SEDIMENTATION SURVEY OF LAGO TOA VACA, PUERTO RICO, JULY 1985

By Carlos Figueroa-Alamo

U.S. GEOLOGICAL SURVEY

Open-File Report 90-199

Prepared in cooperation with the

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

San Juan, Puerto Rico
1991

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CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

For the convenience of readers who may want to use International System units (SI), the data may be converted by using the following factors:

Multiply inch-pound units	By	To obtain SI units
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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ABSTRACT

A survey of the sedimentation of Lago Toa Vaca, a reservoir in the south-central region of Puerto Rico, was conducted on July 23, 1985. The results indicate that the capacity of the reservoir at that time was about 50,620 acre-feet. This was about 16 percent less than the original capacity of 60,100 acre-feet recorded in 1972 and represents the loss of approximately 9,500 acre-feet in capacity. During 1972 to 1985, sediment accumulated at the average rate of 730 acre-feet per year and the reservoir lost 1.2 percent of its original capacity per year. Under these conditions, the remaining usable life of the reservoir at the time of the sedimentation survey (1985) is estimated to be about 70 years.

INTRODUCTION

Lago Toa Vaca is located in the Río Jacaguas basin, just upstream from the Lago Guayabal and approximately 8 miles from the south coast in Villalba, Puerto Rico (fig. 1). The drainage area upstream from the dam is 21.94 square miles. The reservoir provides water for municipal and industrial use and for irrigation of some lands served by the South Coast Irrigation District through the Juana Díaz canal. Lago Toa Vaca is owned and operated by the Puerto Rico Aqueduct and Sewer Authority (PRASA).

Lago Toa Vaca is an important source of freshwater for part of the Ponce area. On July 23, 1985, the U.S. Geological Survey, in cooperation with the U.S. Department of Agriculture, Soil Conservation Service, conducted a bathymetric survey of the reservoir to determine its current capacity, annual sedimentation rate, and expected usable life. Results of this survey and conclusions follow.

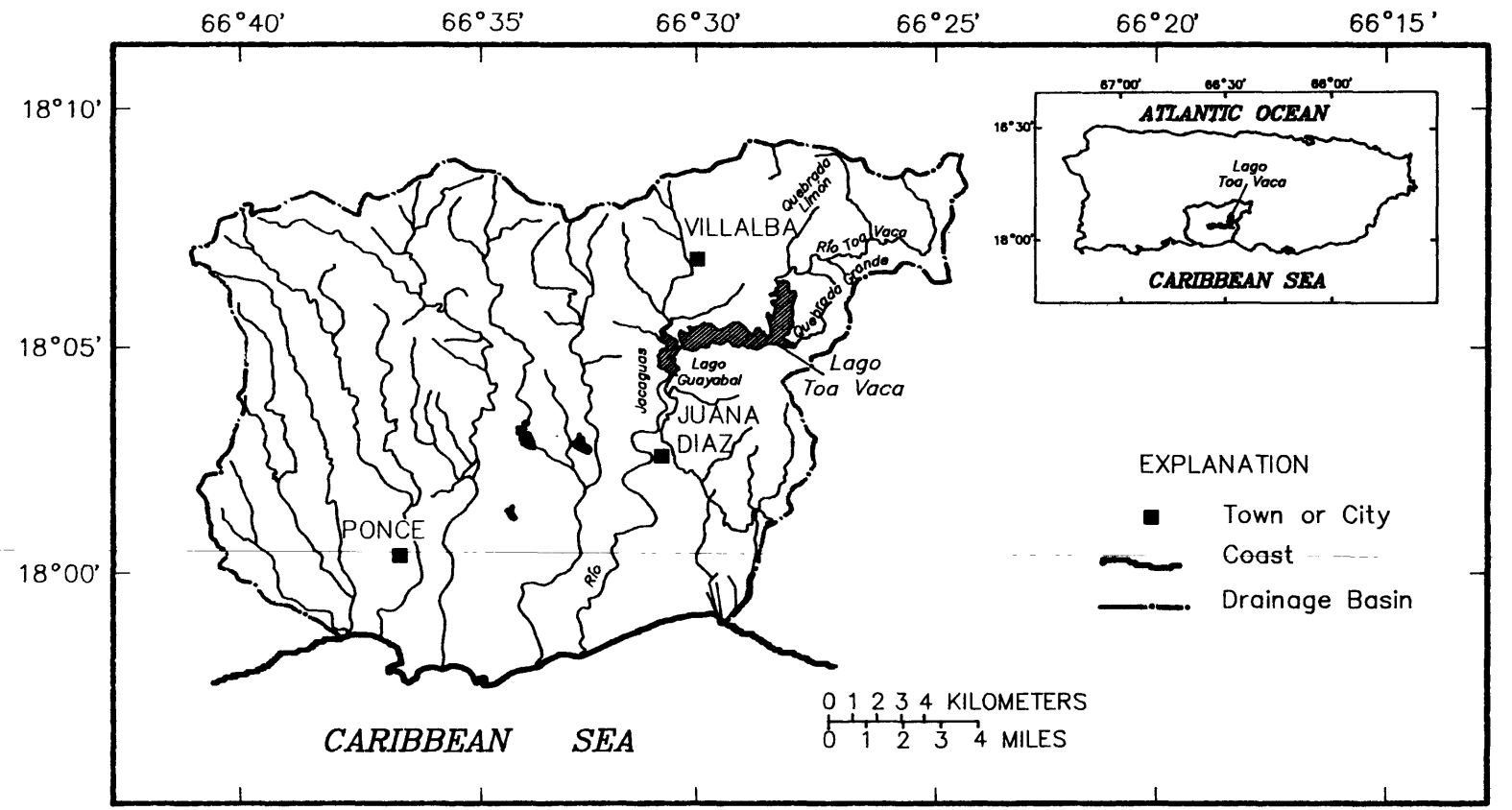

Figure 1.--Location of Lago Toa Vaca in Río Jacaguas basin.

GENERAL DESCRIPTION OF THE BASIN

The Río Jacaguas basin is characterized by two different climatological sectors: the humid mountain-valley region and the semi-arid mountain-valley region. Slopes in the upper area of the watershed are steep, ranging from 20 to 90 percent. Average annual rainfall at the reservoir is approximately 60 inches, compared to 90 inches at higher elevations in the upper part of the basin. Soil types and runoff characteristics in the basin include the following:

a. The Caguabo series are gravelly clay loam soils with slopes ranging from 20 to 60 percent. Runoff is rapid, and soils are susceptible to erosion.

b. The Montegrande series are clay soils with slopes ranging from 2 to 12 percent. Runoff is slow to medium, and soils are susceptible to erosion.

c. The Mucará series are silt clay soils with slopes ranging from 20 to 60 percent. Runoff is rapid, and soils are susceptible to erosion.

d. The Quebrada series are silt clay loam soils with slopes ranging from 12 to 20 percent. Runoff is medium, and soils are susceptible to erosion.

Erosion from the uplands and the resulting siltation of the reservoir is a major concern, because accumulation of sediment reduces storage capacity. Reservoir siltation is caused by erosion of steep agricultural lands, overgrazed pastures, and burned areas of surrounding watershed. Burning has destroyed much of the vegetative cover in the watershed, and this increases erosion (Soil Conservation Service, 1987). Estimates of land use in the watershed are as follows: pasture, 39 percent; forest land, 28 percent; cropland, 21 percent; surface water, 8.25 percent; and others, 2.35 percent. Runoff from heavy rains causes average erosion rates of about 271 tons per acre per year in the watershed (Soil Conservation Service, 1987). Estimates of total sediment loads eroded annually from lands with various uses are in table 1.

Table 1.--*Estimated sediment loads eroded from lands of various uses*
[Data from Soil Conservation Service, 1989]

Land Use	Tons per year
Cropland	474,300
Pasture	328,800
Permanent gullies	105,000
Stream banks	17,458
Forest land	15,760
Road banks	6,900
Construction sites	600

DAM AND RESERVOIR CHARACTERISTICS

The Lago Toa Vaca dam was completed in 1972 on Río Toa Vaca. The dam is located approximately 1.9 miles south of the town of Villalba, 8 miles from the south coast, and 3.75 miles north-northeast of the town of Juana Díaz. The original capacity of the reservoir was about 60,100 acre-feet at a maximum pool elevation of 546.2 feet above sea level. The principal characteristics of the dam and reservoir are summarized in table 2. The main tributaries to the reservoir are Río Toa Vaca, Quebrada Limón, and Quebrada Grande.

Table 2.--*Principal characteristics of the Lago Toa Vaca dam and reservoir*
[Puerto Rico Water Resources Authority, 1975]

Length of dam	1,740 feet
Height of dam	215 feet
Crest elevation of spillway	508 feet
Maximum pool elevation	546.2 feet
Original capacity 1972 (maximum pool)	60,100 acre-ft
Reservoir length (at active conservation pool)	4.13 miles
Drainage area	21.94 square miles
Discharge capacity at maximum pool elevation	77,100 cubic feet per second
Type of dam	earth and rock embankment

METHOD OF SURVEY

The capacity of the reservoir was determined by bathymetric surveys utilizing an Auto-Track Digital Fathometer[1] to determine bottom profiles at 31 transects across the reservoir (fig. 2). The instrument, which consists of a boat-mounted transducer coupled to a velocity meter, records both water depth and distance from a reference point near the shore. The instrument operates over a range of 2 to 1,000 feet, with less than a 0.5-foot error in the 1 to 100 foot range. The instrument was calibrated frequently during the survey using a hand-held sounding device.

The reservoir's capacity was computed using the "Range Method" described by the Soil Conservation Service (1983), and the volume of sediment accumulated in the reservoir was computed by subtracting the current capacity from the original capacity computed by PRASA. Records of the original survey conducted during or after construction of the Lago Toa Vaca dam were not available at the time of this investigation.

A 1968 topographic map prepared by the Puerto Rico Water Resources Authority of the area prior to impoundment was available, but bottom profiles calculated from this map were not detailed enough for a comparison with bottom profiles measured during this bathymetric survey for some transects.

COMPUTED CAPACITY AND SEDIMENTATION RATE

The capacity of Lago Toa Vaca at maximum-pool elevation and including the dead storage capacity in July 1985 was computed as 50,620 acre-feet. This capacity represents a loss of approximately 9,500 acre-feet, or 16 percent of the original capacity of the reservoir. Results of the sedimentation survey are summarized in table 3.

[1] Use of trade names in this report is for identification purpose only and does not constitute endorsement by the U.S. Geological Survey or the U.S. Department of Agriculture, Soil Conservation Service.

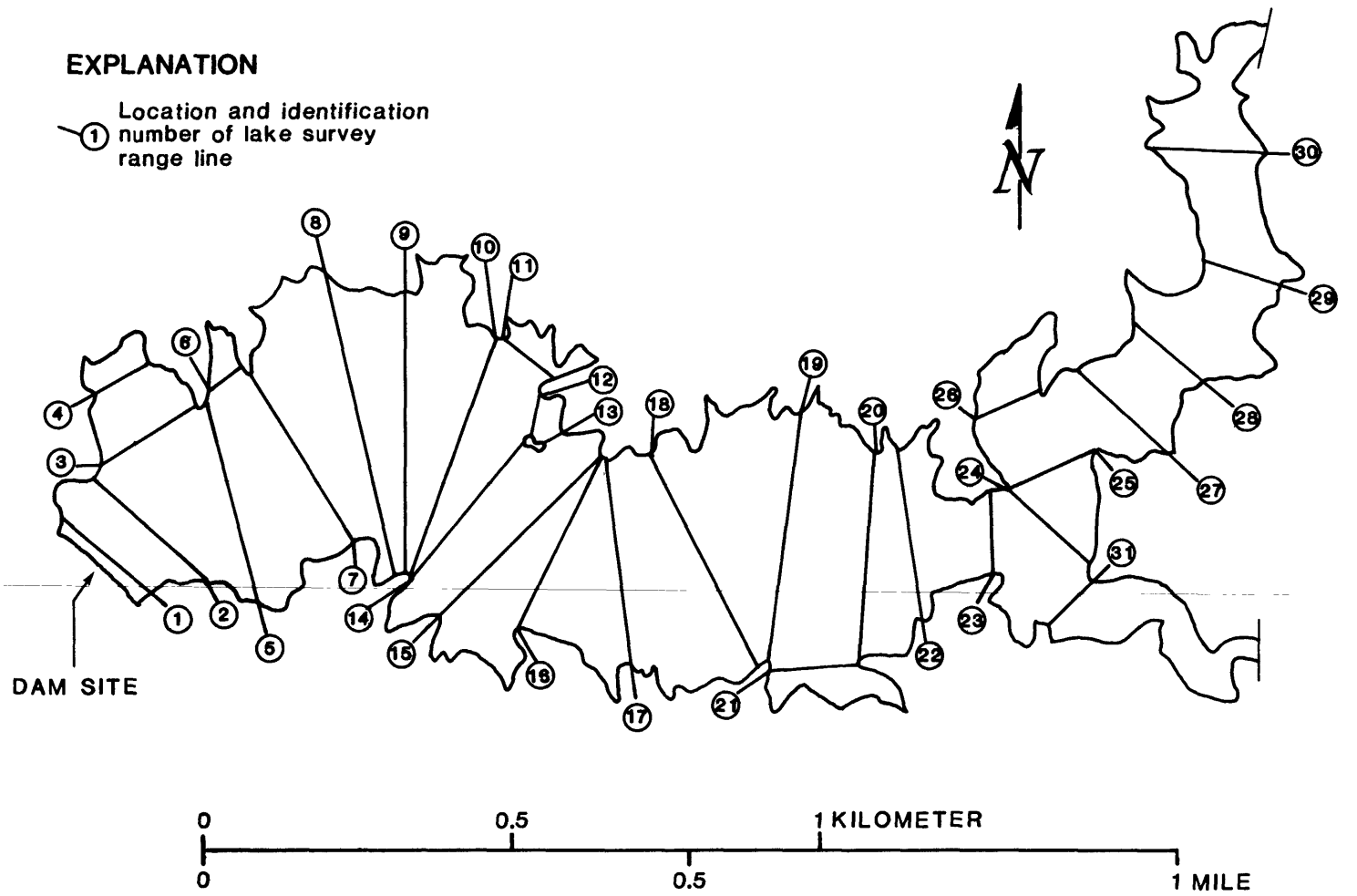

Figure 2.--Transects surveyed at Lago Toa Vaca during July 1985.

Table 3.--*Results of 1985 sedimentation survey of Lago Toa Vaca*

Capacity	50,620 acre-feet
Age	13 years
Sediment accumulated	9,500 acre-feet
Loss in storage	16 percent
Average annual loss in storage	1.2 percent
Average annual sedimentation rate	730 acre-feet per year

The average annual sedimentation rate during the period 1972 to 1985 was 730 acre-feet per year. This corresponds to a loss of 1.2 percent of the original capacity per year. The sedimentation rate may vary over time due to changes in land use (especially agricultural practices), changes in storage capacity, and variations in rainfall. However, if the average rate during 1972 to 1985 is representative of future sedimentation rates, it is estimated that the Lago Toa Vaca reservoir may be filled with sediment in about 70 years from the time of the survey (1985). Many variables affect sedimentation rates, and only one post-reservoir construction survey was available for computing sedimentation rates. Additional surveys during the next 5 to 10 years may be needed to produce more reliable and updated estimates of sedimentation rates and could be used to better project the future capacity of the reservoir.

Longitudinal profiles of the bottom of Lago Toa Vaca were completed in July 1985 by plotting the deepest point in each transect against the distance upstream from the dam. This profile was compared to one developed using the 1968 topographic map prepared by the Puerto Rico Water Resources Authority (fig. 3). This comparison indicates that as much as 30 to 50 feet of sediment has accumulated in the deepest sections of the reservoir.

CONCLUSIONS

The 1985 survey of Lago Toa Vaca indicated that the capacity of the reservoir has been reduced by 16 percent to a storage capacity of 50,600 acre-feet. Sediment has accumulated in the reservoir at an average rate of 730 acre-feet per year. Consequently, the estimated usable life of the reservoir, based on the average sedimentation rate during the period 1972 to 1985, is about 70 years. Additional reservoir surveys, conducted every 5 to 10 years, are needed to provide current estimates of storage capacity and sedimentation rates.

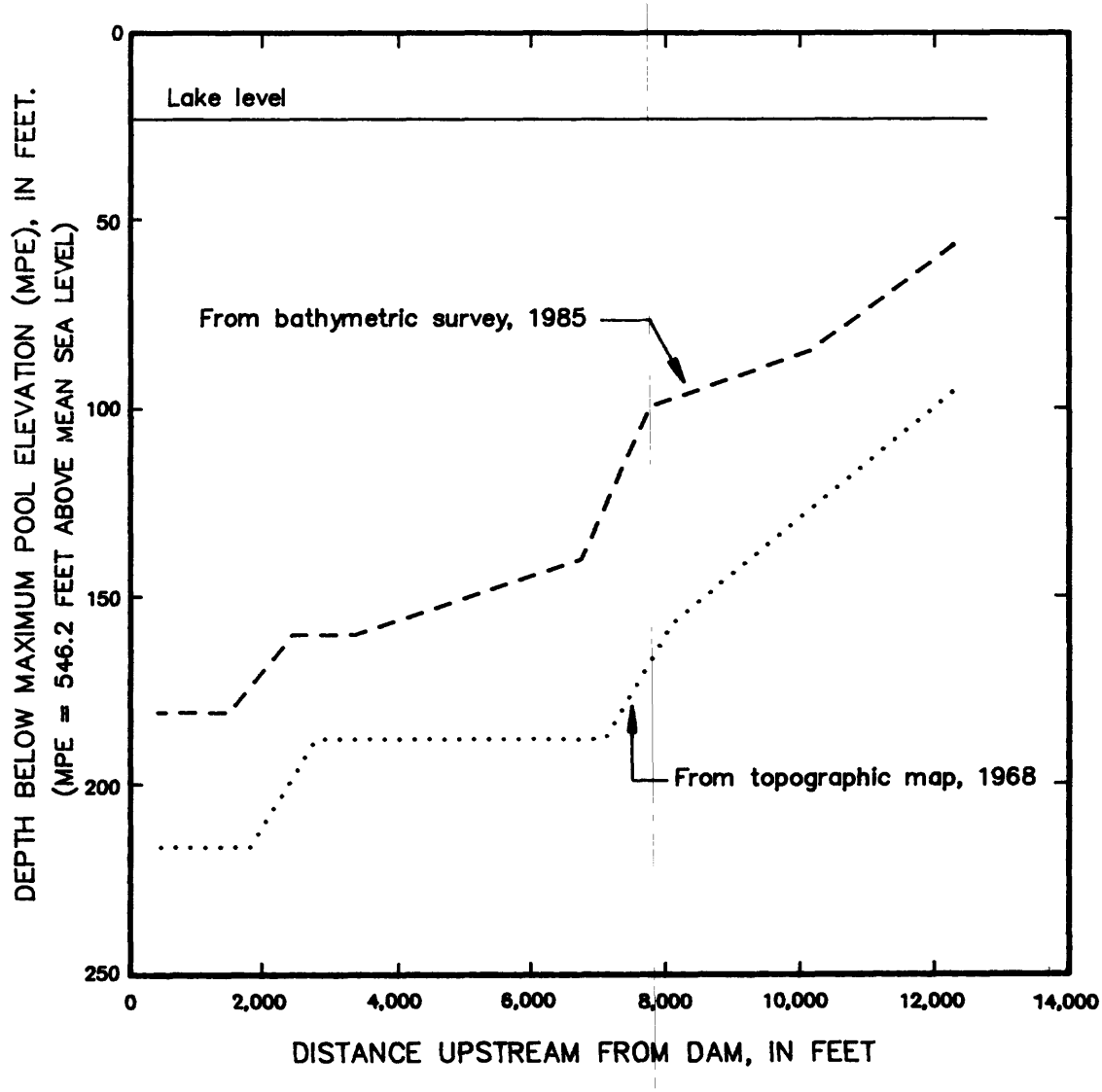

Figure 3.--Bottom profiles of Lago Toa Vaca.

SELECTED REFERENCES

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

Heinemann, H.G., and Dvorak, V.I., 1965, Improved volumetric survey and computation procedures for small reservoirs: Miscellaneous Publication 970, U.S. Department of Agriculture, 845-856 p.

Puerto Rico Water Resources Authority, 1975, Toa Vaca dam inspection report: Puerto Rico Aqueduct and Sewer Authority, San Juan, Puerto Rico, 11 p.

Soil Conservation Service, 1983, National Engineering Book, Section 3, Sedimentation: U.S. Soil Conservation Service, Washington, D.C., 7-1, 7-41 p.

_____ 1987, Preauthorization planning report, Toa Vaca Lake Watershed: U.S. Soil Conservation Service, San Juan, Puerto Rico, 1-18 p.

_____ 1989, Watershed Plan and Environmental Assessment, Toa Vaca Watershed Project: U.S. Soil Conservation Service, San Juan, Puerto Rico, 1-43 p.