

**Introduction**

Lago Guerrero is located in Aguadilla, northwestern Puerto Rico (fig. 1). The reservoir has a surface area of about 32,000 square meters and is excavated in Aymamón Limestone of Miocene age. This bedrock consists of chalk interbedded with solution-riddled hard limestone (Monroe, 1969). The reservoir was constructed in the 1930s as part of the Isabela Hydroelectric System to regulate flows to two hydroelectric plants—Central Isabel No. 2, at an elevation of about 110 meters above mean sea level, and Central Isabel No. 3, at about 55 meters above mean sea level. Hydroelectric power generation was discontinued during the early 1960s, although the exact date is unknown (Puerto Rico Electric Power Authority, written commun., 2007). The principal use of the reservoir since then has been to regulate flow to two public-supply water filtration plants and supply irrigation water for the Aguadilla area. Flow into the reservoir is derived from Lago Guajataca through a 26-kilometer-long Canal Principal de Diversion concrete canal (Puerto Rico Electric Power Authority, written commun., 2001). Additional inflow occurs on an incidental basis only during intensive rainfall from the immediate drainage area. The present Lago Guerrero drainage area is undetermined, due to the irregular and complex topography of the limestone terrain and anthropogenic modifications to the stormwater drainage system. Stormwater runoff, however, is presumed to be negligible compared to the almost constant inflow to the reservoir of about 59,300 cubic meters per day from Lago Guajataca (CSA Group, 2000).

On March 9, 2006, the U.S. Geological Survey (USGS), Caribbean Water Science Center, in cooperation with the Puerto Rico Electric Power Authority (PREPA), conducted a bathymetric survey of Lago Guerrero to determine the storage capacity of the reservoir and sedimentation amount since a previous survey conducted on May 30, 2001. The March 2006 survey was made to develop a bathymetric map of the reservoir, establish baseline data for future reservoir capacity comparisons, and to estimate the average sedimentation rate over the preceding 5 years.

**Method of Survey**

The March 2006 bathymetric survey was conducted using a differential global positioning system (DGPS) coupled to a digital depth sounder similar to the one used for the May 2001 survey (Soler-López, 2002). The bathymetric data were then stored and transferred into a geographic information system (GIS), where final analysis and volume calculations were made following procedures similar to those used to develop a bathymetric map of Lago Guerrero reservoir in May 2001 (Soler-López, 2002). The GIS was used to analyze the bathymetric data for surveys of 2001 and 2006.

For this study, 30 survey navigation lines were established at a spacing of about 5 meters parallel to the northwestern perimeter of the reservoir and continuing upstream. 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 existing PREPA reservoir staff gage before and after the data collection process. The soundings were subsequently adjusted to represent water depths below the spillway elevation. A bathymetric map representing the reservoir bottom in March 2006 was then generated from the field data (fig. 2). A triangulated irregular network (TIN) surface model of Lago Guerrero was created from the bathymetric map, and the reservoir volume was calculated using the GIS. A stage-storage curve (fig. 3) and selected cross sections representing the reservoir bottom (fig. 2) were generated using the TIN surface model and the digital data from the 2001 and 2006 surveys.

**Storage Capacities, Bathymetry, and Sedimentation Rates**

The May 2001 and March 2006 bathymetric data indicate the storage capacity of Lago Guerrero has changed slightly between surveys. Because construction records for Lago Guerrero reservoir and original bathymetry were not available, the volumetric changes and bottom contour morphology are referenced to May

2001 conditions. As of May 30, 2001, Lago Guerrero had a calculated storage capacity of 127,376 cubic meters, and a spillway elevation of 125.73 meters above mean sea level (Puerto Rico Electric Power Authority, written commun., 2001). The storage capacity determined from the March 9, 2006, bathymetric survey was about 121,100 cubic meters, which represents a water storage capacity loss or sediment accumulation of 6,276 cubic meters. The reservoir has lost about 5 percent of its storage capacity over 5 years, which is equivalent to an annual loss rate of 1 percent per year from 2001 to 2006 or about 1,255 cubic meters per year. The relation between water volume and pool elevation of Lago Guerrero for 2006 is listed on table 1.

**Table 1.** Lago Guerrero capacity table for March 9, 2006, at 0.305 meter (about 1 foot) elevation intervals.

Pool elevation, in meters above mean sea level	Storage capacity, in cubic meters
125.73	121,100
125.58	111,659
125.27	102,378
124.97	93,258
124.66	84,339
124.36	75,722
124.05	67,405
123.75	59,394
123.44	51,773
123.14	44,546
122.83	37,708
122.53	31,202
122.22	24,977
121.92	19,034
121.62	13,704
121.31	8,986
121.01	4,837
120.70	1,628
120.40	181
120.09	1
119.83	0

A comparison between the May 30, 2001, and March 9, 2006, bathymetric maps indicates that sediment accumulation in Lago Guerrero from 2001 to 2006 has been minimal and has occurred primarily on the upper reach of the reservoir, nearest to the Canal de Diversion del Lago Guajataca intake (fig. 2, sections 3-6). In this reach, sediment accumulation has raised the reservoir bottom by an average of about 25 centimeters over 5 years. The source of the sediment (including debris such as trash and plant matter) is most likely washed off into the irrigation canal where the channel is bordered by steep embankments. This sediment is transported into Lago Guerrero by the sustained flow in the channel from Lago Guajataca reservoir (fig. 4). Figure 5 shows part of the Lago Guerrero flooded area and the vegetation surrounding it which contributes plant matter.

**Summary and Conclusions**

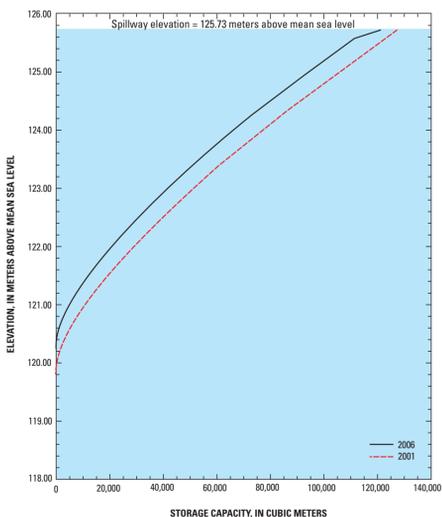
Lago Guerrero is a reservoir with a surface area of 32,000 square meters, constructed as part of the Isabela Hydroelectric System in the 1930s. The reservoir consists of an excavation into the limestone bedrock constructed primarily to regulate flows to two hydroelectric plants. The bathymetric survey conducted on March 9, 2006, indicated a storage capacity of about 121,100 cubic meters. Prior to this survey, a storage capacity of 127,376 cubic meters was determined from a similar survey conducted on May 30, 2001. The difference in storage capacities represents a storage loss of about 6,276 cubic meters between surveys. Based on this storage loss, the inter survey (2001-2006) sedimentation rate of Lago Guerrero is about 1,255 cubic meters per year or about 1 percent of the original storage capacity (127,376 cubic meters) per year. A bathymetric map developed for the current (2006) survey indicates that most of the sedimentation in the reservoir has occurred in the upper part of the reservoir adjacent to the inlet channel. The lost storage capacity is probably sediment and debris washed into the Canal de Diversion del Lago Guajataca from the steep embankments along parts of the canal during stormwater runoff. Based on the current (2006) sedimentation rate of about 1,255 cubic meters per year, Lago Guerrero has an estimated useful life of about 96 more years or the year 2102.

**REFERENCES CITED**

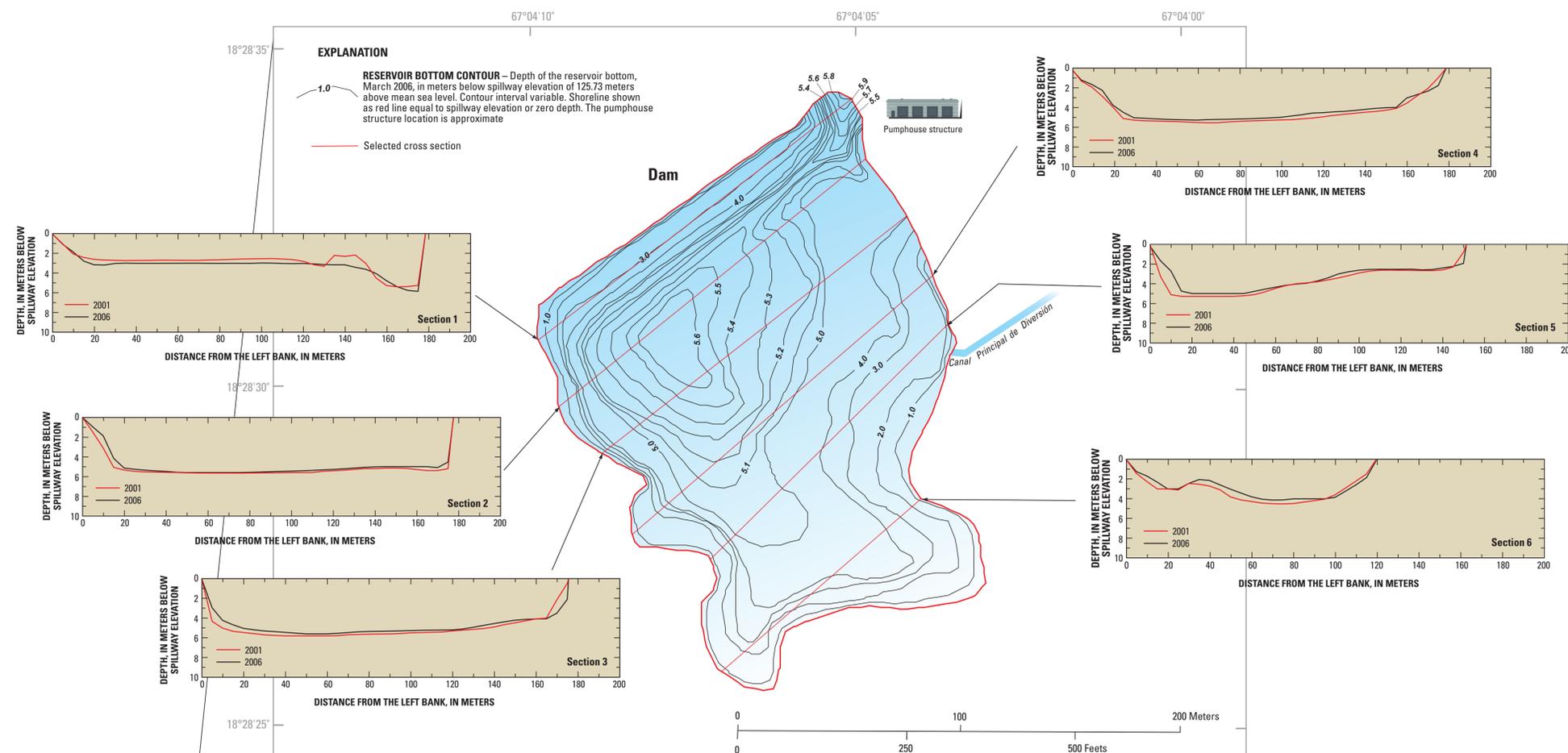
CSA Group, 2000, Evaluación de los canales del sistema de riego de la región noroeste de Puerto Rico: Resumen de Promedios Anuales de Descarga para Cada Estación: Sección 5, Tabla 9.

Monroe, W.H., 1969, Geologic map of the Moca and Isabela quadrangles, Puerto Rico: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-565, 1 pl.

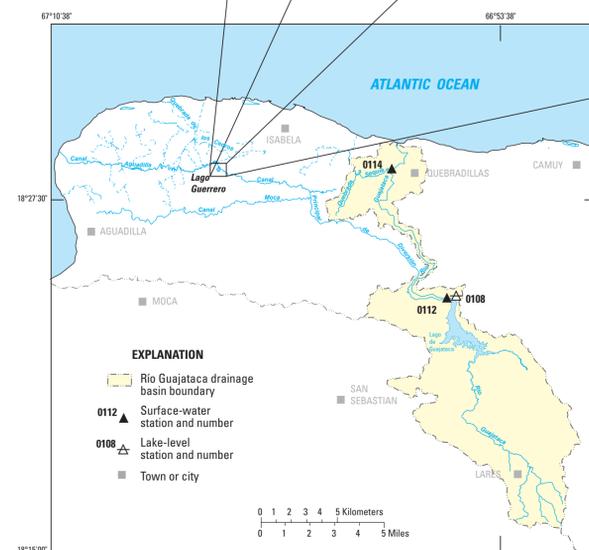
Soler-López, L.R., 2002, Sedimentation survey of Lago Guerrero, Puerto Rico, May 2001: U.S. Geological Survey Water-Resources Investigations Report 02-4169, 12 p., 1 pl.



**Figure 3.** Relation between water storage capacity and pool elevation for Lago Guerrero, Aguadilla, Puerto Rico, for 2001 and 2006.



**Figure 2.** Bathymetric map of Lago Guerrero, Aguadilla, Puerto Rico, March 2006. Shoreline modified from U.S. Geological Survey quadrangle Moca, Puerto Rico, from planetable surveys in 1922 and 1937. Revised in 1964, Lambert conformal conic projection, Puerto Rico state plane coordinate system. (Puerto Rico datum, 1940 adjustment).



**Figure 1.** Location of Lago Guerrero in Aguadilla in northwestern Puerto Rico.



**Figure 4.** Aerial photograph view of Lago Guerrero, Puerto Rico, and part of the Canal Principal de Diversion of Lago Guajataca.



**Figure 5.** Lago Guerrero upstream view -- Upstream view photograph of the Lago Guerrero flooded area taken from the top of the excavation dam. The photograph shows the typical vegetation that surrounds Lago Guerrero, which consists mainly of Puerto Rican almon tree *Prunus amygdalus*. Photograph taken by Luis Soler of the USGS on January 2, 2003.