U.S. Department of the Interior
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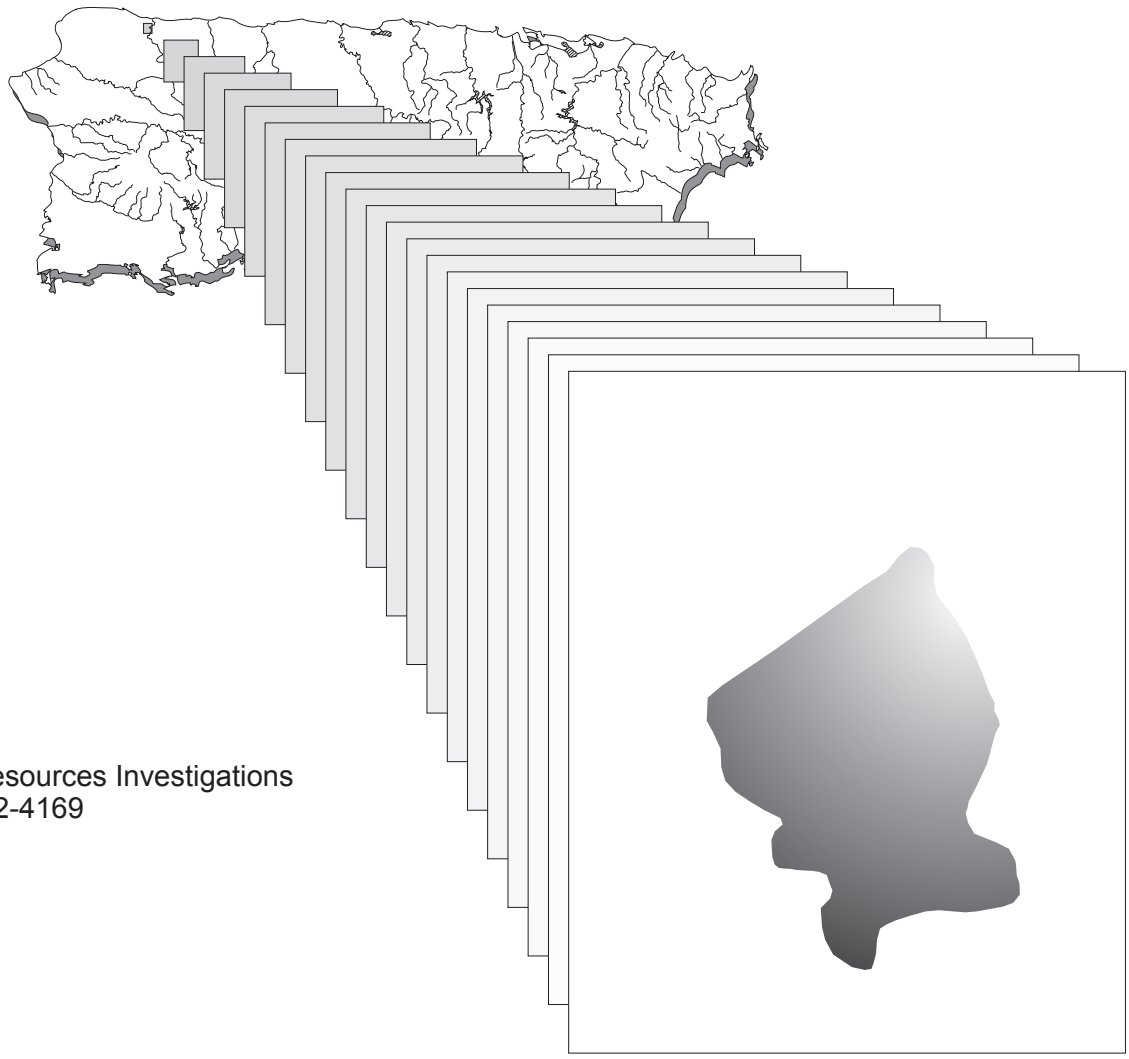
Prepared in cooperation with the
PUERTO RICO ELECTRIC POWER AUTHORITY

Sedimentation Survey of Lago Guerrero, Puerto Rico, May 2001



Water-Resources Investigations
Report 02-4169

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

Sedimentation Survey of Lago Guerrero, Puerto Rico, May 2001

By Luis R. Soler-López

Water-Resources Investigations Report 02-4169

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San Juan, Puerto Rico: 2002

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CONVERSION FACTORS, DATUMS, ACRONYMS, and TRANSLATIONS

Multiply	By	To obtain
	Length	
centimeter	0.03281	foot
millimeter	0.03937	inch
meter	3.281	foot
kilometer	0.6214	mile
	Area	
square meter	10.76	square foot
square kilometer	0.3861	square mile
square kilometer	247.1	acre
	Volume	
cubic meter	35.31	cubic foot
cubic meter	0.0008107	acre-foot
million cubic meters	810.7	acre-foot
	Volume per unit time (includes flow)	
cubic meter per second	35.31	cubic feet per second
cubic meter per second	15,850	gallon per minute
cubic meter per second	22.83	million gallons per day
	Mass per area (includes sediment yield)	
megagram per square kilometer	2.855	ton per square mile

Datums

Horizontal Datum - Puerto Rico Datum, 1940 Adjustment

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called “Seal Level Datum of 1929”.

Acronyms used in this report

BLASS	Bathymetric/Land Survey System
DGPS	Differential Global Positioning System
GIS	Geographic Information System
PREPA	Puerto Rico Energy Power Authority
TIN	Triangulated Irregular Network
USGS	U.S. Geological Survey

Translations

Spanish	English
Lago	Lake (in Puerto Rico, also reservoir)
Río	River

Sedimentation Survey of Lago Guerrero, Puerto Rico, May 2000

By **Luis R. Soler-López**

Abstract

Lago Guerrero, a small reservoir owned by the Puerto Rico Electric Power Authority, is part of the Isabela Hydroelectric System and is located in Aguadilla, in northwestern Puerto Rico. The reservoir had a storage capacity of about 127,376 cubic meters in May 2001 and a maximum depth of about 5.8 meters.

Records on dam construction and original topography and storage capacity were not available; therefore, sedimentation rates could not be determined. However, Lago Guerrero presumably was constructed during the 1930's because it receives water from lago Guajataca, which was constructed in 1928. The May 2001 bathymetric survey of Lago Guerrero established baseline data that are essential to calculate sedimentation rates, sediment yields, storage loss, and sediment deposition sites within the reservoir.

INTRODUCTION

The U.S. Geological Survey (USGS) in cooperation with the Puerto Rico Electric Power Authority (PREPA) has conducted numerous hydrographic and sedimentation surveys in reservoirs used for public water supply, hydroelectric power generation, and irrigation of croplands. On May 30, 2001, the USGS conducted a bathymetric survey of Lago Guerrero to determine the storage capacity of the reservoir and establish baseline data that will be the basis for future reservoir capacity comparisons and sedimentation rate and sediment yield estimates.

Data on geographic location and water depth were collected simultaneously using a differential global positioning system (DGPS) coupled to a digital depth sounder. These data were then stored and transferred into the USGS geographic information system where final analysis and volume calculations took place. A contour map, cross sections representing the reservoir bottom, and a longitudinal section representing the central portion of the reservoir bottom were generated, from the digital data.

DAM AND RESERVOIR CHARACTERISTICS

Lago Guerrero is an excavation structure constructed in the limestone karst region of northwestern Puerto Rico (fig. 1). The reservoir was constructed by digging a hole in the ground and cutting the limestone to form a dam wall. It is part of the Isabela Hydroelectric System and receives water released from Lago Guajataca through a 26-kilometer concrete channel (Pablo Roman, PREPA, written commun., 2001). Additional inflow may come from runoff from the surface water drainage basin of the reservoir; however, it is presumed to be negligible compared to the almost constant inflow from Lago Guajataca.

Records on dam construction, reservoir structures, and original capacity are not available, therefore, reservoir capacity comparisons, sedimentation rate estimates and sediment distribution characterization are not possible. However, the reservoir was probably built in the 1930's since it receives water from Lago Guajataca, which was constructed in 1928, and the logical order of construction for the reservoir system would be from up to downstream.

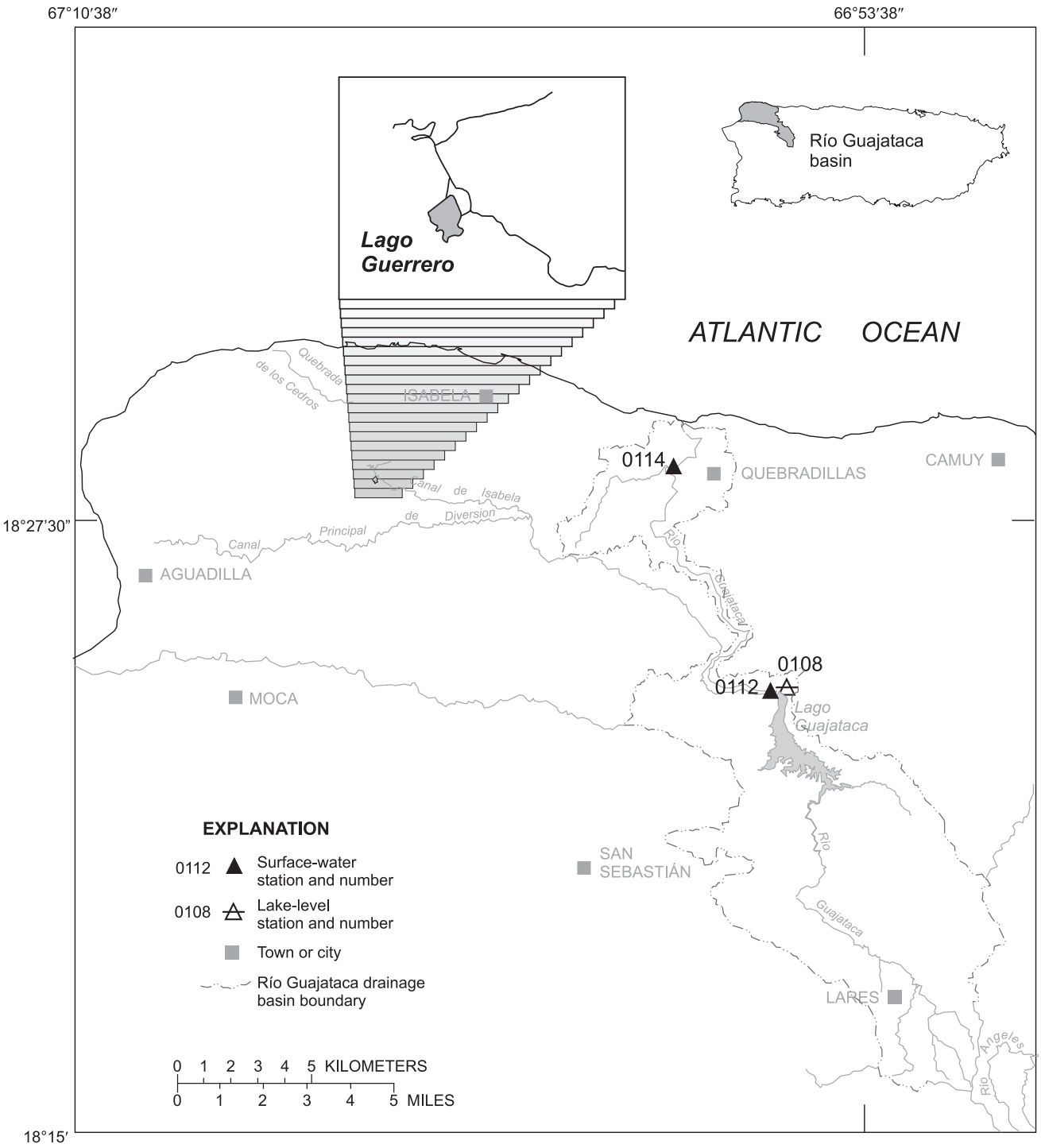

Figure 1. *Location of Lago Guerrero in northwestern Puerto Rico.*

The reservoir is used for hydroelectric power generation at power plant no. 2, located about 0.5 kilometer downstream from the dam. Recently, the reservoir has also been used for water supply by the residents of the Aguadilla area through a pump house located about 20 meters upstream from the dam. An uncontrolled cast-iron pipe spillway with a diameter of 1.22 meters is located on the downstream face of the dam at an elevation of 125.73 meters above mean sea level (Pablo Roman, PREPA, written commun., 2001) (fig. 2). Flow over the spillway is probably infrequent since water inflow is regulated and most of the outflow is through the pump house structure.

METHOD OF SURVEY

The bathymetric survey of Lago Guerrero involved planning, data collection, data processing, and analysis of the results. A geographic information system (GIS), was used to plan the survey lines and to analyze the bathymetric data. Cross-section locations were established at spacings of 15 meters, starting at the dam and continuing upstream to the reservoir (fig. 3). Geographic position and water depths were acquired simultaneously, using a differential global positioning system interfaced to a depth sounder. The soundings were subsequently adjusted to represent water depths below spillway elevation. The pool elevation of the reservoir was measured at the PREPA measuring staff before and after the data collection process. The water level slightly changed during the data-collection process. To account for this change, a time-elevation correction factor was applied to adjust the measured depths to represent depths below spillway elevation. A bathymetric map representing the reservoir bottom in May 2001 was then generated (plate 1).

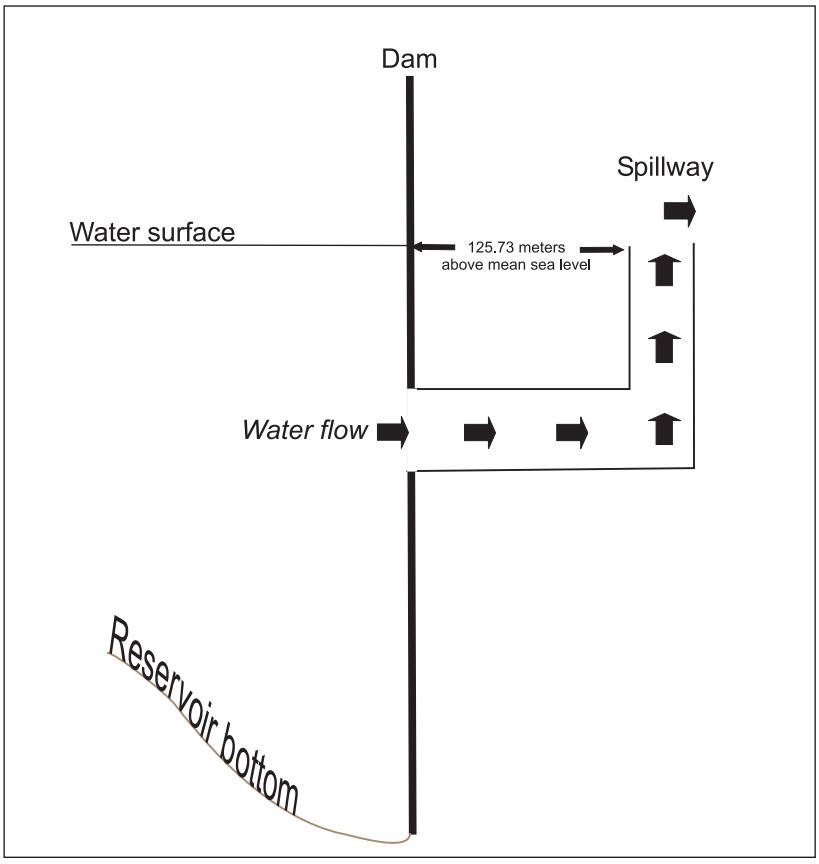

Figure 2. *Spillway structure representation of the Lago Guerrero dam, Puerto Rico.*

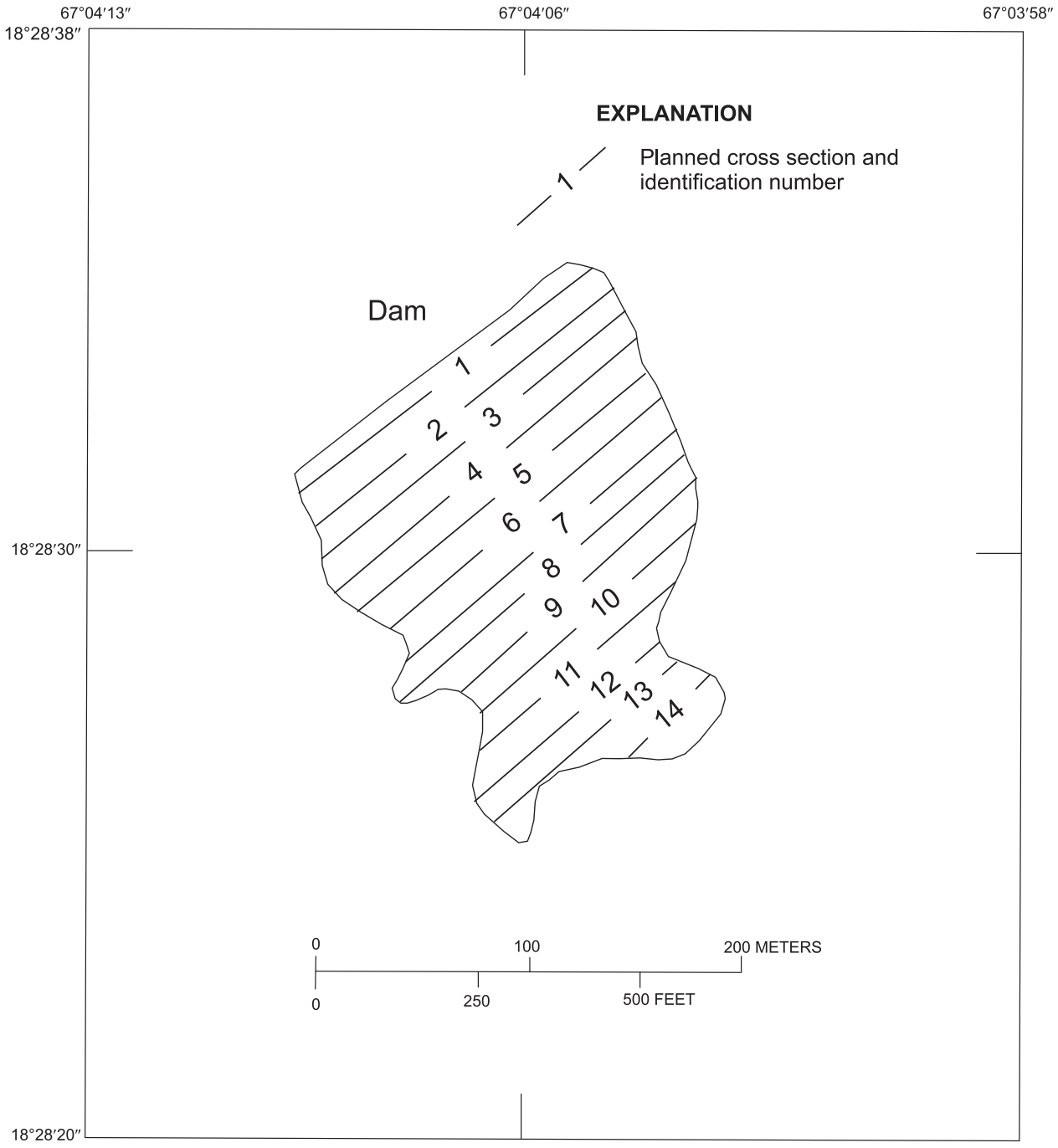

Figure 3. *Planned cross-section locations for May 2001 bathymetric survey of Lago Guerrero, Puerto Rico.*

Field Techniques

The data collection process took place on May 30, 2001. Data were collected using the bathymetric/land survey system (BLASS), developed by Specialty Devices Inc. The system uses two Novatel OEM global position system (GPS) receivers. The GPS units were first used in a static mode to establish reference marks at several sites overlooking the reservoir. These sites were later used as master stations for geographic positioning control. Satellite information was simultaneously recorded for one hour at a control station located at the USGS office, (latitude 18°25'58.9269"N., longitude 66°06'51.7128"W.) established by the USGS and at a benchmark (latitude 18°03'52.0489"N., longitude 67°40'03.7365"W.), at the dam, overlooking the reservoir. Once established, one GPS unit was installed at the dam benchmark station, and the other GPS unit was installed in the survey boat. The GPS on board the survey boat independently calculated a position every second while receiving a set of pseudo-range correction factors from the master station in order to maintain a positional accuracy within 2 meters. Water depths were measured using a SDI-IDS depth sounder. The depth recorder shows depth to the nearest 0.01 meter, and was calibrated at a water depth of 5.5 meters. The bathymetric survey software HYPACK (Coastal Oceanographics, Inc.) received and recorded the geographic position and depth once every second while in survey mode. A total of 1,710 data points were collected over the entire reservoir. HYPACK runs on a portable personal computer, and is used to record data and to navigate. The helmsman of the survey boat is provided with a graphical display showing the lakeshore, the location of the planned cross sections, the real-time position of the survey boat while underway, and indicators of speed and the amount of deviation from the planned lines. A total of 14 cross sections at a 15-meter spacing were planned in the office. The actual track lines of the May 2001 bathymetric survey of Lago Guerrero are shown in figure 4. No electronic or multipath errors, which could affect the satellite signals, occurred during the data collection process.

Data Processing

Initial editing and verification of the position and depth data were performed using the HYPACK program. The edited data were then transferred into the GIS for processing and analysis. The data points were color coded according to the different depths, and contour lines were drawn to match the corresponding color and depth ranges. The bathymetric contour lines were then converted into a surface model by creating a triangulated irregular network (TIN). The TIN surface model of the reservoir bottom consists of thousands of adjoining triangles with x, y and z coordinates assigned to all vertices (Environmental Systems Research Institute, Inc., 1992). The volume of the reservoir was then calculated at incremental pool elevations of 0.3048 meter to develop an elevation-capacity relation curve and table (table 1).

Table 1. *Storage capacity of Lago Guerrero, Puerto Rico, May 2001*

[All elevations are in meters above mean sea level; all capacities are in cubic meters]

Pool elevation	Storage capacity
125.73	127,376
125.58	122,768
125.28	113,642
124.97	104,635
124.67	95,747
124.36	86,999
124.06	78,501
123.75	70,261
123.45	62,271
123.14	54,606
122.84	47,289
122.53	40,309
122.23	33,685
121.92	27,364
121.62	21,328
121.31	15,731
121.01	10,727
120.70	6,238
120.40	2,552
120.09	551
119.79	0

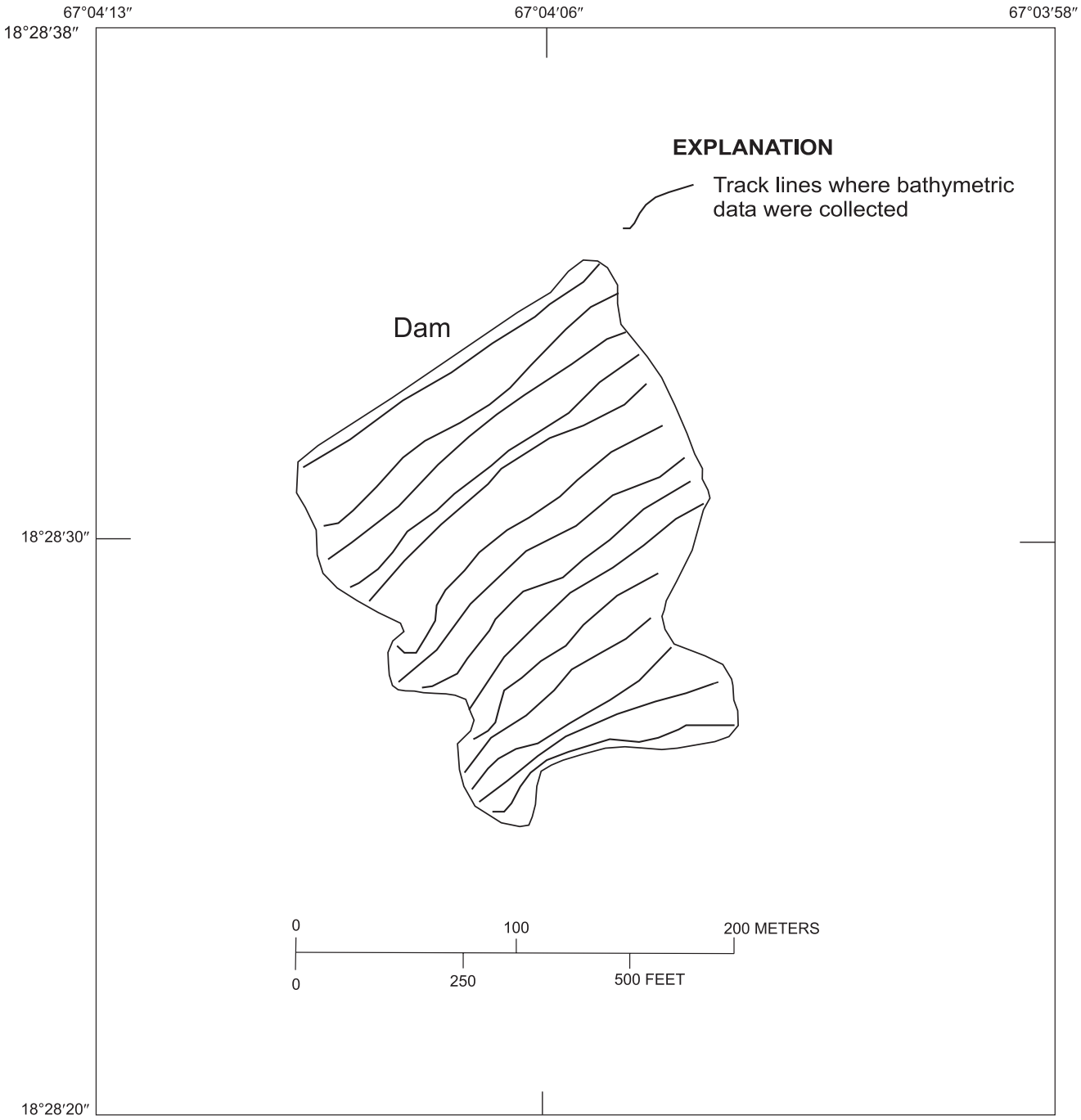

Figure 4. *Actual track lines for the May 2001 bathymetric survey of Lago Guerrero, Puerto Rico.*

STORAGE CAPACITY AND RESERVOIR BATHYMETRY

In May 2001, the storage capacity of Lago Guerrero was 127,376 cubic meters at spillway elevation of 125.73 meters above mean sea level, and a maximum depth of 5.8 meters. The longitudinal distance of Lago Guerrero along the central portion of the reservoir is shown on figure 5. Cross sections depicting the reservoir bottom from shore to shore, and a longitudinal bottom profile of Lago Guerrero are shown on figures 6 and 7, respectively. The reservoir bottom in the vicinity of the spillway pipe is at an elevation of about 121 meters above mean sea level. The relation between pool elevation and storage capacity of Lago Guerrero is shown on figure 8.

The original storage capacity of the reservoir and construction data are not available, therefore, sedimentation rates, sediment yield, and storage capacity loss cannot be calculated. However, all these parameters are expected to be low compared to a reservoir constructed on a natural river channel. The water inflow to Lago Guerrero comes from releases at Lago Guajataca through a concrete channel and erosion is considered to be minimal. Only sediment-rich releases from Lago Guajataca, as well as sheet erosion from the adjacent Lago Guerrero basin, likely discharge sediments into Lago Guerrero. Water releases from Lago Guajataca are probably the most important source of sediment influx to the reservoir. Future bathymetric surveys as well as measurement of suspended sediment concentrations of the water entering the reservoir through the irrigation channel are probably the best tools for monitoring the storage-capacity loss of Lago Guerrero.

REFERENCE

Environmental Systems Research Institute, Inc., 1992, Surface modeling with TIN, Surface analysis and display: Redlands, Cal., 8 chapters.

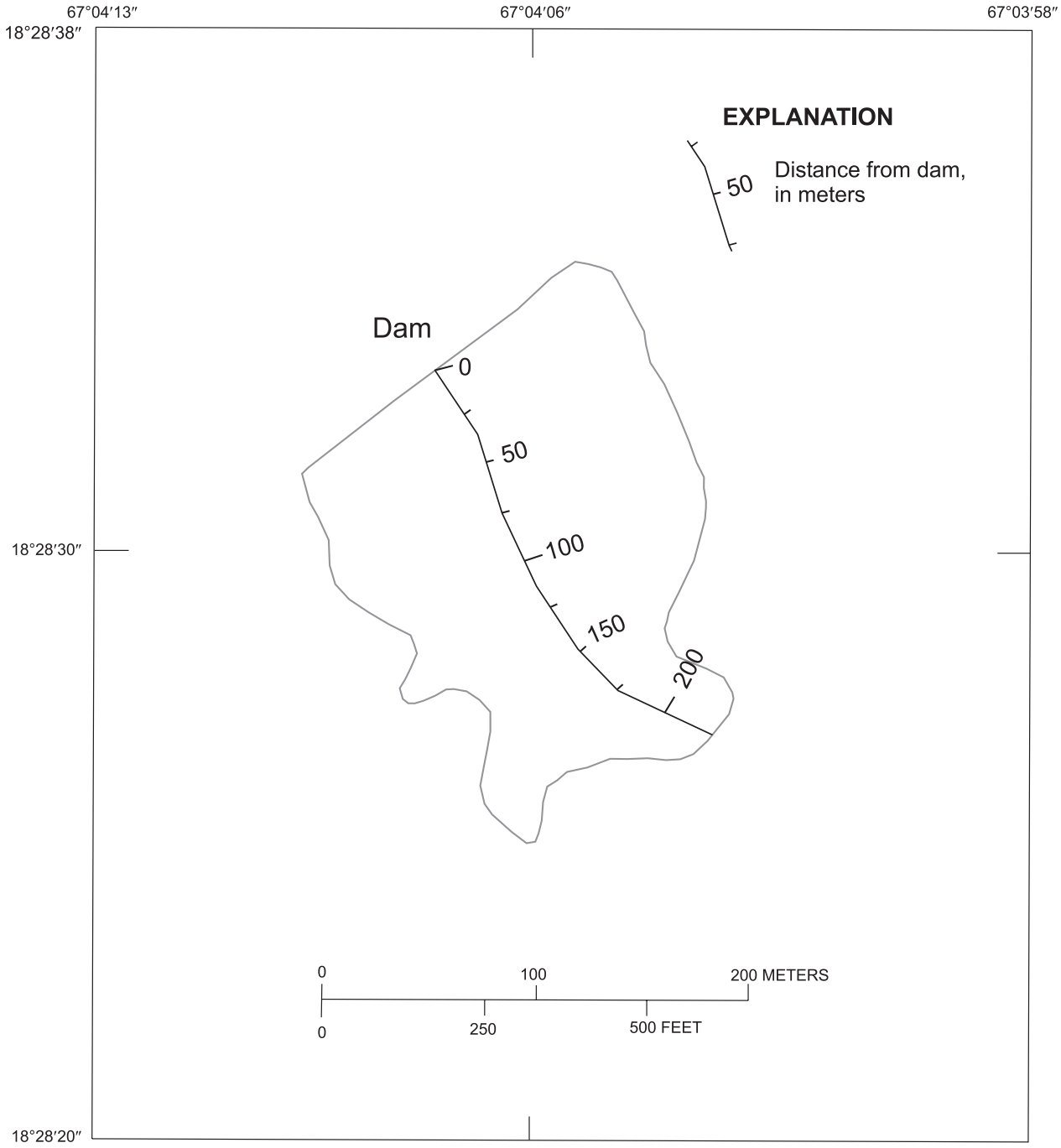

Figure 5. *Longitudinal distance along the central portion of Lago Guerrero, Puerto Rico.*

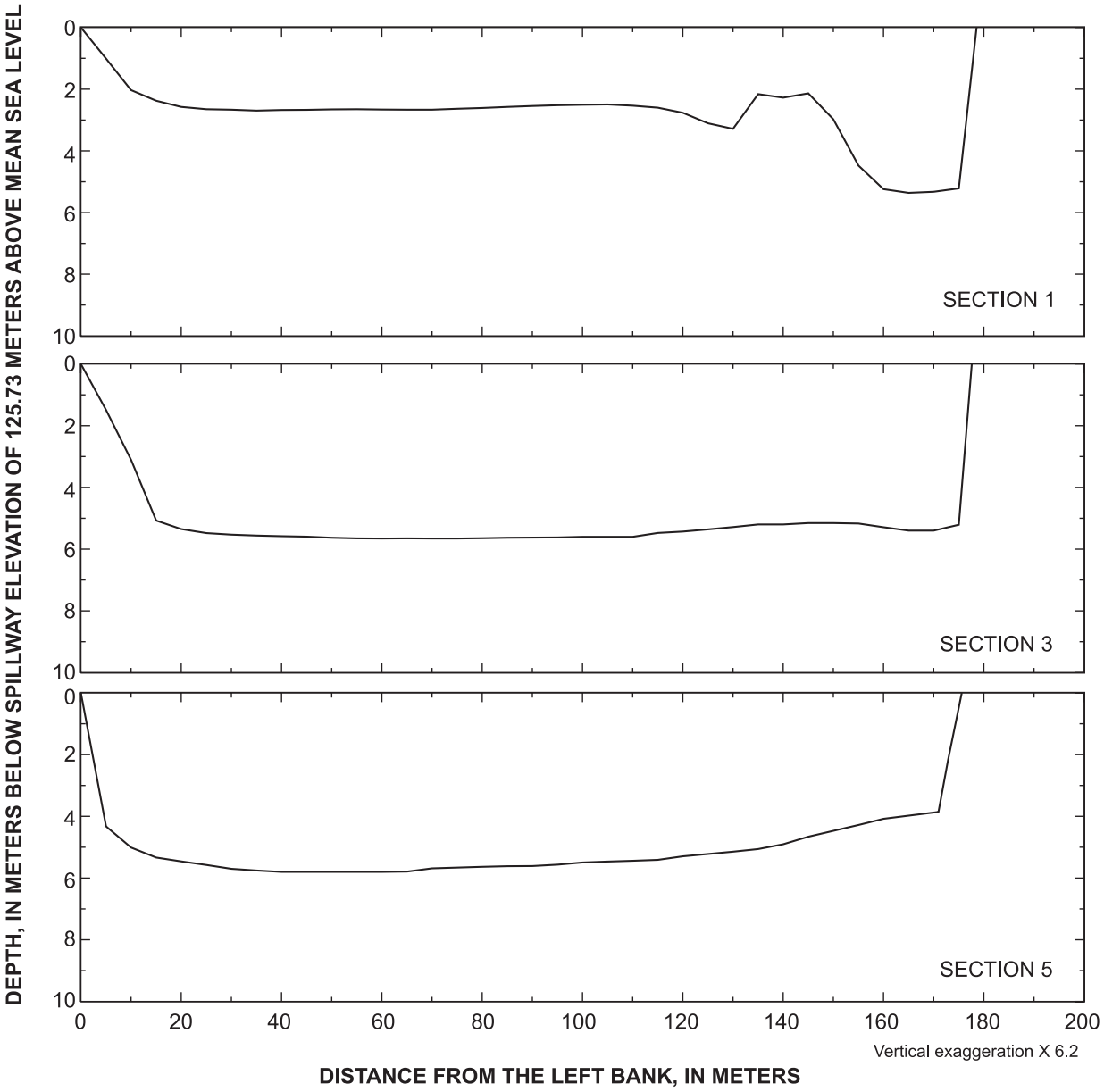

Figure 6. *Selected cross-sections generated from the TIN surface model of Lago Guerrero, Puerto Rico, for May 2001. Refer to figure 3 for cross-section locations.*

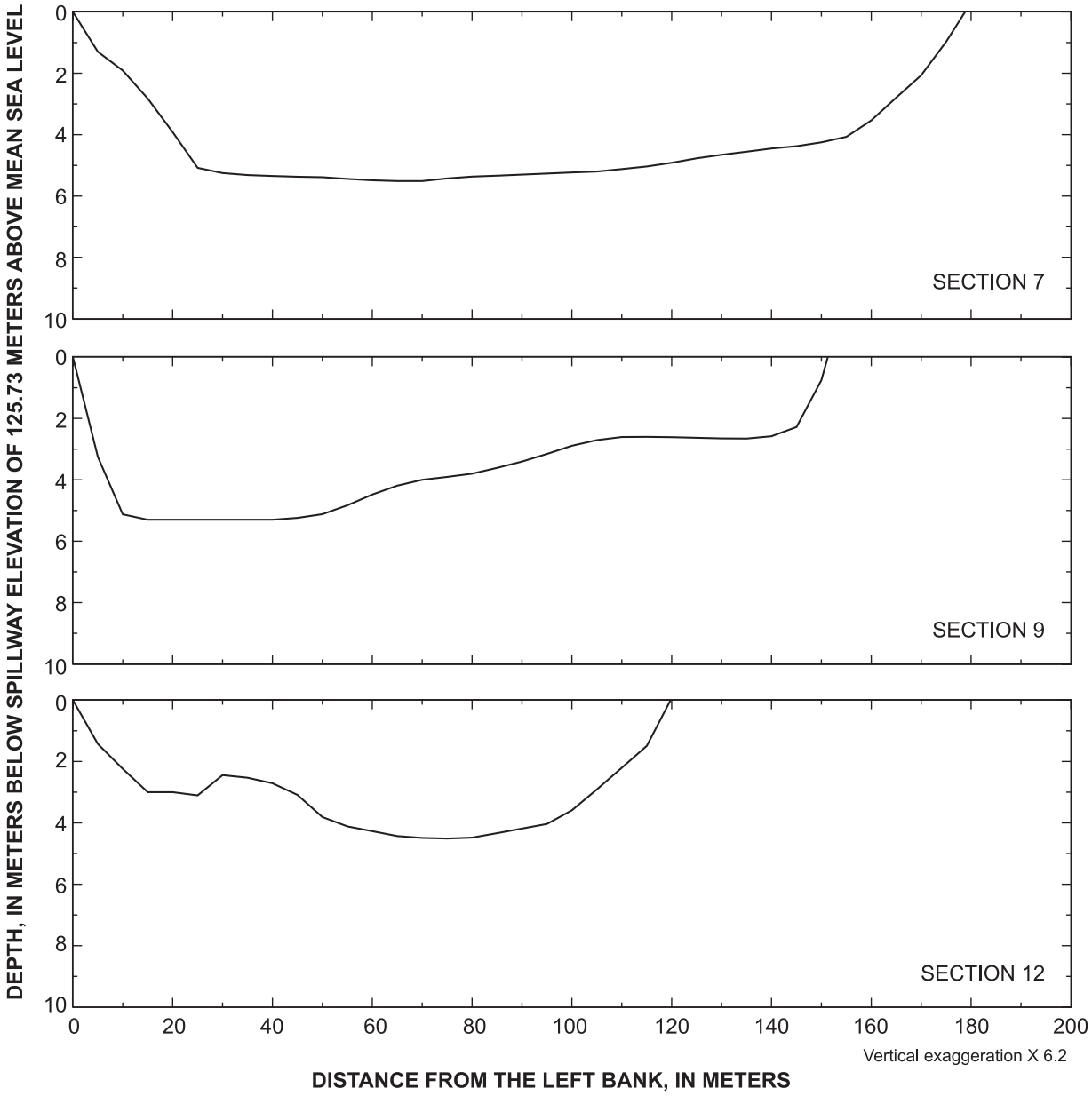

Figure 6. *Selected cross-sections generated from the TIN surface model of Lago Guerrero, Puerto Rico, for May 2001. Refer to figure 3 for cross-section locations–Continued.*

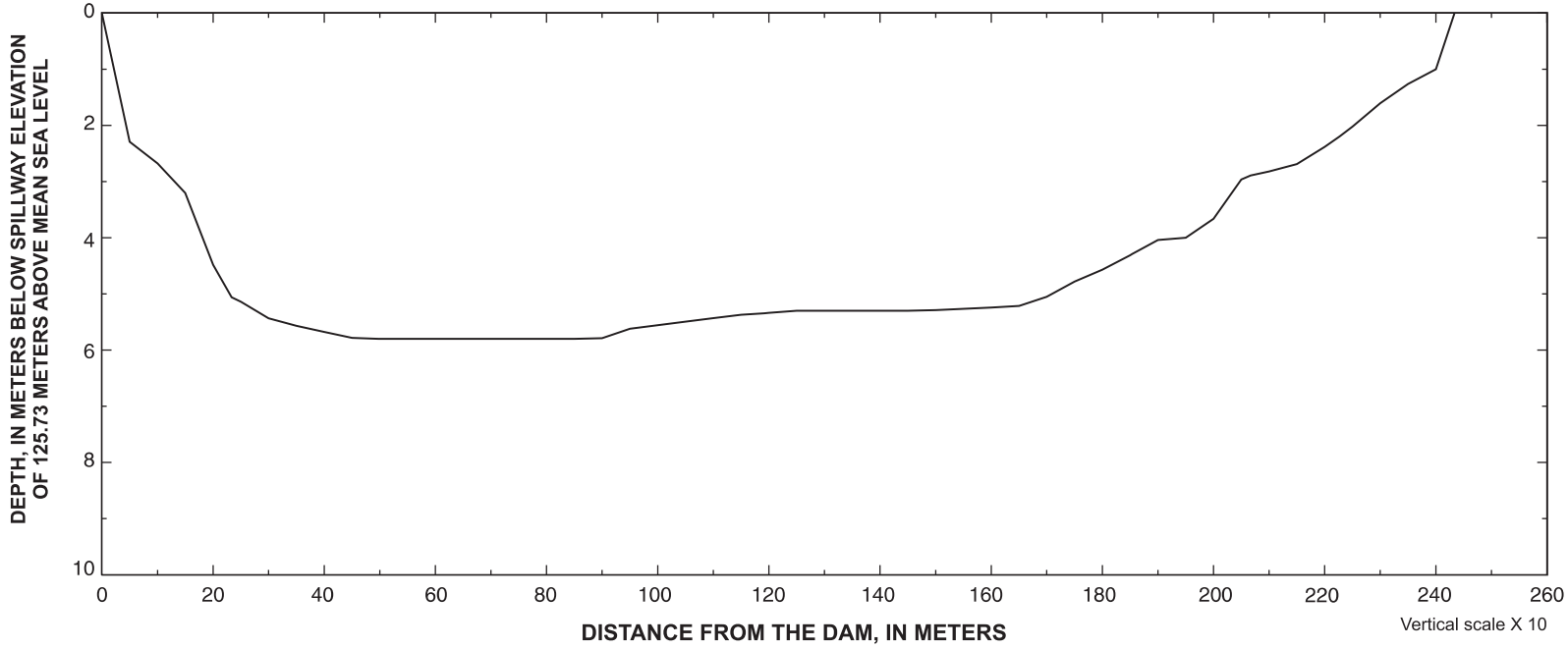

Figure 7. *Longitudinal profile along the central portion of Lago Guerrero, Puerto Rico, for May 2001.*

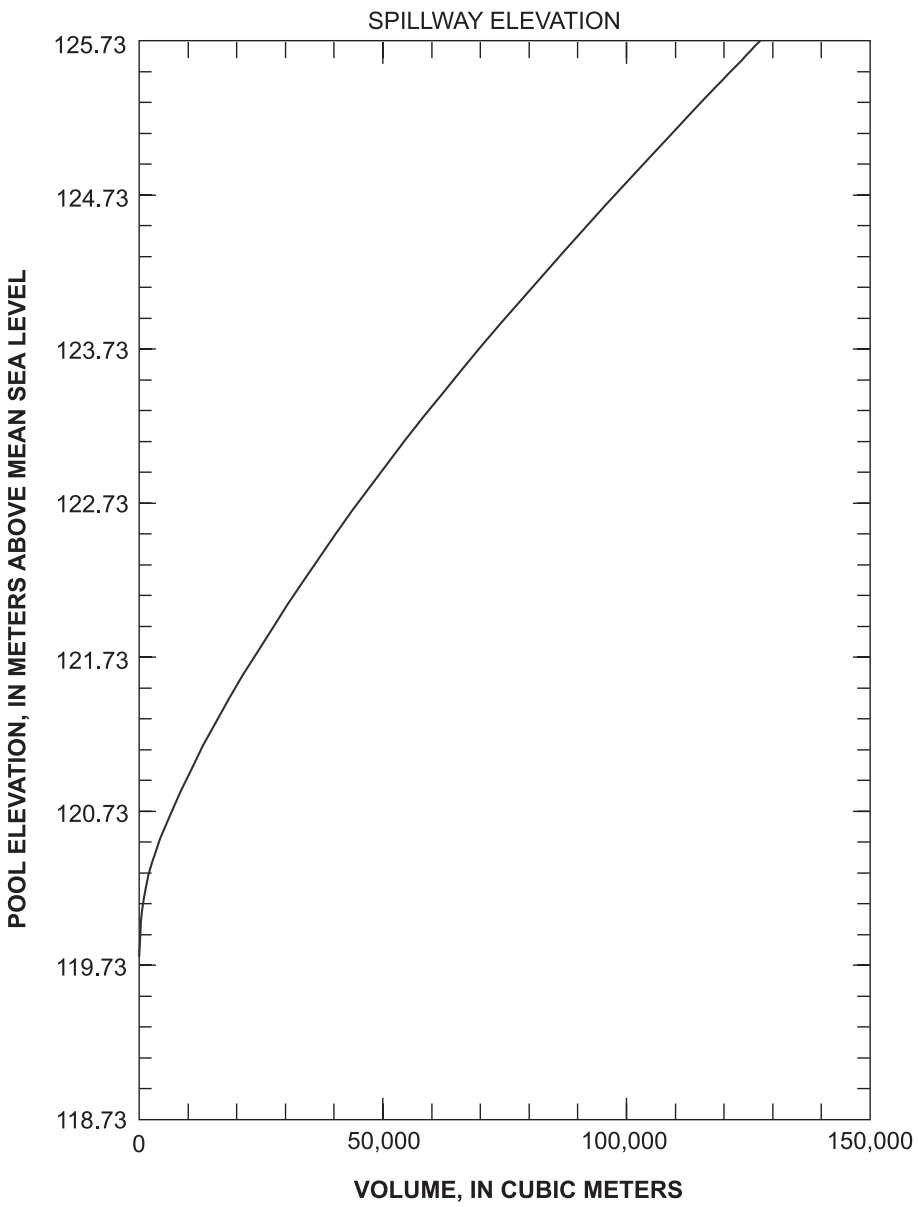

Figure 8. *Relation between water-storage capacity and pool elevation for Lago Guerrero, Puerto Rico, for May 2001.*

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