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SCIENTIFIC INVESTIGATIONS MAP 2008-3016
Comparison of storage capacity and sedimentation trends
of Lago Guayabal, Puerto Rico-December 2001 and October 2006
By Luis R. Soler-López, 2008

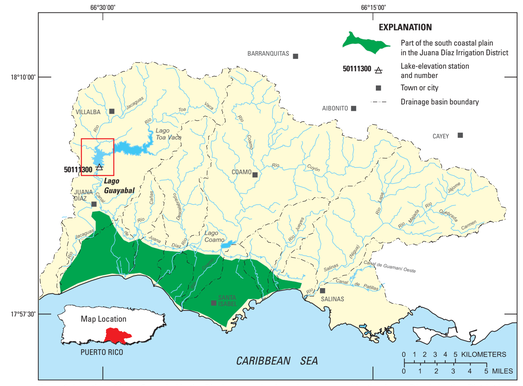

Figure 1. Location of Lago Guayabal in the Río Jacaguas basin and areas served by the Juana Díaz Irrigation District in southern Puerto Rico.

Introduction

Lago Guayabal dam is located on the Río Jacaguas in the municipality of Villalba in southern Puerto Rico, about 4 kilometers north of the town of Juana Díaz and about 5 kilometers south of Villalba (fig. 1). The dam is owned and operated by the Puerto Rico Electric Power Authority (PREPA) and was constructed in 1913 for the irrigation of croplands in the southern coastal plains of Puerto Rico. The reservoir impounds the waters of the Río Jacaguas and those of the Río Toa Vaca, when the Toa Vaca dam overflows or releases water. The reservoir has a drainage area of 53.8 square kilometers. The dam is a concrete gravity structure with a normal pool (at top of flashboards) elevation of 103.94 meters above mean sea level (Puerto Rico Electric Power Authority, 1988).

During October 2006, the U.S. Geological Survey (USGS), Caribbean Water Science Center, in cooperation with the Puerto Rico Aqueduct and Sewer Authority (PRASA) conducted a bathymetric survey of Lago Guayabal to update the reservoir storage capacity and actualize the reservoir sedimentation rate by comparing the 2006 data with the previous 2001 bathymetric survey results. The purpose of this report is to describe and document the USGS sedimentation survey conducted at Lago Guayabal during October 2006, including the methods used to update the reservoir storage capacity, sedimentation rates, and areas of substantial sediment accumulation since December 2001. The Lago Guayabal sedimentation history up to 2001 was published by the USGS in 2003 (Soler-López, 2003); therefore, this report focuses on the comparison between the 2001 and current bathymetric surveys of Lago Guayabal.

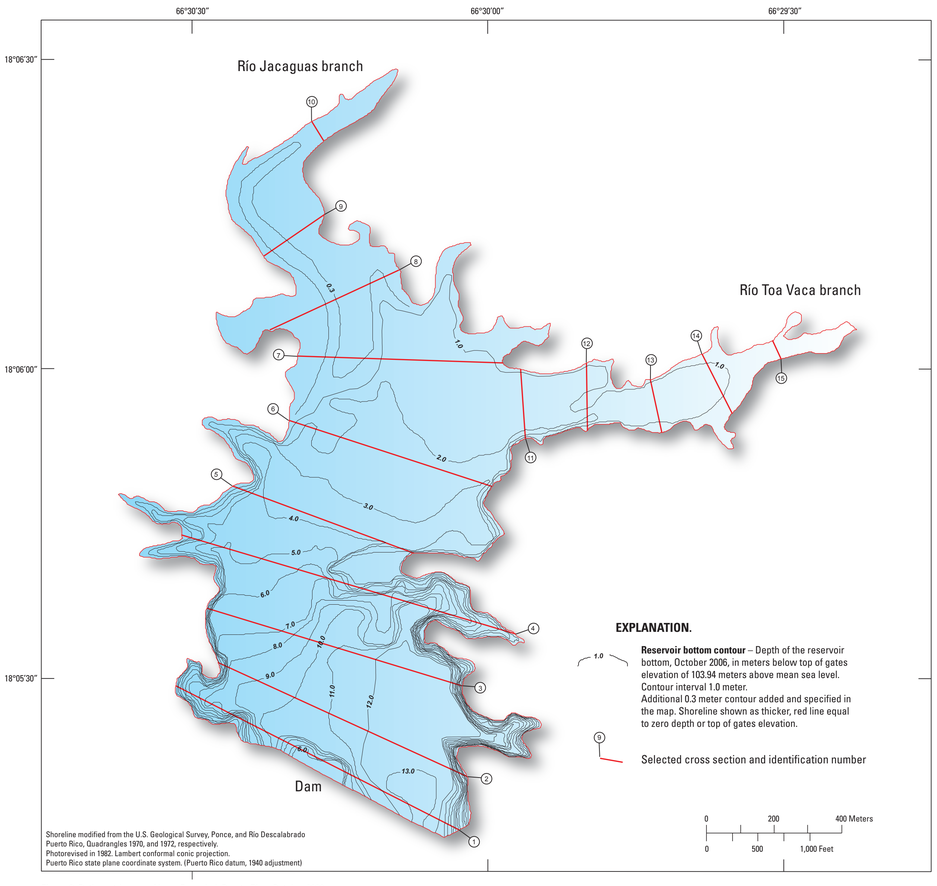

Figure 2. Bathymetric map of Lago Guayabal, Puerto Rico, October 2006.

Method of Survey and Analysis

The field techniques and bathymetric data reduction processes used for the 2006 survey were performed following procedures established by the USGS Caribbean Water Science Center and described in the previous bathymetric survey report of Lago Guayabal (Soler-López, 2003). The October 2006 bathymetric survey was conducted using a differential global positioning system (DGPS) coupled to a digital depth sounder similar to the setup used for the survey conducted in December 2001 (Soler-López, 2003). The survey navigation lines were established at a spacing of about 50 meters parallel to the dam face of the reservoir and continuing upstream along the Río Jacaguas branch and the Río Toa Vaca branch (fig. 2). Geographic position and water depths were acquired simultaneously using a DGPS interfaced to a depth sounder. The pool elevation of the reservoir was measured at the USGS lake-level station 50111300 (Lago Guayabal at damsite near Juana Díaz). The soundings were subsequently adjusted to represent water depths below normal pool elevation.

The 2006 data were stored and transferred into the USGS geographic information system (GIS) where final analysis and volume calculations were made following similar procedures used to develop the 2001 bathymetric map of Lago Guayabal reservoir (Soler-López, 2003). From the field data a bathymetric map representing the reservoir bottom in October 2006 was generated (fig. 2). A triangulated irregular network (TIN) surface model of Lago Guayabal was then created from the bathymetric map, and the reservoir volume was calculated using the GIS. From the TIN surface model, a stage-storage curve (fig. 3) and longitudinal profiles along the different tributary branches of Lago Guayabal were in turn generated from the digital data for 2001 and 2006.

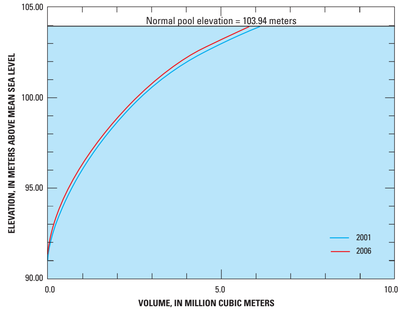

Figure 3. Relation between pool elevation and storage capacity of Lago Guayabal, Puerto Rico, for 2001 and 2006.

Storage Capacities, Sedimentation Rates, and Reservoir Life Expectancy

The December 2001 storage capacity of the reservoir was 6.12 million cubic meters (Soler-López, 2003), and by October 2006, the reservoir storage capacity was reduced to 5.82 million cubic meters (table 1). This represents a reduction between 2001 and 2006 of 300,000 cubic meters (or 5 percent in 5 years) for an annual storage capacity loss rate of about 60,000 cubic meters. An actualized storage capacity table and curve were generated by calculating the TIN volume at 1-meter elevation intervals (table 2, fig. 3).

Sediment accumulation in Lago Guayabal between 2001 and 2006 has been minimal. Figure 4, which shows selected cross sections of the Lago Guayabal bottom from shore to shore, indicates that the reservoir bottom has changed little, particularly near the dam (fig. 5), where accumulation is negligible. The greatest changes, though minimal, have occurred in the reach extending from cross section 5 (fig. 2) up to the Río Jacaguas branch of Lago Guayabal (fig. 6). In this area, an average of about 1 meter of sediment has accumulated since 2001, for an average deposition rate of about 20 centimeters per year.

The Lago Guayabal drainage area sediment yield rate decreased slightly from 1,235 cubic meters per square kilometer per year to 1,184 cubic meters per square kilometer per year between 2001 and 2006 (table 1). This change, however, represents a difference of only 4 percent, which is statistically negligible. According to the current storage capacity loss of about 60,000 cubic meters per year estimated for 2001-2006, the Lago Guayabal life expectancy is about 97 more years or to year 2103; this result is essentially equal to the life expectancy determined for 2001, which was to year 2101.

Table 1. Comparison between the 2001 and 2006 sedimentation survey results of Lago Guayabal, Puerto Rico.

Data descriptor	Year of survey 2001[1]	2006
Drainage area at damsite, in square kilometers	53.8	53.8
Reservoir surface area, in square kilometers	1.44	1.36
Pool elevation, in meters above mean sea level	103.94	103.94
Capacity, in million cubic meters	6.12	5.82
Live storage, in million cubic meters	6.12	5.82
Dead storage, in million cubic meters	0.0	0.0
Years since construction	88	93
Inter-survey storage loss, in million cubic meters	0.64	0.30
Inter-survey annual loss of capacity, in million cubic meters	42,667	60,000
Long-term storage loss, in percent	107	110
Inter-survey annual loss of capacity, in percent	0.30	0.60
Estimated drainage area annual runoff, in million cubic meters	24.22	24.22
Trapping efficiency, in percent	93	93
Sediment yield, in cubic meters per square kilometer per year	1,235	1,184
Year the reservoir would fill with sediments	2,101	2,103

[1]All 2001 data are derived from Soler-López (2003).

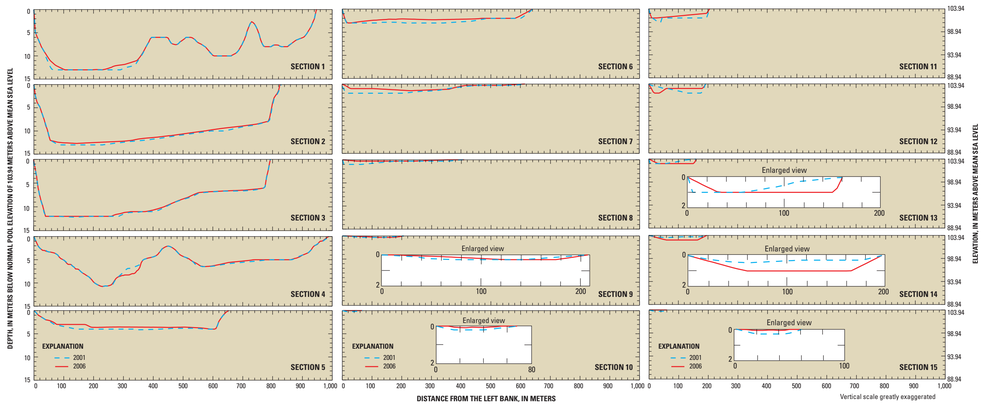

Figure 4. Selected cross sections generated from the triangulated irregular network (TIN) surface model of Lago Guayabal, Puerto Rico, for 2001 and 2006.

Summary and Conclusions

During October 2006, the U.S. Geological Survey, Caribbean Water Science Center, in cooperation with the Puerto Rico Aqueduct and Sewer Authority, conducted a bathymetric survey of Lago Guayabal to update the reservoir storage capacity and actualize the reservoir sedimentation rate by comparing the 2006 data with the previous 2001 bathymetric survey results.

The Lago Guayabal storage capacity was 6.12 million cubic meters in December 2001, which was reduced to 5.82 in million cubic meters by October 2006. The inter-survey (2001-2006) storage capacity loss is about 5 percent for a decrease of about 1 percent per year. This loss represents a reservoir sedimentation rate of about 60,000 cubic meters per year.

Most of the storage capacity loss of Lago Guayabal has occurred along the Río Jacaguas tributary branch, where an average of about 1 meter of sediment has accumulated between 2001 and 2006. Along the Río Toa Vaca branch, accumulation has been negligible because the Toa Vaca Dam acts as an effective sediment trap. The Lago Guayabal drainage area sediment yield is essentially unchanged compared to the previous survey. The drainage area sediment yields are estimated at about 1,235 and 1,184 cubic meters per square kilometer per year for the 2001 and 2006 surveys, respectively.

Although the life expectancy of about 97 years for Lago Guayabal may not be a pressing concern (assuming a long-term storage loss rate of about 60,000 cubic meters per year), sediment accumulation in the Río Jacaguas branch of the reservoir has continued forward towards the deepest parts of Lago Guayabal, which could eventually start filling the reservoir near the dam. If the sedimentation rate of 60,000 cubic meters estimated between 2001 and 2006 continues, the useful life of Lago Guayabal may end by the year 2103.

Table 2. Storage capacity table for Lago Guayabal, Puerto Rico, for October 2006.

Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters
103.94	5.82
102.94	4.65
101.94	3.76
100.94	3.07
99.94	2.51
98.94	2.02
97.94	1.59
96.94	1.22
95.94	0.88
94.94	0.60
93.94	0.35
92.94	0.16
91.94	0.03
90.94	0.00

Figure 5. Aerial photograph of the Guayabal Dam and Lago Guayabal looking in the upstream direction. Photograph courtesy of the Puerto Rico Electric Power Authority, taken on May 9, 2006, during a dam-safety inspection helicopter flight.

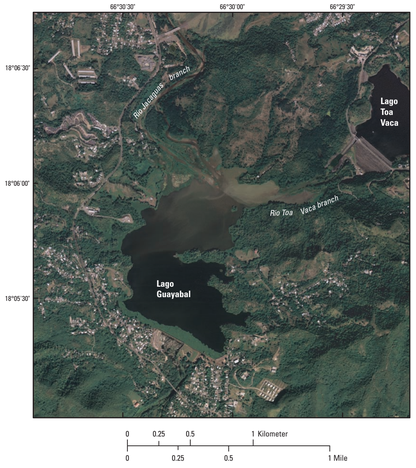

Figure 6. Aerial photograph of Lago Guayabal and part of Lago Toa Vaca, and surroundings showing development. Photograph from the U.S. Army Corps of Engineers, 2007 Puerto Rico.

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Puerto Rico Electric Power Authority, 1988, Guayabal Dam, Villalba, Puerto Rico, Phase 1 Inspection Report: National Dam Safety Program, 1986.

Soler-López, L.R., 2003, Sedimentation History of Lago Guayabal, Puerto Rico, 1913-2001: U.S. Geological Survey Water-Resources Investigations Report 03-4198, 28 p., 2 pls.

COMPARISON OF STORAGE CAPACITY AND SEDIMENTATION TRENDS OF LAGO GUAYABAL, PUERTO RICO-DECEMBER 2001 AND OCTOBER 2006

By Luis R. Soler-López

2008