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U.S. GEOLOGICAL SURVEY
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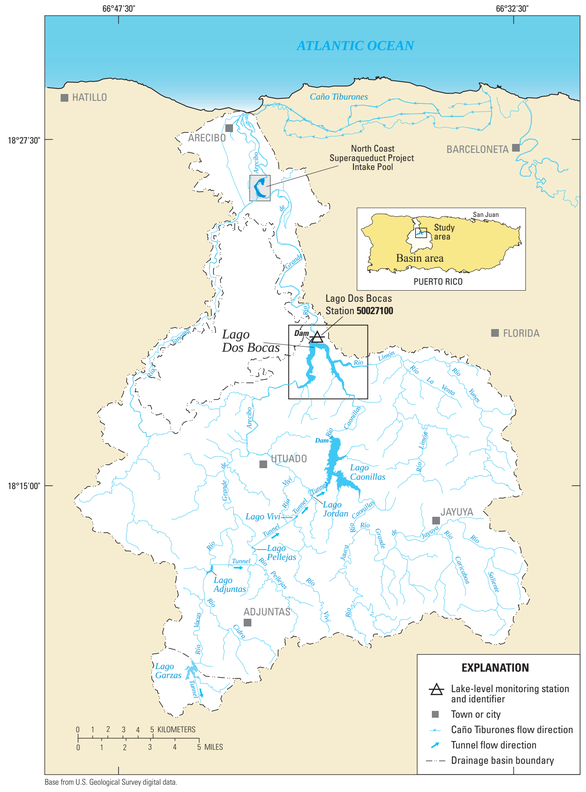
PUERTO RICO ELECTRIC POWER AUTHORITY

SCIENTIFIC INVESTIGATIONS MAP 3217
Sedimentation Survey of Lago Dos Bocas, Utuado, Puerto Rico, January 2010
By Luis R. Soler-López, 2012



Base from U.S. Geological Survey digital data.

Figure 1. Location of Lago Dos Bocas within the Río Grande de Arecibo basin.

Introduction

Lago Dos Bocas reservoir was completed in 1942 to provide water for hydroelectric power generation along the northern coast of Puerto Rico. The reservoir had an original storage capacity of 37.50 million cubic meters (Mm^3). The dam is located about 9 kilometers (km) northeast of the town of Utuado, immediately downstream of the original confluence of the Río Grande de Arecibo and the Río Caonillas (fig. 1).

The Puerto Rico Electric Power Authority (PREPA) owns and operates the Lago Dos Bocas reservoir, and since 1996, the reservoir has become an essential part of the Puerto Rico Aqueduct and Sewer Authority (PRASA) North Coast Superaqueduct Project. The Superaqueduct is supplied by controlled releases for hydroelectric power generation that replenish the public-supply raw-water intake pool located about 10 km downstream from the Lago Dos Bocas Dam (fig. 1). As of 2005, the Superaqueduct supplies about 4.03 cubic meters per second (m^3/s) (348,192 cubic meters per day [m^3/d]) of potable water to communities along the northern coast, from Arecibo to the San Juan metropolitan area.

Because of the importance of the reservoir to the North Coast Superaqueduct, the U.S. Geological Survey (USGS), in cooperation with PRASA, conducted a sedimentation survey of Lago Dos Bocas in January 2009. The results of this survey were used to estimate the useful life and the firm yield of the reservoir, and evaluate the need to dredge the reservoir.

Method of Survey and Analysis

The field techniques and bathymetric data reduction processes used for the 2010 survey were performed following procedures established by the USGS Caribbean Water Science Center (CWSC) and described in a previous survey report of Lago Dos Bocas (Soler-López, 2007). The January 2010 bathymetric survey was conducted using a Bathymetric/Land Survey System developed by Specialty Devices Inc., consisting of a global positioning system (GPS) coupled to a digital depth sounder similar to the setup used for the survey conducted in August 2005 (Soler-López, 2007). A total of 178 survey navigation lines were established at a spacing of about 50 meters (m), beginning at the dam and continuing upstream along the different river branches of the reservoir. Geographic position (accuracy of less than 2 m) and water depths (accuracy of 2 centimeters [cm] ± 1 percent of the measured depth) were acquired simultaneously using the GPS interfaced to the depth sounder. The reservoir pool elevation was monitored at the continuous recording USGS lake-level monitoring station Lago Dos Bocas at dam site near Utuado, Puerto Rico, station number 50027100 (fig. 1). The fathometer was calibrated prior to each day of survey by using a bar check.

The pool elevation of Lago Dos Bocas was below the crest of the spillway structure; therefore, the sounding data were adjusted using a time-elevation correction factor to represent depths relative to the crest of spillway elevation of 89.92 m above mean sea level. A total of 17,039 data points were collected over the entire reservoir. The 2010 data were stored in a portable computer and transferred into the USGS geographic information system (GIS) where final analysis and volume calculations were made following procedures similar to those used to develop the August 2005 bathymetric map of Lago Dos Bocas (Soler-López, 2007). Field data from the January 2010 survey were used to generate a bathymetric map representing the reservoir bottom in January 2010 (fig. 2). Data points were color-coded according to their specific depths, and same-color points were connected with a line to draw depth contours. A triangulated irregular network (TIN) surface model of Lago Dos Bocas was then generated from the bathymetric map, and the reservoir volume was calculated using the GIS. The TIN surface model was used with the digital data for 2005 and 2010 to generate a stage-storage curve and longitudinal profiles along the different river branches of Lago Dos Bocas. A storage capacity table and curve were generated by calculating the TIN volume at 1.00-m elevation intervals and are shown on table 2 and figure 3, respectively.

Storage Capacity, Sedimentation Rate, and Useful Life

The storage capacity of Lago Dos Bocas decreased slightly from 17.26 Mm^3 in August 2005 (Soler-López, 2007) to 16.74 Mm^3 in January 2010 (table 1). The inter-survey (2005–2010) storage capacity loss was about 3 percent, equaling a decrease of about 0.6 percent per year. This decrease represents a reduction of 520,000 cubic meters (m^3) between 2005 and 2010, for an annual storage capacity loss rate of about 104,000 m^3.

The Lago Dos Bocas long-term capacity loss rate due to sedimentation has not changed substantially, decreasing from 321,000 cubic meters per year (m^3/yr) in 2005 to 305,000 m^3/yr in 2010, for a reduction of only 5 percent (table 1). Although the long-term sedimentation rate has remained nearly unchanged (321,000 compared to 305,000 m^3/yr), the annual loss rate of Lago Dos Bocas for the last 5 years has shown a gradual decrease (Soler-López, 2007), from 130,000 m^3/yr in 2005 to 104,000 m^3/yr in 2010. This trend may be due to sediment depletion in the Lago Dos Bocas Basin after Hurricane Georges (1998) in which the sedimentation rate increased threefold (1,090,000 m^3/yr). Hurricane Georges flushed material stored upstream of the Lago Dos Bocas Basin and not only deposited it within the reservoir, but also reduced readily available sediments for transport. Similar trends were observed after Hurricane Georges at three other reservoirs in Puerto Rico, Lago Patillas, Lago de Cidra, and Lago Loíza (Soler-López, 2010a, b; 2012).

The comparison of longitudinal bottom profiles for 2005 and 2010 indicates that sediment accumulation in Lago Dos Bocas for this period was insignificant (less than 1 m at limited locations, fig. 4). The greatest buildup occurred at the Río Grande de Arecibo delta where sediment accumulation has reduced the flooded area of Lago Dos Bocas by about 800 m in length and about 100,000 square meters (m^2) in area since 2005 (figs. 4 and 5). In the Río Limón delta, sediment accumulation reduced the flooded area by about 150 m in length and about 1,700 m^2 in area (fig. 4). Sediment accumulation was minimal in the Río Caonillas branch of Lago Dos Bocas; previous survey data indicate that the Lago Caonillas Dam acts as a sediment trap upstream of the branch (Soler-López, 2007).

The long-term drainage area sediment yield rate of Lago Dos Bocas has remained nearly constant. Based on a long-term sediment trapping efficiency of 79.4 percent (Soler-López, 2007), the sediment yield of the reservoir basin has decreased from 1,312 to 1,247 cubic meters per square kilometer, per year [(m^3/km^2)/yr] from 2005 (Soler-López, 2007) to 2010 (table 1). The inter-survey drainage area sediment yield, however, decreased from 567 to 466 (m^3/km^2)/yr, a decline of about 18 percent.

Based on the current long-term storage-capacity loss of about 305,000 m^3 per year estimated for the 2005–2010 period, and assuming a constant sedimentation rate, the projected useful life of Lago Dos Bocas is about 55 years, ending in 2065. This predicted useful life of Lago Dos Bocas is nearly equal to the previously estimated useful life of 54 years (Soler-López, 2007).

Table 1. Comparison between the August 2005 and the January 2010 sedimentation surveys of Lago Dos Bocas, Puerto Rico.

Data descriptor	Year of survey	
	2005	2010
Capacity, in million cubic meters	17.26	16.74
Live storage, in million cubic meters	16.50	16.30
Dead storage, in million cubic meters	.76	.44
Years since construction	63	68
Sediment accumulated, in million cubic meters	20.24	20.76
Inter-survey sediment accumulation, in million cubic meters	.78	.52
Long-term storage loss, in percent	54	55
Long-term annual loss of capacity, in million cubic meters	.321	.305
Annual loss of capacity, in percent	.86	.81
Inter-survey loss of capacity, in million cubic meters per year	.13	.104
Sediment trapping efficiency, in percent	72	72
Long-term sediment yield, in cubic meters per square kilometer per year	1,312	1,247
Inter-survey sediment yield, in million cubic meters per year	567	466
Year reservoir would fill with sediments	2059	2065

Table 2. Storage capacity for Lago Dos Bocas, Puerto Rico, January 2010.

Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters
89.92	16.74
88.92	15.21
87.92	13.79
86.92	12.46
85.92	11.20
84.92	10.01
83.92	8.89
82.92	7.85
81.92	6.89
80.92	5.98
79.92	5.14
78.92	4.36
77.92	3.64
76.92	3.05
75.92	2.49
74.92	1.99
73.92	1.52
72.92	1.10
71.92	.74
70.92	.43
69.92	.19
68.92	.05
67.92	.00

Summary and Conclusions

During January 2010, the U.S. Geological Survey, in cooperation with the Puerto Rico Aqueduct and Sewer Authority, conducted a bathymetric survey of Lago Dos Bocas to update the reservoir storage capacity and actualize the reservoir sedimentation rate by comparing the 2010 bathymetric survey data with 2005 data.

The Lago Dos Bocas storage capacity was 17.26 million cubic meters in August 2005, which decreased to 16.74 million cubic meters by January 2010. The inter-survey (2005–2010) storage capacity loss was 1 percent, equaling a decrease of about 0.2 percent per year; this loss represents a reservoir sedimentation rate of about 104,000 cubic meters per year between 2005 and 2010. On a long-term basis (1942–2010), however, the sedimentation rate has remained nearly constant, decreasing from about 321,000 to 305,000 cubic meters per year from 2005 to 2010. Most of the storage capacity loss of Lago Dos Bocas has occurred along its Río Grande de Arecibo and Río Limón branches in the form of flooded-area reduction. Sediment accumulation has been minimal along the Río Caonillas branch. The Lago Dos Bocas drainage area sediment yield has decreased by about 18 percent, from 567 cubic meters per square kilometer per year in 2005 to 466 cubic meters per square kilometer per year in 2010. On a long-term basis, however, the sediment yield has remained relatively unchanged, decreasing from 1,312 to about 1,247 cubic meters per square kilometer, per year from 2005 to 2010. If the long-term sedimentation rate of 305,000 cubic meters per year remains constant, the useful life of Lago Dos Bocas may end in 2065.

References Cited

Soler-López, L.R., 2007, Sedimentation history of Lago Dos Bocas, Puerto Rico, 1942-2005: U.S. Geological Survey Scientific Investigations Report 2007-5053, 36 p., 1 pl. http://pubs.usgs.gov/sir/2007/5053/.

Soler-López, 2010a, Sedimentation Survey of Lago Patillas, Puerto Rico, March 2007: U.S. Geological Survey Scientific Investigations Map 2010–3128, 1 plate., available at http://pubs.usgs.gov/sim/3128/.

Soler-López., 2010b, Sedimentation Survey of Lago de Cidra, Puerto Rico, August 2007: U.S. Geological Survey Scientific Investigations Map 3118, 1 plate., available at http://pubs.usgs.gov/sim/3118/.

Figure 3. Relation between water-storage capacity and pool elevation of Lado Dos Bocas, for 2005 and 2010.

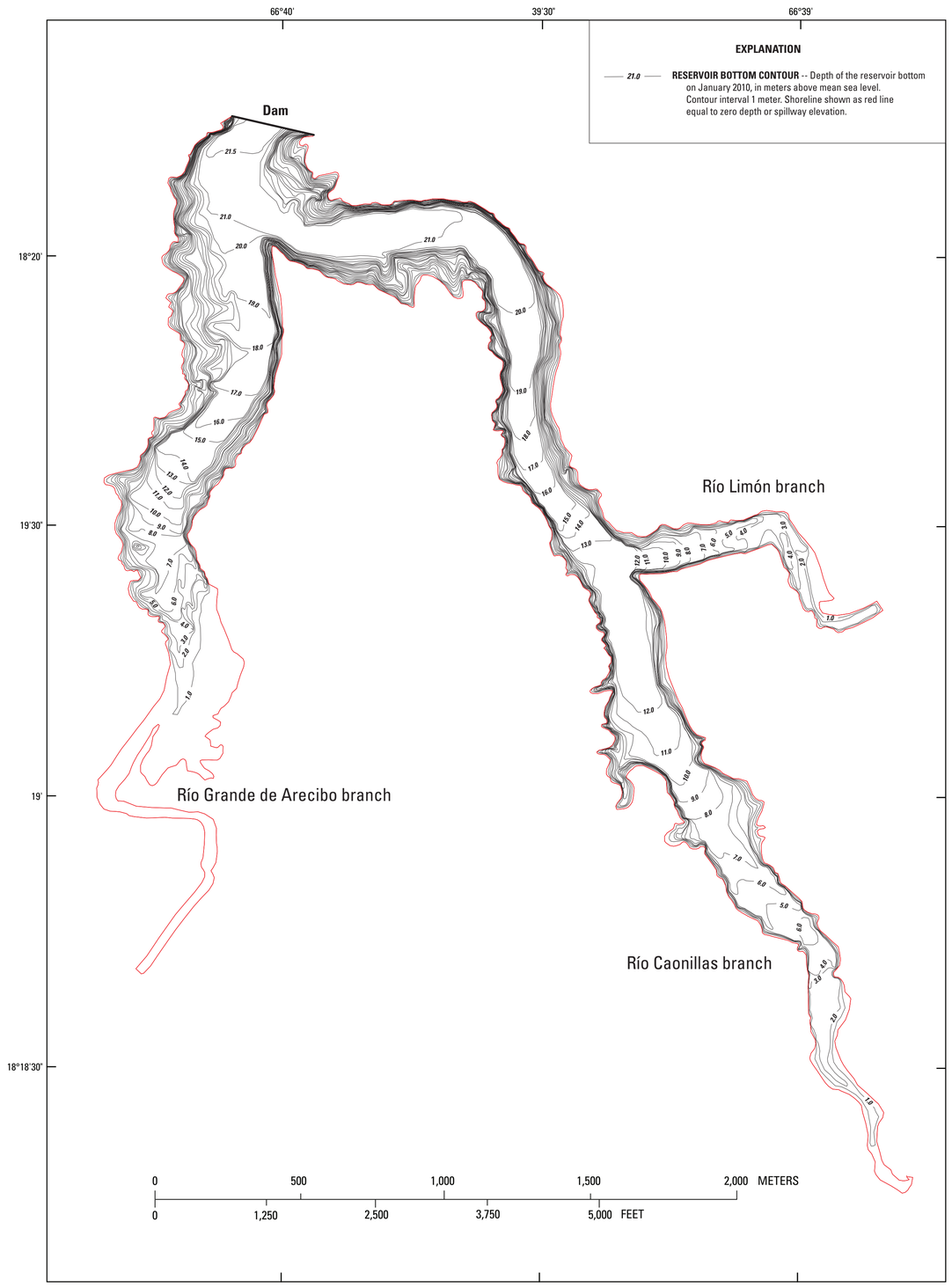


Figure 2. Bathymetric map of Lago Dos Bocas, Utuado, Puerto Rico for January 2010.

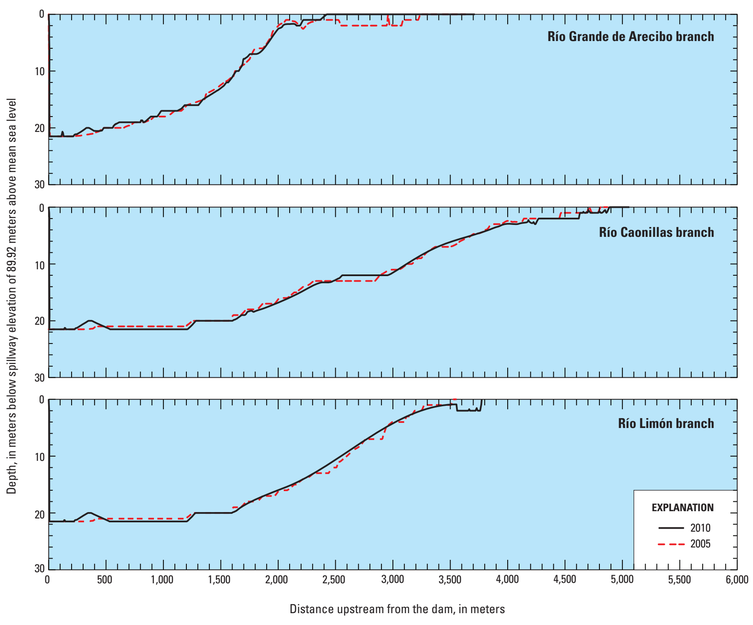


Figure 4. Longitudinal bottom profiles along the thalweg of the Río Grande de Arecibo, Río Caonillas, and Río Limón branches of Lago Dos Bocas, Puerto Rico, for 2005 and 2010.

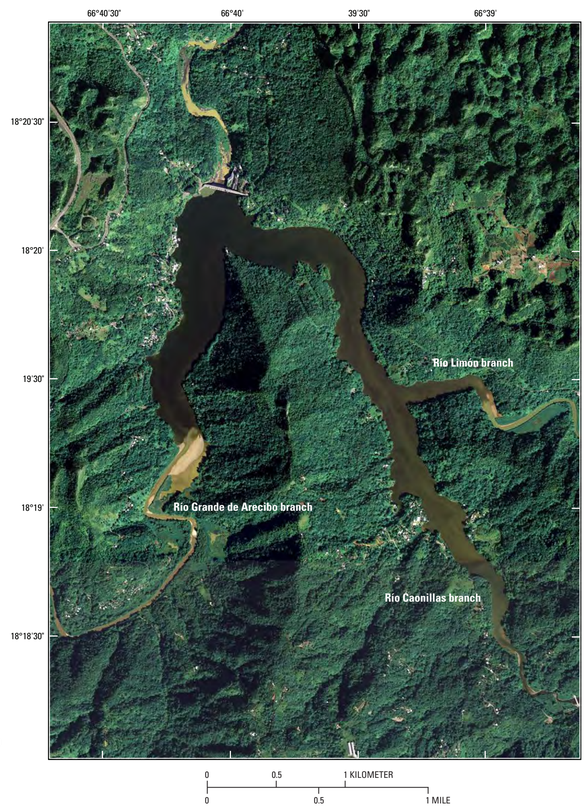


Figure 5. Aerial photograph of Lago Dos Bocas and surroundings areas showing development. Photograph from the Centro de Recaudaciónes de Ingresos Municipales (CRIM) 2007 Puerto Rico.

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