

Figure 1. Location of Lago La Plata between Naranjito and Toa Alta, Puerto Rico.

Shoreline modified from Mark Hard Aerial Surveys, Río de La Plata development project, from aerial photographs taken in January 1964. Lambert conformal conic projection, Puerto Rico state plane coordinate system (Puerto Rico datum, 1940 adjustment)

Figure 2. Bathymetric map of Lago La Plata, Puerto Rico, July 2006.

Introduction

Lago La Plata dam is located between the municipalities of Naranjito and Toa Alta in north central Puerto Rico, about 5 kilometers south of the town of Toa Alta and about 5 kilometers north of the town of Naranjito (fig. 1). The reservoir impounds the waters of the Río de La Plata, the Río Guadiana, and the Río Cañas, and is part of the San Juan Metropolitan Water District, which provides about 35 percent of the total water demand for the area (Soler-López and others, 2000). The reservoir has a drainage area of about 469 square kilometers. The dam was constructed in 1974 and is a concrete gravity structure with a normal pool elevation of 52.00 meters above mean sea level (Puerto Rico Electric Power Authority, 1979).

During October 1998, 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 La Plata to assess the impact of Hurricane Georges on the storage capacity of the reservoir. Between July 17 and 20, 2006, the USGS and the PRASA conducted an additional bathymetric survey of Lago La Plata to update the reservoir storage capacity and determine the reservoir sedimentation rate by comparing the 2006 survey data with the 1998 survey data.

The purpose of this report is to update the reservoir storage capacity, sedimentation rates, and areas of substantial sediment accumulation since 1998. Historical (1974) data are referenced as needed to account for long-term storage capacity loss trends.

Method of Survey and Analysis

The field techniques and bathymetric data reduction processes used for the July 2006 survey were performed following procedures similar to those established by the USGS Caribbean Water Science Center in 1994 and described in the previous bathymetric survey of Lago La Plata (Soler-López and others, 2000).

The survey navigation lines were established at a spacing of about 50 meters parallel to the dam face of the reservoir and continuing upstream to the reservoir tail along the different river branches. Geographic position and water depths were acquired simultaneously using a differential global positioning system (DGPS) interfaced to a depth sounder. The pool elevation of the reservoir was measured at the USGS lake-level station (50045000, Lago La Plata at damsite). The soundings were subsequently adjusted to represent water depths below normal pool elevation. The bathymetric survey was conducted using a DGPS coupled to a digital depth sounder similar to the setup used for the survey conducted in October 1998 (Soler-López and others, 2000).

The July 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 1998 bathymetric map of Lago La Plata reservoir (Soler-López and others, 2000). The GIS was used to analyze the bathymetric data.

From the field data, a bathymetric map representing the reservoir bottom in July 2006 was generated (fig. 2). A triangulated irregular network (TIN) surface model of Lago La Plata 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 and longitudinal profiles along the different tributary branches of Lago La Plata were in turn generated from the digital data for 1998 and 2006.

Storage Capacity, Sedimentation, and Useful Life

The original storage capacity of Lago La Plata was 40.21 million cubic meters in 1974 at a normal pool elevation of 52.00 meters above mean sea level (Puerto Rico Electric Power Authority, 1979). By October 1998, the storage capacity of the reservoir had decreased to 35.46 million cubic meters, and by July 2006 the reservoir storage capacity was reduced further to 31.27 million cubic meters (table 1). This represents a total reduction between 1974 and 2006 of 8.94 million cubic meters (22 percent in 32 years) for an annual storage capacity loss rate of about 0.28 million cubic meters. The sedimentation rate, however, for the period 1998-2006 of about 0.52 million cubic meters per year is 2.6 times higher than the previous 1974-1998 rate of about 0.20 million cubic meters per year. The accelerated sedimentation rate between 1998 and 2006 may be the result of recent development that has occurred in the immediate vicinity of Lago La Plata reservoir. An actualized storage capacity table and curve were generated by calculating the TIN volume at 1-meter elevation intervals (table 2, fig. 3).

The Lago La Plata TIN surface model was subdivided into three distinct segments; the Río de La Plata segment (light tan color on fig. 2), the Río Guadiana segment (light green color on fig. 2), and the Lago La Plata dam segment (light yellow color on fig. 2), and their individual volumes were calculated using the GIS to evaluate and compare sediment accumulation in different areas of the reservoir since 1998. The 2006 data indicate the Río de La Plata segment has been most affected by sediment accumulation. Between 1998 and 2006, the volume of the Río de La Plata segment decreased about 2.06 million cubic meters equivalent to about 258,000 cubic meters per year. During the same period, sediment accumulation has decreased the volume of the Lago La Plata dam segment by 1.59 million cubic meters, or about 199,000 cubic meters per year. Along the Río Guadiana segment, about 0.54 million cubic meters of sediment have accumulated between 1998 and 2006 equivalent to a rate of about 67,500 cubic meters per year.

Figure 4 shows the individual bottom profiles along the central portion of Lago La Plata, beginning at the dam and continuing upstream to the different tributaries of Lago La Plata. Within the Río de La Plata tributary branch, sediment accumulation is greatest along a reach that extends from about 4,000 to 8,000 meters upstream from the dam, averaging about 3 meters in thickness (fig. 4). Within the Río Guadiana and Río Cañas tributary branches, the average sediment accumulation is about 2 meters (fig. 4).

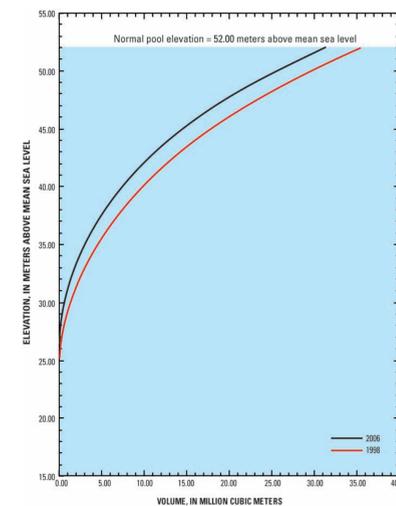


Figure 3. Relation between water-storage capacity and pool elevation of Lago La Plata, for 1998 and 2006.

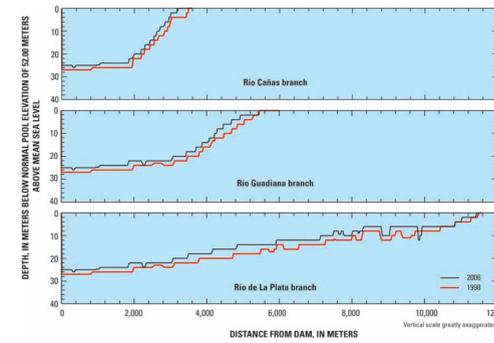


Figure 4. Longitudinal bottom profiles for 1998 and 2006 along the Río Cañas, Río Guadiana, and Río de La Plata branches of Lago La Plata.

Table 1. Comparison between the 1998 and the July 2006 sedimentation surveys of Lago La Plata, Puerto Rico. The 1998 data are derived based on the original 1974 information (Soler-López and others, 2000).

Data descriptor	Years of survey	
	1998	2006
Total capacity, in million cubic meters	35.46	31.27
Live storage, in million cubic meters	33.69	30.33
Dead storage, in million cubic meters	1.77	0.94
Years since construction	24	32
Sediment accumulation, in million cubic meters	4.75	8.94
Inter-survey sediment accumulation, in million cubic meters	4.75	4.19
Long-term storage loss, in percent	12	22
Long-term annual loss of capacity, in million cubic meters per year	0.20	0.28
Annual loss of capacity, in percent	0.5	0.7
Inter-survey loss of capacity, in million cubic meters per year	0.20	0.52
Sediment trapping efficiency, in percent ¹	88	87
Long-term sediment yield, in cubic meters per square kilometer per square year ²	483	689
Inter-survey sediment yield, in cubic meters per square kilometer per square year ³	483	1,292
Estimated year the reservoir would fill with sediments	2175	2118

¹ Estimated based on the relation between storage capacity and water inflow volume established by Brune in 1953.
² Adjusted by the average long-term trapping efficiency until the year of survey.
³ Adjusted by the average trapping efficiency between survey years.

Table 2. Relation between pool elevation and storage capacity of Lago La Plata, Puerto Rico, for July 2006.

Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters
52.00	31.27
51.00	28.32
50.00	25.54
49.00	23.00
48.00	20.58
47.00	18.36
46.00	16.28
45.00	14.48
44.00	12.79
43.00	11.29
42.00	9.89
41.00	8.62
40.00	7.44
39.00	6.39
38.00	5.40
37.00	4.54
36.00	3.73
35.00	3.04
34.00	2.39
33.00	1.86
32.00	1.36
31.00	0.94
30.00	0.55
29.00	0.32
28.00	0.10
27.00	0.00

The long-term sediment yield for the Lago La Plata drainage area increased from 483 cubic meters per square kilometer per year between 1974 and 1998, to 689 cubic meters per square kilometer per year between 1974 and 2006 (table 1). Between 1998 and 2006, however, the inter-survey sediment yield increased to about 1,292 cubic meters per square kilometer per year probably as a result of adjacent urban development. Based on the long-term (1974-2006) storage capacity loss of about 280,000 cubic meters per year estimated for 2006, the useful life of Lago La Plata decreased by about 60 years between 1998 and 2006 (table 1), although it is still substantial at about 112 years. However, if the two-fold sedimentation rate estimated for the 1998 and 2006 period continues unchanged, the useful life of Lago La Plata could be about half of the 112-year value estimated previously—about 60 years or until the year 2066. As development within the Lago La Plata drainage area slows because of decreased land availability (fig. 5), the reservoir sedimentation rate and basin sediment yield may revert back to the long-term value of about 280,000 cubic meters per year.

Although the life expectancy of Lago La Plata presently does not appear to be a pressing concern, sediment deposition in the vicinity of the Lago La Plata dam has raised the reservoir bottom about 2 meters since the 1998 survey. In 1998, the lower operational water intake structure (elevation 25.00 meters above mean sea level) used to withdraw water from Lago La Plata (fig. 6) was in jeopardy



Figure 5. Aerial photograph of Lago La Plata and its immediate surroundings showing development. Photograph from the U.S. Army Corps of Engineers, Puerto Rico 2007.

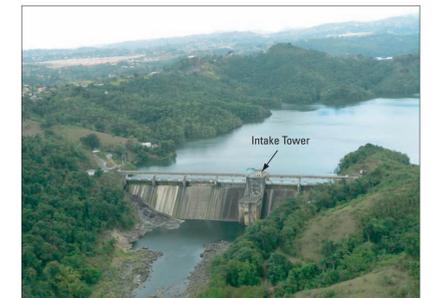


Figure 6. May 2006 aerial photograph of the Lago La Plata dam. The pumphouse and intake tower are visible in the middle of the photograph, as well as the six bascule gates used for water releases over the dam. In addition, four spillway bays to the left of the intake-pumphouse structure and two to the right of the intake-pumphouse structure are visible. Photograph courtesy of the Puerto Rico Electric Power Authority.

of being disabled by sediment accumulation (Soler-López and others, 2000). The 2006 data indicate that the reservoir bottom in the area is at an elevation of 27.00 meters above mean sea level (25.00 meters in depth). Consequently, the intake structure could be rendered unusable if not operated on a regular basis. Sediment accumulation has also decreased the Lago La Plata dead storage, which is the volume of space provided to accommodate sediments without disabling reservoir structures; dead storage has decreased by about 0.83 million cubic meters (1.77 - 0.94 = 0.83; table 1).

Summary

During July 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 La Plata to update the reservoir storage capacity and determine the reservoir sedimentation rate by comparing the 2006 data with the 1998 survey data.

The Lago La Plata original storage capacity was 40.21 million cubic meters in 1974, which was decreased to 35.46 million cubic meters in 1998 and to 31.27 million cubic meters in 2006. The long-term (1974-2006) storage capacity loss is 22 percent, of which 12 percent has occurred between 1998 and 2006. The increase in storage capacity loss rate between 1998 and 2006 may be the result of recent urban development within the immediate Lago La Plata basin. The annual storage loss rate between 1998 and 2006 is 520,000 cubic meters or about 1.5 percent per year between 1998 and 2006. Most of the storage loss of Lago La Plata has occurred on the Río de La Plata tributary branch where an average about 3 meters of sediment have accumulated between 1998 and 2006. Along the Río Guadiana and Río Cañas branches, the sediment accumulation averages about 2 meters in thickness, for the same period.

The Lago La Plata long-term drainage area sediment yield increased from 483 cubic meters per square kilometer per year in 1998 (1974 - 1998), to 1,292 cubic meters per square kilometer per year in 2006 (1998-2006). The long-term basin sediment yield (1974-2006) is about 689 cubic meters per square kilometer per year.

References Cited

Brune, G.M., 1953, Trap efficiency of reservoir: Transactions of the American Geophysical Union, v.34, no. 3, p. 407-418.
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