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

Prepared in cooperation with the
Puerto Rico Aqueduct and Sewer Authority

Scientific Investigations Map 3368
Sheet 1 of 1

Introduction

Construction of the Lago Caonillas reservoir was completed in 1948 to provide water for hydroelectric power generation along the northern coast of Puerto Rico. The reservoir had an original storage capacity of 55.66 million cubic meters (Mm^3) (Soler-López, 2001). The dam is located about 4 kilometers (km) east of the town of Utuado and 6 km northwest of the town of Jayuya (fig. 1).

The Puerto Rico Electric Power Authority (PREPA) owns and operates the Lago Caonillas reservoir, and since 1996, the reservoir has become an essential part of the Puerto Rico Aqueduct and Sewer Authority (PRASA) North Coast Superaqueduct Project. Water releases for hydroelectric power generation from Lago Caonillas are captured in Lago Dos Bocas downstream of the Caonillas Dam where hydroelectric power is generated again. Releases from Lago Dos Bocas flow into the Río Grande de Arecibo, which replenishes the public-supply raw-water intake pool of the North Coast Superaqueduct about 10 km downstream from the Lago Dos Bocas Dam. As of 2010, the Superaqueduct supplied about 4.44 cubic meters per second (m^3/s) (348,616 cubic meters per day [m^3/d]) of potable water to communities along the northern coast, from Arecibo to the San Juan metropolitan area (Molina-Rivera, 2010).

Because of the importance of Lago Caonillas to the North Coast Superaqueduct, the U.S. Geological Survey (USGS), in cooperation with PRASA, conducted a sedimentation survey of Lago Caonillas between September and November 2012. The results of this survey were compared to the results of a similar survey (Soler-López, 2001) conducted in February 2000 to infer the loss of reservoir storage caused by sedimentation. Data collection began in September 2012; however, low water levels restricted the survey extent to about half of the reservoir, leaving the river deltas unaccounted for in the survey. Intense rainfall during October 2012 raised the water level to spillway elevation, and the remaining part of the reservoir was then surveyed. The results of this survey were used to update estimates of the reservoir's storage capacity and its useful life.

Methods of Survey and Analysis

The field techniques and bathymetric data reduction processes used for the 2012 survey were performed following procedures established by the USGS and described in a previously published survey report of Lago Caonillas (Soler-López, 2001). The September–November 2012 bathymetric survey was conducted using a bathymetric/land survey system, consisting of a global positioning system (GPS) coupled to a digital depth sounder. A total of 155 survey navigation lines were established at 50-meter (m) intervals, beginning at the dam and continuing upstream along the 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 Caonillas at damsite near Utuado, Puerto Rico, USGS station number 50026140 (fig. 1). The fathometer was calibrated prior to each day of survey by using a bar check.

The September 2012 pool elevation data for Lago Caonillas were adjusted to represent the depth relative to the spillway elevation. For November 2012, however, the reservoir was at the crest of the spillway structure, and therefore, depth data did not require adjustment. A total of 21,513 data points were collected over the entire reservoir. Volumetric calculations of reservoir capacity were made using a geographic information system (GIS) following procedures similar to those described in Soler-López (2001). Field data from the September–November 2012 survey were used to generate a bathymetric map representing the reservoir bottom (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 Caonillas was then generated from the bathymetric map, and the reservoir volume was calculated using GIS. The 2000 and 2012 TIN surface models were used to compare the 2000 and 2012 sedimentation surveys (table 1), and to generate a stage-storage curve and longitudinal profiles along the different branches of Lago Caonillas for 2000 and 2012. 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. Bathymetry data used for this analysis are available in Soler-López (2016).

Figure 1. Location of Lago Caonillas within the Río Grande de Arecibo Basin, Puerto Rico.

Storage Capacity, Sedimentation Rate, and Useful Life

The storage capacity of Lago Caonillas decreased slightly from 42.27 Mm^3 in February 2000 (Soler-López, 2001) to 39.55 Mm^3 in September–November 2012 (table 1). This decrease represents a reduction of 2.72 Mm^3, for an annual storage capacity loss rate of about 226,670 m^3/yr. The intersurvey (2000–2012) storage capacity loss was about 6 percent, representing a decrease of about 0.5 percent per year.

The Lago Caonillas long-term capacity loss rate attributed to sedimentation has not changed substantially relative to its capacity in 1948 when the reservoir was completed. The capacity decreased from 257,500 cubic meters per year (m^3/yr) during 1948–2000 to 251,720 m^3/yr during 1948–2012, for a reduction of 2.2 percent (table 1). Although the long-term sedimentation rate has remained nearly unchanged (257,500 in 2000 compared to 251,720 m^3/yr in 2012), the annual loss rate of Lago Caonillas has shown a gradual decrease from 257,500 m^3/yr during 1948–2000 to 226,670 m^3/yr during 2000–2012. This trend may be due to sediment depletion in the Lago Caonillas hydrographic basin following Hurricane Georges (1998). The hurricane flushed sediment stored upstream of the Lago Caonillas Basin and not only deposited it within the reservoir, but also reduced readily available sediments for transport. Similar trends were observed at the following four reservoirs in Puerto Rico following Hurricane Georges: Lago Patillas, Lago de Cidra, Lago Loíza, and Lago Dos Bocas (Soler-López, 2010a, b; 2012a, b).

Most of the sediment accumulation and associated storage capacity loss of Lago Caonillas has occurred within the eastern and Río Caonillas branches of the reservoir. Within the eastern branch, sediment accumulation is noticeable from about 1,500 m upstream from the dam, where about 2 to 7 m of sediment was deposited between 2000 and 2012 (fig. 4*A*). Within the Río Caonillas branch, sediment accumulation is evident from about 3,500 m upstream from the dam, where about 2 to 4 m of sediment was deposited between 2000 and 2012 (fig. 4*B*). Within the southern branch, sediment accumulation is noticeable from about 3,200 m upstream from the dam, where about 2 to 5 m of sediment was deposited between 2000 and 2012. fig. 4*C*). In the vicinity of the Caonillas Dam, minor sediment deposition and scour occurred.

The sediment trapping efficiency of Lago Caonillas for 2012 was estimated by using the capacity-to-inflow ratio established by Brune (1953). On the basis of the long-term annual sediment inflow of 248.01 Mm^3 and the 2012 water storage capacity of 39.55 Mm^3, the trapping efficiency was estimated to be 93 percent.

The long-term drainage area sediment yield rate of Lago Caonillas has remained nearly constant since 2000. Based on a long-term sediment trapping efficiency of 93 percent (Soler-López, 2001), the sediment yield of the reservoir basin decreased from 1,266 cubic meters per square kilometer, per year ([m^3/km^2]/yr) in 2001 to 1,237 [m^3/km^2]/yr in 2012 (table 1, Soler-López, 2001).

Based on the long-term (1948–2012) storage-capacity loss of about 251,720 m^3/yr and assuming a constant sedimentation rate, the projected useful life of Lago Caonillas is about 157 years, ending in about 2169. This predicted useful life of Lago Caonillas is nearly equal to the previously estimated useful life of 164 years (Soler-López, 2001).

Summary and Conclusions

During September–November 2012, the U.S. Geological Survey, in cooperation with the Puerto Rico Aqueduct and Sewer Authority, conducted a sedimentation survey of Lago Caonillas to estimate current (2012) reservoir storage capacity and the recent (2000–2012) reservoir sedimentation rate by comparing the 2012 bathymetric survey data with the February 2000 data.

The Lago Caonillas storage capacity, which was 42.27 million cubic meters in February 2000, decreased to 39.55 million cubic meters by September–November 2012. The intersurvey (2000–2012) storage capacity loss was about 6 percent, corresponding to a decrease of about 0.5 percent per year; this loss represents a reservoir sedimentation rate of about 226,670 cubic meters per year between 2000 and 2012. On a long-term basis, however, the sedimentation rate has remained nearly constant, decreasing from about 257,500 to 251,720 cubic meters per year during 1948–2000 and 1948–2012, respectively.

Most of the sediment accumulation and associated storage capacity loss of Lago Caonillas has occurred within the eastern and Río Caonillas branches of the reservoir. In the vicinity of the Caonillas Dam, minor sediment deposition and scour have occurred.

The Lago Caonillas drainage area sediment yield has decreased by about 2 percent since the previous survey, from 1,266 cubic meters per square kilometer per year in 2000 to 1,237 cubic meters per square kilometer per year in 2012. If the long-term sedimentation rate of 251,720 cubic meters per year remains constant, the useful life of Lago Caonillas may end in about 2169.

Selected References

Brune, G.M., 1953, Trapping efficiency of reservoirs: Transactions of the American Geophysical Union, v. 34, no. 3, p. 407–418.

Molina-Rivera, W.L., Estimated water use in Puerto Rico, 2010: U.S. Geological Survey Open-File Report 2014–1117, 35 p., accessed June 2014 at http://dx.doi.org/10.3133/ofr20141117.

Soler-López, L.R., 2001, Sedimentation survey of Lago Caonillas, Puerto Rico, February 2000: U.S. Geological Survey Water-Resources Investigations Report 01–4043, 25 p., 1 plate.

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

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

Soler-López, L.R., 2012, Sedimentation survey of Lago Dos Bocas, Utuado, Puerto Rico, January 2010: U.S. Geological Survey Scientific Investigations Map 3217, 1 sheet. [Also available at http://pubs.usgs.gov/sim/3217/.]

Soler-López, L.R., 2016, Spatial data for the sedimentation survey of Lago Caonillas, Utuado, Puerto Rico, September–November 2012: U.S. Geological Survey data release, accessed July 2016 at https://dx.doi.org/10.5066/F74M92NT.

Soler-López, L.R., and Licha-Soler, N.A., 2012, Sedimentation survey of Lago Loíza, Puerto Rico, July 2009: U.S. Geological Survey Scientific Investigations Map 3219, 1 plate. [Also available at http://pubs.usgs.gov/sim/3219/.]

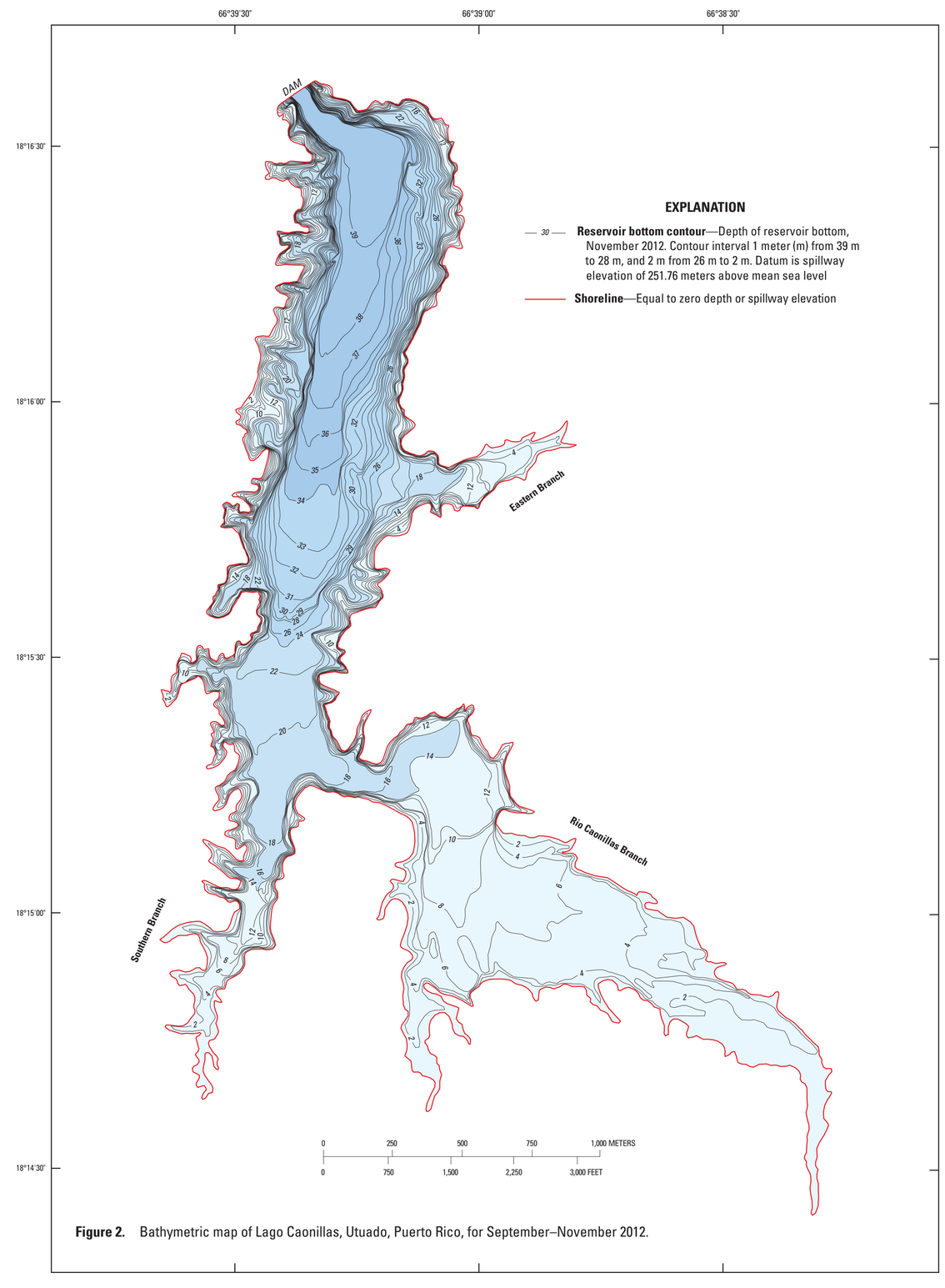

Figure 2. Bathymetric map of Lago Caonillas, Utuado, Puerto Rico, for September–November 2012.

Table 1. Comparison of results of historical reservoir sedimentation surveys.

[km^2, square kilometer; Mm^3, million cubic meters; m^3, cubic meter; m^3/km^2-yr, cubic meter per square kilometer per year; N/A, not applicable]

Data descriptor	Year of survey	
	2000	2012
Reservoir surface area, in km^2	2.69	2.39
Change in full reservoir surface area (relative to year 2000), in km^2	N/A	0.30
Change in full reservoir surface area (relative to year 2000), in percent	N/A	11
Capacity, in Mm^3	42.27	39.55
Years since construction	52	64
Sediment accumulated since construction, in Mm^3	13.39	16.11
Long-term (from reservoir construction) storage loss, in percent	24.1	28.9
Long-term (from reservoir construction) annual loss of capacity, m^3	257,500	251,720
Long-term (from reservoir construction) annual loss of capacity, in percent	0.46	0.45
Sediment trapping efficiency, in percent	93	93
Drainage area sediment yield, in m^3/km^2-yr	1,266	1,237

Table 2. Storage capacity for Lago Caonillas, Puerto Rico, 2012, at 1-meter elevation intervals.

Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters	Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters
251.76	39.55	231.76	9.78
250.76	37.22	230.76	8.95
249.76	34.98	229.76	8.16
248.76	32.90	228.76	7.43
247.76	30.90	227.76	6.72
246.76	29.03	226.76	6.03
245.76	27.25	225.76	5.37
244.76	25.63	224.76	4.73
243.76	24.06	223.76	4.11
242.76	22.56	222.76	3.51
241.76	21.12	221.76	2.94
240.76	19.72	220.76	2.41
239.76	18.37	219.76	1.92
238.76	17.12	218.76	1.48
237.76	15.91	217.76	1.11
236.76	14.78	216.76	0.79
235.76	13.68	215.76	0.50
234.76	12.63	214.76	0.27
233.76	11.62	213.76	0.10
232.76	10.68	212.76	0.00

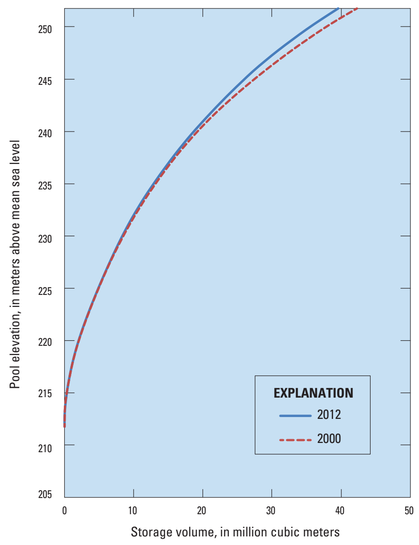

Figure 3. Relation between water-storage capacity and pool elevation of Lago Caonillas, Puerto Rico, for 2000 and 2012.

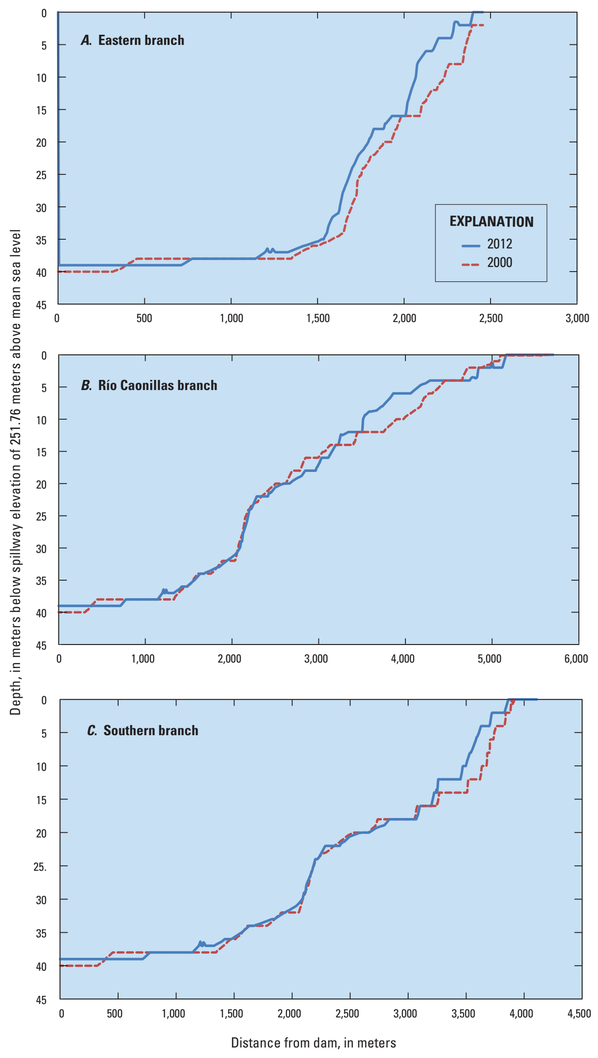

Figure 4. Longitudinal bottom profiles along the thalweg of the, *A*, eastern, *B*, Rio Caonillas, and *C*, southern branches of Lago Caonillas, Puerto Rico, for 2000 and 2012.

For sale by U.S. Geological Survey, Information Services, Box 25286, Federal Center, Denver, CO 80225, 1–888–ASK–USGS

Digital files available at http://dx.doi.org/10.3133/sim3368.

Suggested citation: Soler-López, L.R., 2016, Sedimentation survey of Lago Caonillas, Utuado, Puerto Rico, September–November 2012: U.S. Geological Survey Scientific Investigations Map 3368, 1 sheet, http://dx.doi.org/10.3133/sim3368.

ISSN 2329-132X (online)

Sedimentation Survey of Lago Caonillas, Utuado, Puerto Rico, September–November 2012

By
Luis R. Soler-López

2016