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SCIENTIFIC INVESTIGATIONS MAP 2010-3128
Sedimentation Survey of Lago Patillas, Puerto Rico, March 2007
By Luis R. Soler-López, 2010

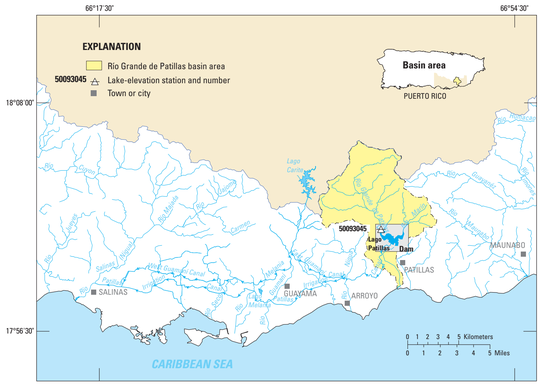

Figure 1. Location of Lago Patillas in the Río Grande de Patillas basin, Puerto Rico.

Table 1. Comparison of the 1997 and 2007 sedimentation surveys of Lago Patillas, Puerto Rico.

[Historic information about Lago Patillas can be obtained from Soler-López and others, 1999]

Data descriptor	Year of survey	
	1997	2007
Total capacity, in million cubic meters	13.84	13.57
Years since construction[1]	83	93
Years since storage capacity was informed (1961)	36	46
Sediment accumulation since 1961[2], in million cubic meters	3.80	4.07
Sediment accumulation since previous survey, in million cubic meters	3.06	0.27
Storage loss since 1961, in percent	22	23
Annual loss of capacity since 1961, in cubic meters	106,000	88,500
Annual loss of capacity since 1961, in percent	0.61	0.50
Years since previous survey	20	10
Inter-survey loss of capacity, in cubic meters per year	153,000	27,000
Long-term sediment trapping efficiency, in percent[3]	92	92
Long-term sediment yield, in cubic meters per square kilometer per year	1,740	1,450
Inter-survey sediment yield, in cubic meters per square kilometer per year	1,600	445
Year reservoir would fill with sediments (based on the inter-survey annual loss of capacity for each year)	2123	2509

[1] Using the construction date of 1914 (Puerto Rico Water Resources Authority, 1979).
[2] Calculations were made based on the reported storage capacity 0f 17.64 million cubic meters for 1961 (Soler-López, 1999). There was no original (1914) storage capacity information.
[3] Using the capacity to inflow relation established by Brune (1953).

Table 2. Storage capacity table for Lago Patillas, Puerto Rico, March 2007.

Pool elevation, in meters above mean sea level	Storage capacity, in million cubic meters
67.67	13.57
66.67	12.46
65.67	11.40
64.67	10.38
63.67	9.42
62.67	8.52
61.67	7.65
60.67	6.83
59.67	6.06
58.67	5.34
57.67	4.67
56.67	4.04
55.67	3.46
54.67	2.91
53.67	2.45
52.67	2.05
51.67	1.69
50.67	1.37
49.67	1.07
48.67	0.79
47.67	0.55
46.67	0.33
45.67	0.14
44.67	0.00

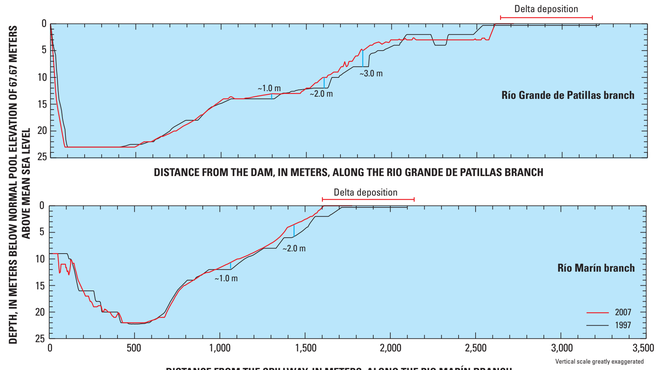

Figure 5. Longitudinal bottom profiles for 1997 and 2007 along the Río Grande de Patillas and Río Marín branches of Lago Patillas.

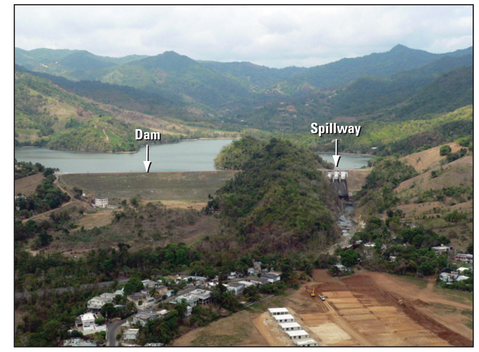

Figure 6. Aerial photograph of the Lago Patillas earthfill dam and spillway section. Photograph courtesy of the Puerto Rico Electric Power Authority.

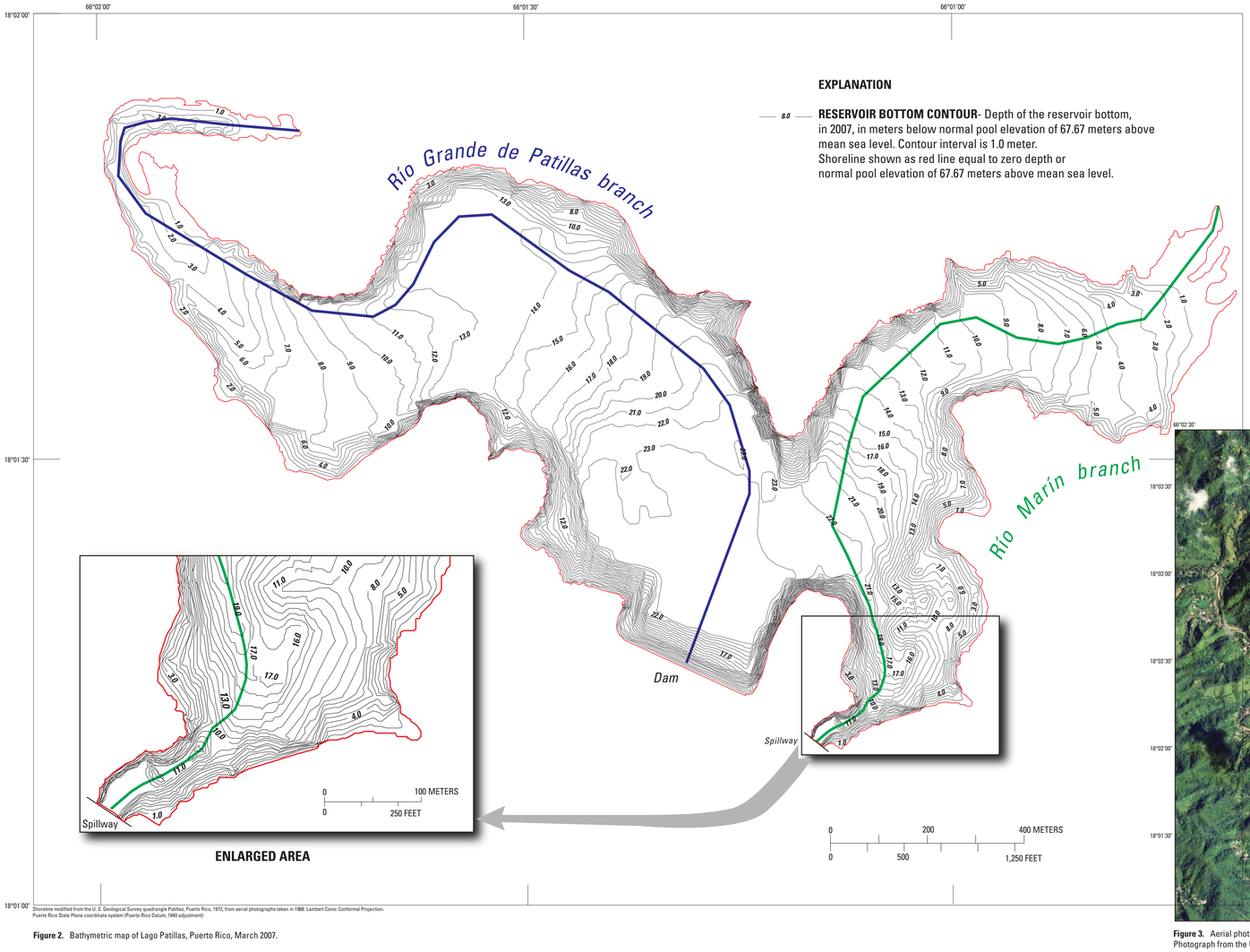

Figure 2. Bathymetric map of Lago Patillas, Puerto Rico, March 2007.

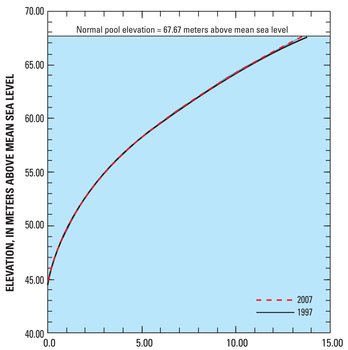

Figure 4. Relation between water-storage capacity and pool elevation of Lago Patillas, for 1997 and 2007.

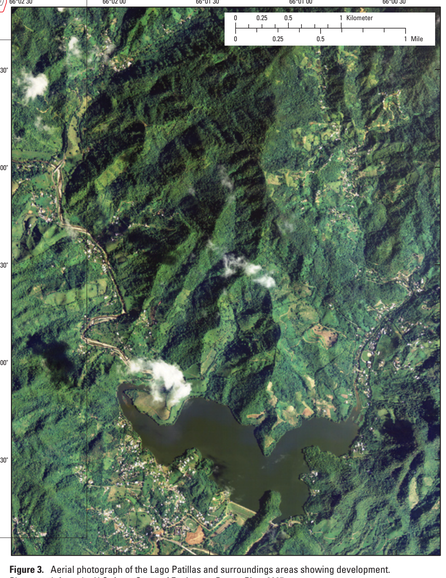

Figure 3. Aerial photograph of the Lago Patillas and surroundings areas showing development. Photograph from the U.S. Army Corps of Engineers, Puerto Rico, 2007.

Introduction

Lago Patillas is a reservoir located on the confluence of Río Grande de Patillas and Río Marín, in the municipality of Patillas in southern Puerto Rico, about 3 kilometers north of the town of Patillas and about 8 kilometers northeast of the town of Arroyo (fig. 1). The dam is owned and operated by the Puerto Rico Electric Power Authority (PREPA) and was constructed in 1914 for the irrigation of croplands in the southern coastal plains of Puerto Rico along the towns of Arroyo, Guayama, Patillas, and Salinas. Irrigation releases are made through the outlet works into the Patillas Irrigation Canal that extends 32.2 kilometers from the Patillas dam to Río Salinas. The dam is a semi-hydraulic earthfill with a structural height of 44.80 meters, a top width of 4.57 meters, a base width of 190.49 meters, and a crest length of 325.21 meters. The spillway structure is physically separated from the earthfill dam, has an elevation of 58.21 meters above mean sea level, and has three radial arm gates (Puerto Rico Electric Power Authority, 1979). The reservoir impounds the waters of the Río Grande de Patillas and Río Marín. The reservoir has a drainage area of 66.3 square kilometers. Additional information and operational procedures are listed in Soler-López and others (1999).

During March 14-15, 2007, the U.S. Geological Survey (USGS), Caribbean Water Science Center (CWSC), in cooperation with the PREPA conducted a bathymetric survey of Lago Patillas to update the reservoir storage capacity and update the reservoir sedimentation rate by comparing the 2007 bathymetric survey data with previous 1997 data. The purpose of this report is to update the reservoir storage capacity, sedimentation rates, and areas of substantial sediment accumulation since April 1997.

Method of Survey and Analysis

The field techniques and bathymetric data reduction processes used for the 2007 survey were performed following procedures similar to those established by the USGS CWSC in 1994, and described in the previous bathymetric survey report of Lago Patillas (Soler-López and others, 1999). The March 2007 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 April 1997 (Soler-López and others, 1999).

The survey navigation lines were established at a spacing of about 50 meters, beginning at the dam and spillway 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 the DGPS interfaced to the depth sounder. The pool elevation of the reservoir was measured at USGS lake-level station 50093045, Lago Patillas at Damsite near Patillas. The soundings were subsequently adjusted to represent water depths below normal pool elevation. The 2007 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 1997 bathymetric map of Lago Patillas reservoir (Soler-López and others, 1999). Field data were used to generate a bathymetric map representing the reservoir bottom in March 2007 (fig. 2). A triangulated irregular network (TIN) surface model of Lago Patillas was then created from the bathymetric map, and the reservoir volume was calculated using the GIS. The TIN surface model was used with the digital data for 1997 and 2007 to generate a stage-storage curve and longitudinal profiles along the different tributary branches of Lago Patillas. An actualized storage capacity table and curve were generated by calculating the TIN volume at 1-meter elevation intervals (table 2, fig. 4).

Storage Capacity, Sedimentation Rates, and Useful Life

Bathymetric data indicate storage capacity of the reservoir decreased slightly from 13.84 million cubic meters in April 1997 (Soler-López and others, 1999) to 13.57 million cubic meters by March 2007 (table 1). This decrease represents a reduction between 1997 and 2007 of 270,000 cubic meters (or 2 percent over 10 years) for an annual storage capacity loss rate of about 27,000 cubic meters. The nearly 75 percent reduction in sedimentation rate from 1997 to 2007 (table 1) may be a result of the nearly undisturbed Lago Patillas drainage area (fig. 3). An actualized storage capacity table and curve were generated by calculating the TIN volume at 1-meter elevation intervals (table 2, fig. 4).

Sediment accumulation in Lago Patillas between 1997 and 2007 has been minimal, as indicated by a comparison of 1997 and 2007 longitudinal bottom profiles of Lago Patillas along the thalweg of the Río Grande de Patillas and Río Marín branches of the reservoir (fig. 5). Although these profiles are slightly different from those presented in Soler-López and others (1999), the profiles shown in figure 5 were generated from both surface models (1997 and 2007) in a simpler, more descriptive way to depict the reservoir bottom along the different river branches upstream from the dam and spillway. Near the confluence of the Río Marín and Río Grande de Patillas, the reservoir bottom for 2007 is flat with no change since 1997; therefore, the comparison generated shows one flat line overlapping the other with no discernable difference between profiles. The comparison indicates that the greatest sediment accumulation has occurred along the riverine zones of Lago Patillas. Along the Río Grande de Patillas tributary branch, sediment accumulation is greatest in a section that extends from about 1,500 to 2,100 meters upstream from the dam, averaging about 2.5 meters in thickness. Within the Río Marín tributary branch, the average sediment accumulation along a reach extending from about 900 to 1,700 meters upstream from the confluence with the Río Grande de Patillas is about 1.5 meters. Sediment accumulation near the dam and the spillway structure is minimal. The sediment deposition rates from 1997 to 2007 were about 25 and 15 centimeters per year, respectively, along the Río Grande de Patillas Río Marín branches. The more noticeable effect of material accumulation is that the reservoir surface area has been reduced on the Río Grande de Patillas and Río Marín riverine zones (fig. 5). Figure 6 shows an aerial photograph of the Lago Patillas earthfill dam and the spillway section.

The Lago Patillas drainage area sediment yield rate decreased substantially from 1,740 cubic meters per square kilometer per year between 1961 and 1997 (Soler-López and others, 1999) to 445 cubic meters per square kilometer per year between 1997 and 2007 (table 1). This reduction in storage capacity loss and sediment yield rate recorded between 1997 and 2007 could be because the major amount of coarse sediment eroded from the basin has been deposited along the river beds upstream from the reservoir and along the riverine zones of the reservoir, which is not accounted for by the conventional bathymetric surveys conducted for the this study. This material, however, has the potential to be flushed suddenly downstream into the reservoir by a major flood.

According to the current storage capacity loss of about 27,000 cubic meters per year estimated for 1997-2007, the projected useful life of Lago Patillas life is about 502 years, to year 2509.

Summary and Conclusions

During March 2007, the USGS Caribbean Water Science Center, in cooperation with the Puerto Rico Electric Power Authority, conducted a bathymetric survey of Lago Patillas to update the reservoir storage capacity and actualize the reservoir sedimentation rate by comparing the 2007 bathymetric survey data with 1997 data.

The Lago Patillas storage capacity was 13.84 million cubic meters in April 1997, which decreased to 13.57 in million cubic meters by March 2007. The inter-survey (1997-2007) storage capacity loss is about 2 percent, for a decrease of about 0.2 percent per year. This loss represents a reservoir sedimentation rate of about 27,000 cubic meters per year. Most of the storage capacity loss of Lago Patillas has occurred along the Río Grande de Patillas tributary branch, where an average about 2.5 meters of sediment has accumulated between 1997 and 2007. Along the Río Marín tributary branch, sediment accumulation is about 1.5 meters.

The Lago Patillas drainage area sediment yield decreased substantially from 1,740 cubic meters per square kilometer per year between 1961 and 1997 to 445 cubic meters per square kilometer per year between 1997 and 2007. This substantial reduction in sediment yield rate may be because the greater amount of sediment eroded from the basin has been deposited along river beds upstream from the reservoir and within the riverine zones, which was not accounted for by the standard bathymetric survey conducted for this study. However, this eroded material has the potential of suddenly being flushed down into the reservoir by a large magnitude flood.

Although the life expectancy of about 502 years for Lago Patillas is not a pressing concern (assuming a long-term storage loss rate of about 27,000 cubic meters per year), sediment accumulation in the Río Grande Patillas and Río Marín branches of the reservoir will continue downstream towards the deepest parts of Lago Patillas, which will eventually start filling the reservoir near the dam. If the sedimentation rate of 27,000 cubic meters estimated between 1997 and 2007 continues, the useful life of Lago Patillas may end by the year 2509.

References Cited

Brune, G. M. 1953: Trap efficiency of reservoirs. Transactions of the American Geophysical Union 34, 407-418.

Puerto Rico Electric Power Authority, 1979, Patillas Dam, Patillas, Puerto Rico: Phase I Inspection Report: National Dam Safety Program, 1979.

Soler-López, L. R., Webb, R.M.T., and Pérez-Blair, Francisco, 1999, Sedimentation survey of Lago Patillas, Puerto Rico, April 1997: U.S. Geological Survey Water-Resources Investigations Report 99-4030, 14 p., 1 pl.

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