Table 12. Simulation Results for Dam Break Analysis

Location	Water Surface Elevations (m)				
	PMF No Breach	PMF Breach	100-Year No Breach	100-Year Breach	Sunny-day Breach
Valenciano dam	102.46[a]	99.78	98.51	98.39	96.22
Downstream of dam	85.26	90.94	80.63	84.18	80.13
Near Juncos	66.65	68.78	65.37	66.1	57.2
Junction with Gurabo river	59.83	60.96	57.45	58.95	57.2
After Gurabo	51.35	51.62	50.11	50.35	49.92
Upstream of Loíza river	50.8	51.08	49.3	49.52	49.04

a- To preclude a zero flow condition, which could result in instabilities, a relatively small initial flow was assumed to occur over the spillway. This flow exists at a depth slightly higher than 0.5 meters. Thus, the PMF flow elevation will not exceed 102.0 meters when the reservoir is actually full with no outflow.

The PMF No-Breach scenario yielded a lower downstream-of-dam elevation than that of the Breach scenario due to the increased storage behind the reservoir. Similar observations apply to the 100-year simulations.

A comparison of the water surface profiles obtained for the breach scenarios is depicted in Exhibits 4 and 5. The difference between the water surface profiles is greater for the steeper area since the flow is more concentrated than the one pertaining to the lower reach. The extent of the flooding from the dam break scenarios is depicted in plan view in Exhibit 6. In the exhibit,

peak flow arrival times are listed at some of the critical locations in the study. These times were obtained from the routed runoff hydrographs, which are depicted in Figure 6. The following table lists the wave travel times, flow depths, and attendant flow velocities for the PMF breach event.

Table 13. Peak Flow Arrival Times at Various Locations

Location	Time Since Breach[a] (min)	Peak Flow (m^3/s)	Flood Elevation (m)	Flow Velocity (m/s)
Near Juncos	10	7,116	68.8	13.6
Junction with Gurabo river	20	5,726	61.0	4.4
After Gurabo	120	5,485	51.6	2.6
Upstream of Loíza river	170	3,827	51.1	1.2

a- Since flows near the peak values can occur well before the listed travel times, the latter should be considered upper limits

The longer travel times in the above table reflect the flow storage effects along the lower reach of the Gurabo river. Within this zone runoff hydrographs will present a flatter profile and, consequently, larger flows can persist longer than they would along a steep stretch. This fact implies that flows and stages close to the peak values may occur for some time before the peaks themselves are attained. For the Gurabo location, the simulation demonstrated that a flood elevation of 51.0 meters is attained about 60 minutes after the Valenciano dam breach, which is just shy of the 51.6-

meter stage listed in Table 13 at 120 minutes after the breaching. This suggests that the times in Table 13, mainly for the downstream area of the Gurabo river, should be considered upper limits in the sense that elevations close to the peak stage will occur at some time prior to the listed values.

The extent to which the inundation from the studied scenarios can affect developed areas is depicted in Exhibits 7, 7a, and 7b (based on 1998 FEMA images). The most affected area would be the municipality of Juncos, which would have a very short lead time before becoming inundated in the event of a dam break occurrence.

The peak flows resulting from the various breach and no-breach scenarios can also be compared. This comparison is presented in the table below.

Table 14. Comparison of Scenario Peak Flows

Location	Peak Flow (m^3/s)				
	PMF No Breach	PMF Breach	100-Year No Breach	100-Year Breach	Sunny-day Breach
Downstream of dam	2511	6505	735	1900	632
Near Juncos	2831	7116	1179	2087	851
Junction with Gurabo river	3007	5726	1106	1843	809
After Gurabo	4448	5485	2647	3028	2402
Upstream of Loíza river	3484	3827	1931	2127	1718

The flows at the limit of the study area reflect the influence of the attenuation effect as the flood encounters flatter terrain. At other locations the effect of the lateral inflows from the contributing areas along the stream are evident. The increase in the PMF breach scenario flood peak near Juncos reflects this effect.

The hydraulic model data file and simulation output reports are presented in Appendix D.

3.5 Discussion of Results

The unsteady flow analysis performed in this study required a number of generalizations to produce a workable model, particularly with regards to the number of cross sections. Nevertheless, the results are deemed reasonable to the extent that they are comparatively consistent. The scenarios themselves, such as those with the PMF flood occurring only within the Valenciano basin, and the sunny day breach are, in effect, abstractions appropriate to the planning framework within which dam break studies are usually conducted. As such, the goal of achieving precise simulation results under such scenarios, given the concomitant need for extensive field data collection surveys, will probably only show marginally better results at a much greater effort.

IV. CONCLUSIONS AND RECOMMENDATIONS

1. The hydrologic analysis of the Valenciano river basin yielded a PMP depth of 52 inches(1,321 mm), with an estimated return period exceeding 1,200 years.
2. The resulting runoff hydrograph from the Valenciano Probable Maximum Precipitation (PMP) yielded a Probable Maximum Flood (PMF) estimate of 2,757 cubic meters per second at the proposed dam site.
3. Tailwater elevations of 90.9 and 85.3 meters were obtained at the Valenciano dam for the PMF breach and PMF no-breach scenarios, respectively. Near Juncos, the corresponding flood elevations are 68.8 and 66.6 meters, while near Gurabo elevations of approximately 51.62 and 51.35 meters are obtained for the same scenarios. A nearly 2.0 meter difference in expected water surface elevation would exist at Juncos, while near Gurabo it would taper to nearly 0.3 meters.
4. The peak flood stage from the PMF breach would reach Juncos within a period of 10 minutes after the failure of the dam. For Gurabo, the peak stage should be arriving within a period not exceeding 120 minutes from the onset of the break. However, for Gurabo a smaller arrival time could be envisaged since a flood stage within 2% of the peak stage is attained 60

minutes after the Valenciano dam break, largely due to the flow attenuation effect occurring along the milder segment of the Gurabo river.

5. The impact of the PMF dam breach will have largely petered out at a location about 600 meters upstream of the confluence between the Gurabo and Loíza rivers. The computed difference in water surface elevations between the PMF breach and PMF no-breach scenarios is less than 0.3 meters.

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VI. CERTIFICATION

I hereby certify that the study described in this document was performed by following the best applicable engineering practice pertaining to this type of project, and that the data used herein is faithful to that provided by the contracting party.

To this effect I provide this signed certification, today, Tuesday the fourteenth of March, 2007.

Rafael Segarra-García, Ph.D., P.E.

VII. FIGURES

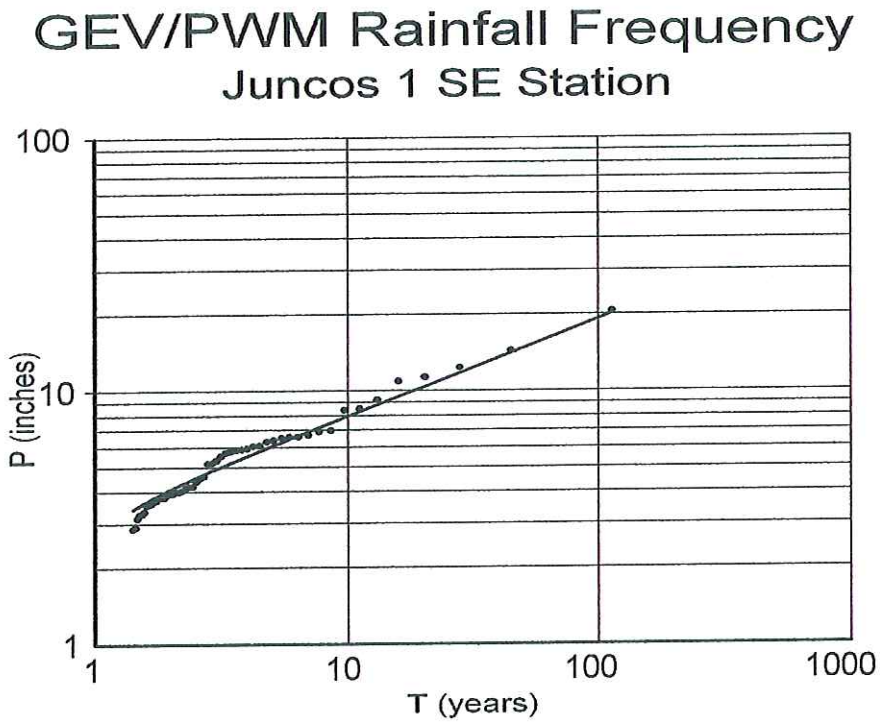


Figure 1. GEV/PWM Rainfall Frequency: Juncos 1 SE Station

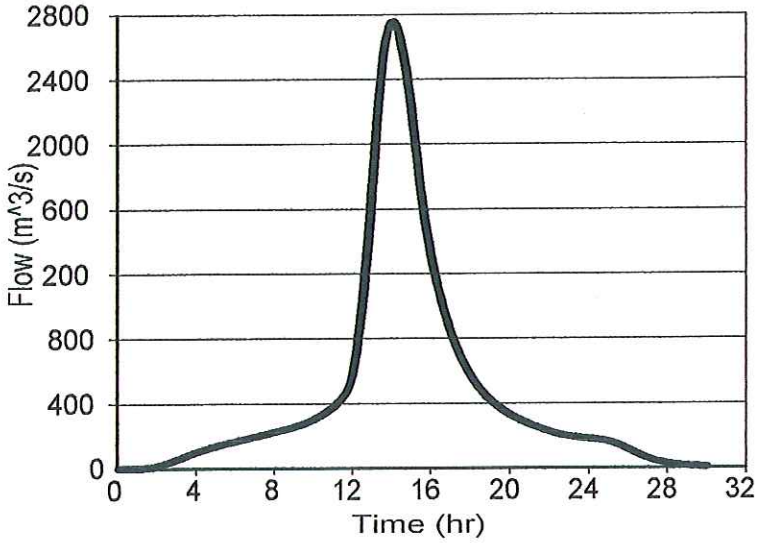
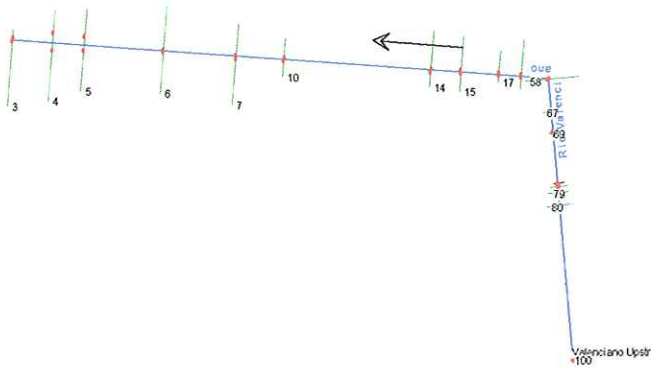


Figure 2. PMP Runoff Hydrograph at Valenciano Dam



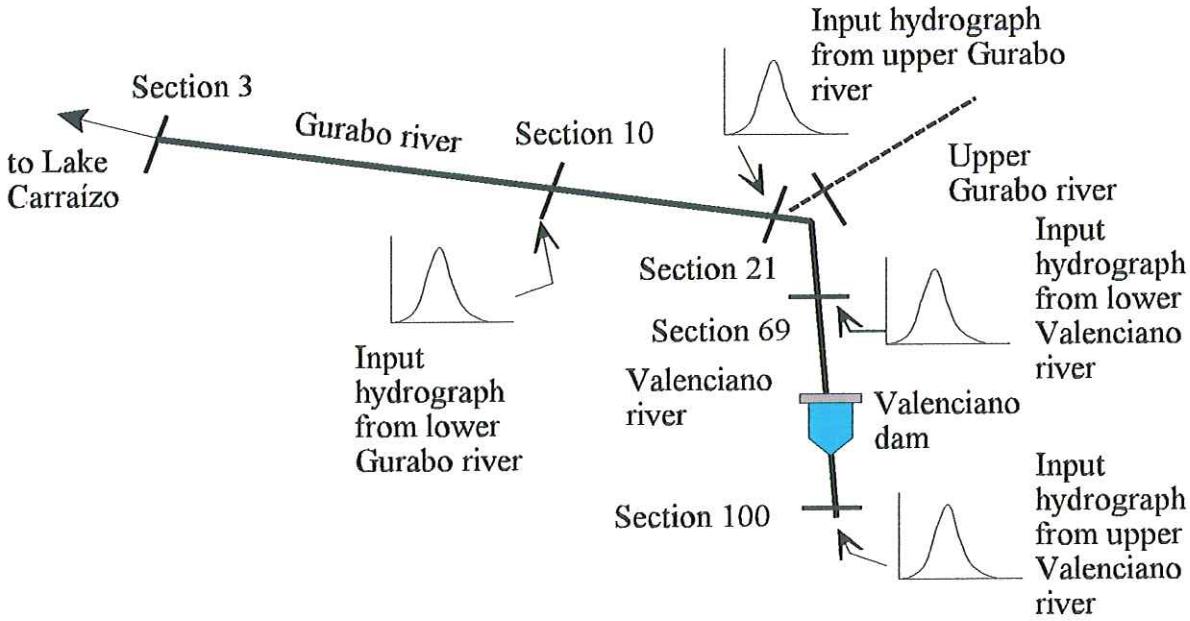


Figure 3. Channel Network in Hydraulic Model and Boundary Condition Schematic

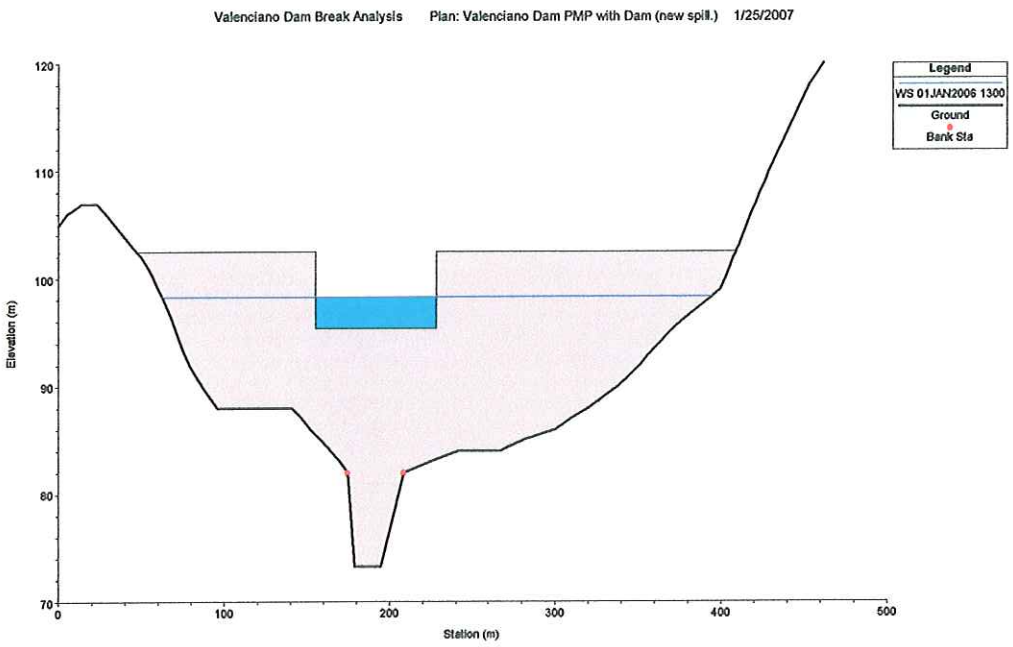


Figure 4. Representation of the Valenciano Dam in Hydraulic Model

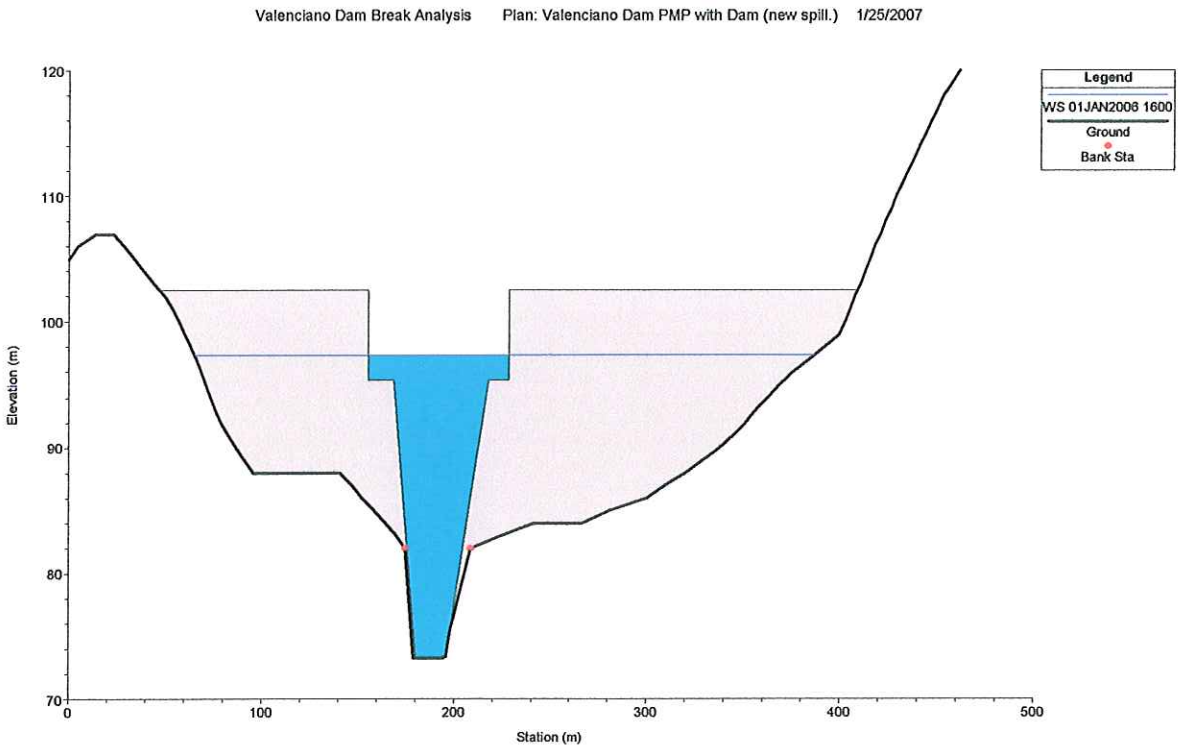
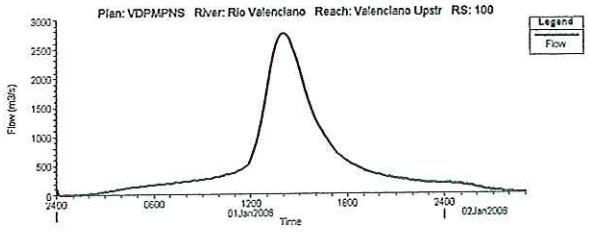
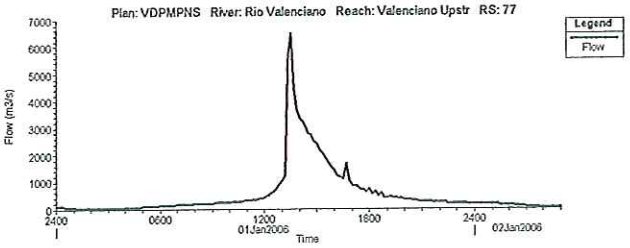


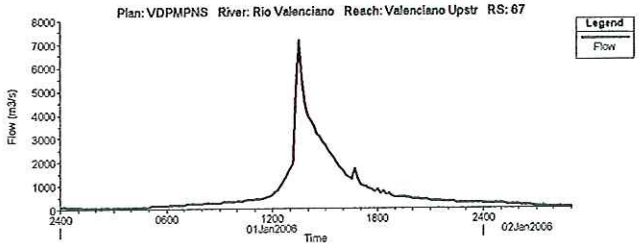
Figure 5. Breach Geometry at Dam Break



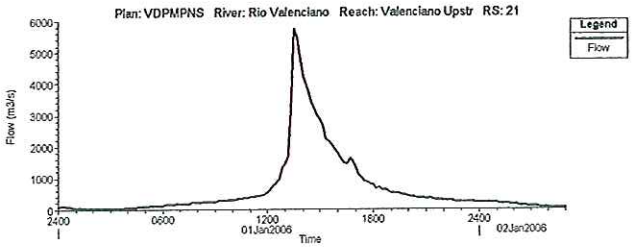
(a) At Valenciano dam



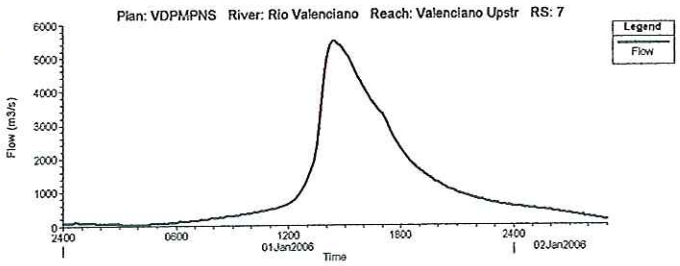
(b) Downstream of Valenciano dam



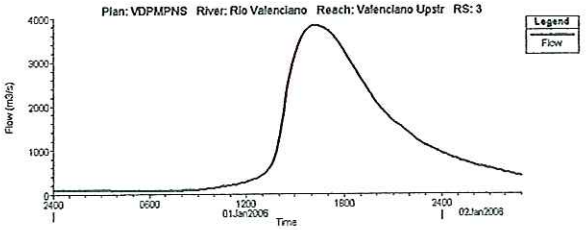
(c) Near Juncos



(d) At junction with Gurabo river



(e) Near Gurabo



(f) Upstream of Loíza river

Figure 6. Runoff Hydrographs for PMF Valenciano Dam Breach

VIII. EXHIBITS

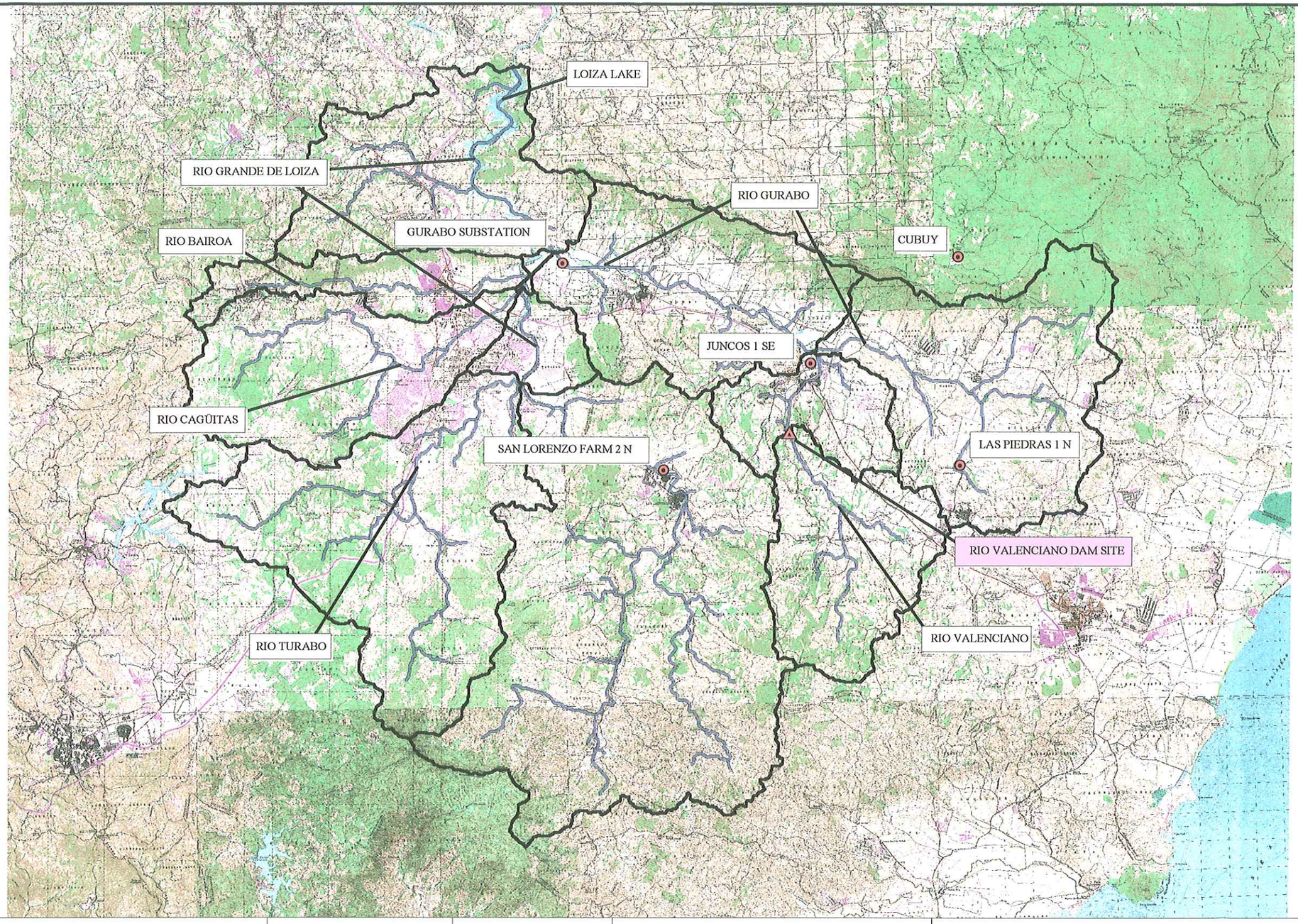


EXHIBIT 1.

RIO VALENCIANO DAM WATERSHED
PRECIPITATION STATIONS

N

LEGEND

- VALENCIANO DAM SITE
- PRECIPITATION STATIONS
- WATERSHED BOUNDARIES
- RIVER NETWORK

SCALE 1:150,000

4 0 4 Kilometers

5 0 5 Miles

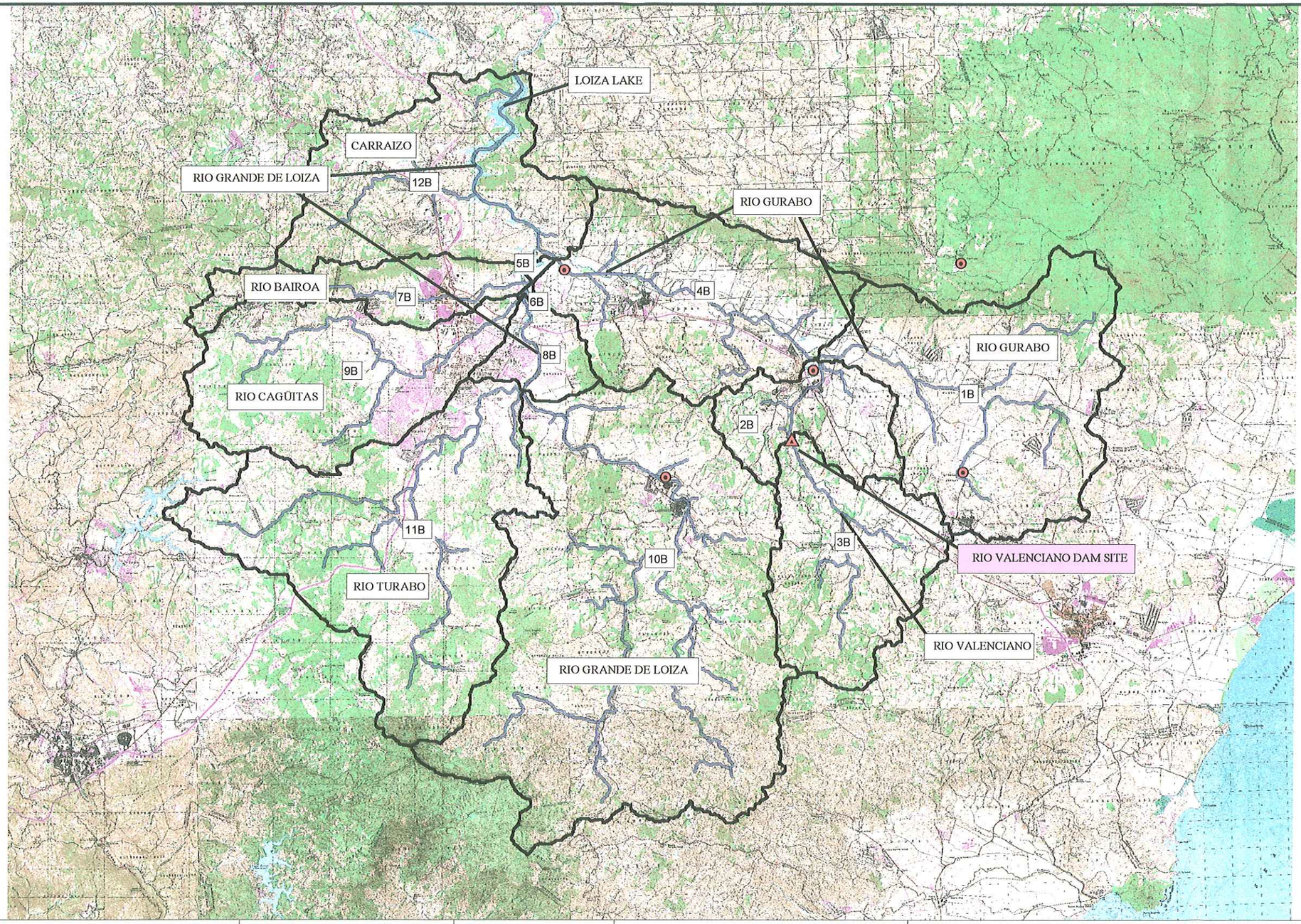


EXHIBIT 2.

RIO VALENCIANO DAM WATERSHED AND SUB-BASINS

N

LEGEND

- VALENCIANO DAM SITE
- PRECIPITATION STATIONS
- WATERSHED BOUNDARIES
- RIVER NETWORK

SCALE 1:150,000

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5 0 5 Miles

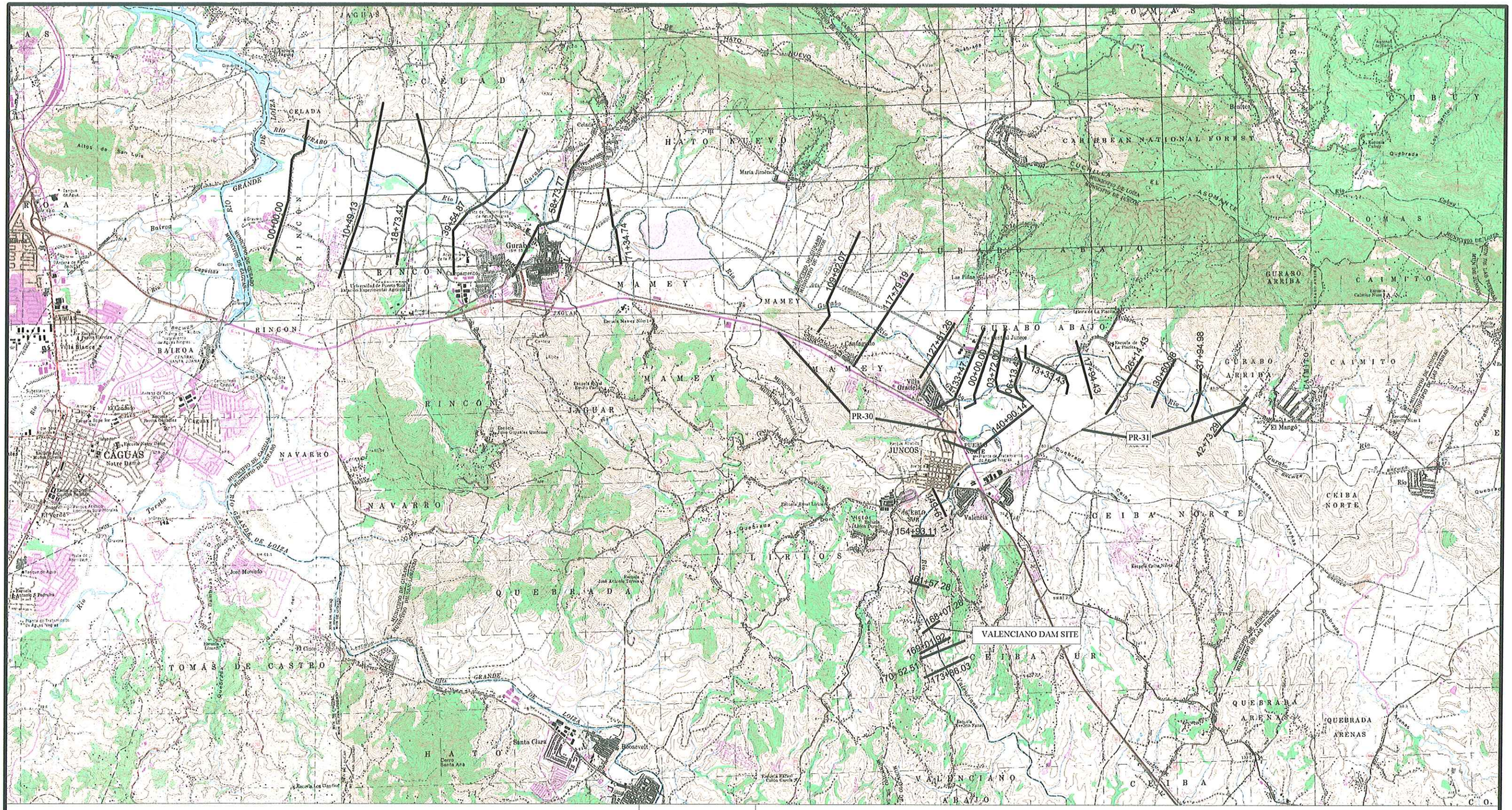

EXHIBIT 3.

RIO VALENCIANO DAM BREACH ANALYSIS
CROSS SECTIONS

N

SCALE 1:50,000

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1 0 1 2 Miles

EXHIBIT 4.
RIO GURABO UPSTREAM OF CONFLUENCE WITH RIO VALENCIANO
WATER SURFACE PROFILES

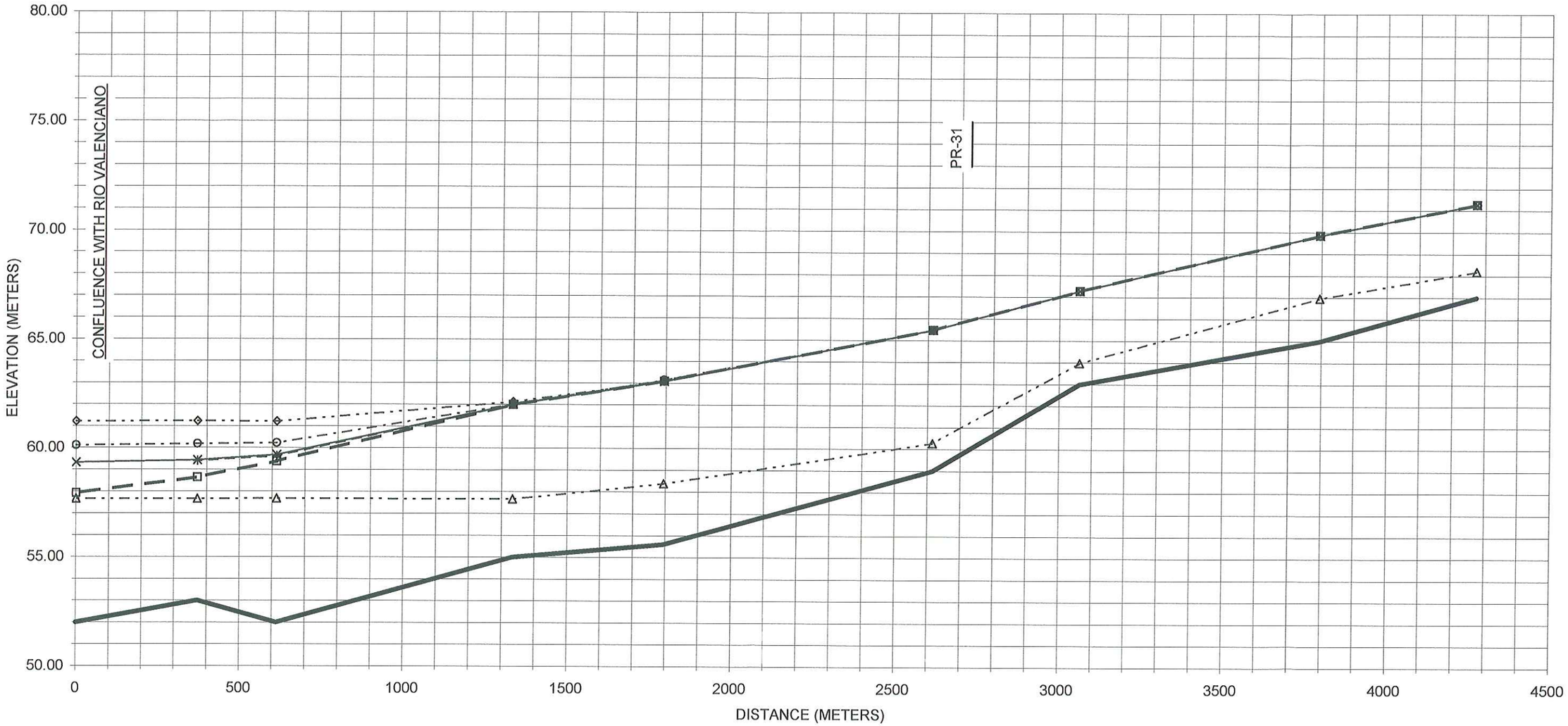

EXHIBIT 5.
RIO VALENCIANO DAM
WATER SURFACE PROFILES