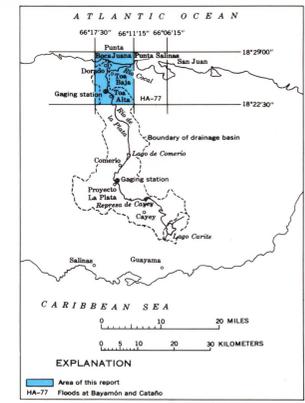
Effective planning for the economic development of flood plains requires an evaluation of their flood characteristics. This report presents hydrologic data that provide a technical basis for making decisions concerning the use of flood-plain lands. The data were obtained from stream-flow investigations being conducted by the U. S. Geological Survey on Río de la Plata, supplemented by historical flood information.

The approximate areas inundated by Río de la Plata between Toa Alta and the Atlantic Ocean during the floods of August 8, 1899, and September 6, 1960, are shown on a topographic map to portray the flood hazard graphically. East of Highway 165 and north of Highway 2 the area inundated by the 1899 flood could not be defined because of the lack of floodmarks. The city of Toa Baja was completely inundated during the flood of September 6, 1960, and again during the slightly lower flood of August 27, 1961. The cities of Toa Alta and Dorado, which are situated on low hills, were subjected to flooding only in certain areas. Both floods inundated about 13 square miles of residential property, commercial and industrial sites, and agricultural land mostly in pasture and sugar cane. About 4 square miles of normally swampy land in Ciénaga de San Pedro and an area south of Sabana Seca also were inundated.

Cooperation and acknowledgment -- The preparation of this report is a part of a flood-mapping program financed through a cooperative agreement between the Department of Public Works, Commonwealth of Puerto Rico, and the U. S. Geological Survey.

Acknowledgment is made to the Puerto Rico Water Resources Authority and to the Department of Public Works who furnished flood data. Historical flood information was obtained from documents made available through the courtesy of the General Archives of the Instituto de Cultura Puertorriqueña. Additional data were obtained from municipal officials, plant managers, and local residents.

Río de la Plata drainage basin -- Figure 1 shows the area of the map in relation to the Río de la Plata drainage basin. The headwaters of Río de la Plata are on the north slope of the Sierra de Cayey about 44 kilometers south of San Juan and only 9 kilometers from the south coast of Puerto Rico. Lago Carite with a capacity of 11,300 acre-feet, stores the runoff from 8.2 square miles. Streamflow is diverted from Lago Carite to the south slope of Sierra de Cayey for hydroelectric power. Uncontrolled releases over the spillway have added to the floodflow of Río de la Plata in 23 of the 50 years that have elapsed since the dam was completed. The volume of water contributed to floods by the reservoir releases varies with reservoir storage conditions and operating procedures but is not great because Lago Carite regulates flow from only about 4 percent of the drainage basin.



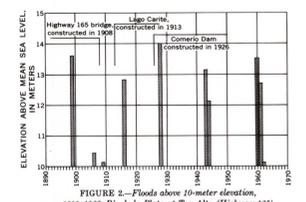
From Lago Carite, Río de la Plata flows northwest approximately 18 kilometers to Proyecto la Plata, the site of a Geological Survey gaging station, then north 36 kilometers to the Atlantic Ocean near Dorado. The reservoirs of a low-head hydroelectric dam near Cayey and of the Comerio hydroelectric dam have insufficient storage to significantly affect flood peaks in the lower reaches of Río de la Plata.

Río de la Plata emerges from the mountains and flows through the limestone karst topography near Toa Alta. The drainage area at the Geological Survey gaging station just north of Toa Alta at Highway 165 is 196 square miles, excluding the drainage area of Lago Carite.

A low natural levee extends along the east bank of Río de la Plata from Highway 2 to the mouth. Toa Baja is built on this natural levee and on a part of the alluvial fan that slopes to the northeast from the river.

Flood height -- The height of a flood at a gaging station usually is stated in terms of the gage elevation or stage, which is the elevation of the water surface above a selected datum plane. Elevations shown on the map are in meters above mean sea level.

Many floodmarks for the floods of 1899, 1928, 1945, 1960, and 1961, were found. The Geological Survey gaging station on Río de la Plata at Toa Alta (Highway 165) recorded the annual peaks during 1899-1906, 1909, 1916, 1928, and 1943 at the gaging station site were obtained from highway bridge drawings, flood-damage surveys, and local residents. Elevations of these floods at the gage are shown in figure 2. Many minor floods of which there are no records probably have occurred.

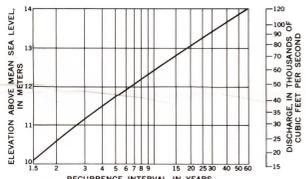


The bridge at the gaging station at Toa Alta was built in 1908. Discharges for the peaks of 1899 and 1906 thus could not be determined from the present stage-discharge relation at the gage. Because of the backwater caused by the highway fill, the 1928 peak elevation at the gage upstream from the bridge was higher than that of 1899, but the 1899 flood elevations were the highest found throughout the rest of the lower flood plain.

Flood frequency -- Historical records and floodmark elevations obtained during the survey were used to derive a flood-frequency relation on Río de la Plata at the gaging station at Toa Alta. Records of discharge at Toa Alta and Comerio Dam were used to develop the stage-discharge relation which is used in the flood-frequency analysis.

As applied to flood events, recurrence interval is the average interval of time within which a given flood height will be equaled or exceeded once. The recurrence interval is inversely related to the chance of a given flood being equaled or exceeded in any one year. Thus, the 20-year flood has a 5 percent chance (1 in 20) of being equaled or exceeded in any one year.

The general relation of recurrence interval to both flood height and flood discharge for Río de la Plata at Highway 165 in Toa Alta is shown in figure 3 and is tabulated below:



Recurrence interval (years)	Elevation (meters)	Discharge (cubic feet per second)
40	14.0	120,000
25	13.2	85,000
10	12.4	52,000
5	11.7	41,000
3	11.1	31,000

Flood profiles -- Profiles of the water surface of the floods of August 8, 1899, September 6, 1960, and August 27, 1961, are shown in figure 4. Distances used for the profiles correspond to those marked along the channel on the map. The flood profiles represent the elevations near the center of the floodplain. From Highway 2 southward (upstream) there is little difference in flood elevations across the valley except for some super-elevation at sharp bends. However, from Highway 2 northward (downstream) there is some flow away from the main channel when the water surface elevation exceeds the top of the natural levees. These floodwaters flow northeastward over an alluvial fan toward Ciénaga de San Pedro and eventually empty into the Atlantic Ocean through the mouth of Río Cocai at a point 6 kilometers east of the mouth of Río de la Plata.

Floodwaters from Río de Bayamón also flow into Ciénaga de San Pedro from the east, and at times add to the flow of Río Cocai to produce the flooding shown on the map in the Ciénaga de San Pedro area.

To define the overland flow northeastward toward the Ciénaga de San Pedro area and to supplement the flood profile, water-surface contours north of Highway 2 are shown on the map for the flood of September 6, 1960. The flow northeast from Río de la Plata crossed many new sections of Highway 165, which was constructed in 1959 east of the main river from Highway 2 to the coast. Elevations of this northeast flow may have been higher before 1959, but records are not available to substantiate this.

Flood profiles in the lower reaches of the river are affected by variable backwater from tides and storm waves. The mouth of the Río de la Plata usually is obstructed by a sand bar which becomes partially overtopped and washed out during floods. Ordinarily, water flows in a narrow channel past the sandbar into the Atlantic Ocean. Observations during and after the severe storm waves of November 16 and 17, 1962, (fringe effects of a distant storm) indicated that during high tide waves broke over the top of the sand bar at an elevation of 3.6 meters above mean sea level. The flow of the river was approximately 150 cubic feet per second and the water-surface elevation in the river behind the sand bar rose to 1.8 meters, which was about 1.5 meters above its normal elevation. The backwater from waves extended upstream to Toa Baja, but no local flooding occurred there.

Depth of flooding -- The depth of flooding at any point on the Río de la Plata flood plain may be determined by subtracting the ground elevation shown on the map from the flood elevation indicated on the profile or from the water-surface contour line at that point.

Floods on Río de la Plata are the principal causes of flooding at the mouths of tributary streams. Delineation of inundated areas along the tributary streams Río Bucarabones and Río Lajas is based on the elevation of the Río de la Plata flood profile.

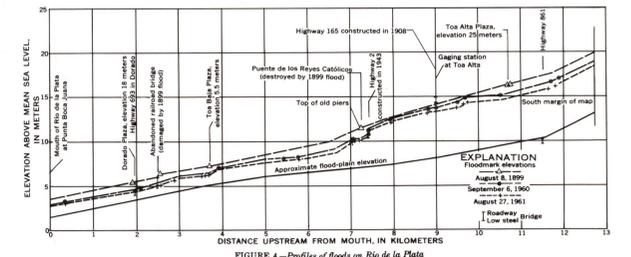
Additional information pertaining to floods on Río de la Plata may be obtained at the office of the U. S. Geological Survey, 12 Calle Arroyo, Hato Rey, Puerto Rico, or at Sección de Control de Inundaciones, Negociado de Operaciones, Departamento de Obras Públicas, Stop 22 1/2 Avenida Ponce de León, Santurce, Puerto Rico, and from the following published report:

Lopez, M. A., 1962, Floods at Bayamón and Cataño, Puerto Rico: U.S. Geol. Survey Hydrol. Inv. Atlas HA-77.

RIO DE LA PLATA FLOODS

Flood elevations reached at Highway 165 at Toa Alta. Overflow limits for only the 1899 and 1960 floods are shown on the map.

Date of flood	Elevation above mean sea level (meters)	Discharge (cubic feet per second)
August 8, 1899	13.6	70,000
August 22, 1916	12.8	120,000
September 23, 1928	14.0	85,000
June 16, 1943	13.1	52,000
October 14, 1943	12.1	52,000
September 6, 1960	13.5	95,500
August 27, 1961	12.7	68,000



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