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BAQUIRIVÚ RIVER FLOODPLAIN PARK, BRAZIL

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ABSTRACT: Metropolitan Region of São Paulo (MRSP) is a dense urbanized area with recurrent flooding problems on this main watershed because its drainage system complexity. In Baquirivú Guaçú River Basin, one of priorities and most vulnerable watershed, an important flood control system based on SUDS principles was designed. This system is composed by a 20 km channel, five detention basins, a floodplain park along all main stream and reservoirs and a new 10 km road. After this intervention, it's expected to reduce flood risk significantly, to preserve and protect floodplain areas and create new spaces for population leisure. In a second stage, it is expected that authorities work on water quality improvement to complete the implementation of an integral solution for regional urban drainage.

Key Words: Detention basin, floodplain park, sustainable urban drainage system.

1. INTRODUCTION

Metropolitan Region of São Paulo (MRSP) comprises 19 million inhabitants spread over an area of 8.000 km², which is completely within the Upper Tietê River Basin. Recurrent flooding problems on this watershed occur mainly because of drainage system complexity, which conducts the entire runoff of this urban area to the same watercourse, Tietê River.

In this context, this paper presents a study of Baquirivú Guaçú River Basin, set as a priority watershed by Upper Tietê Urban Drainage Master Plan (PDMAT) studies, as one of the most vulnerable areas of MRSP. This project assumes aggregated interventions for flooding control according PDMAT and following sustainable urban drainage systems principles.

The Baquirivú Guacu River is one of the most important tributaries of the Tietê River in the São Paulo Metropolitan Region with a watershed area of 163 km^2. Nowadays it receives investment for the implementation of the Baquirivú Guacu Floodplain Park. The project has the following scope:

1. **Baquirivú-Guaçú river canalization:** open channel with more than 20 km, with larger sections from Arujá city to its mouth in Tietê river (Guarulhos City).
2. **Floodplain park:** restoration of affected vegetation and afforestation, construction of walking and bike path, leisure furniture such as benches, tables, drinking fountains, bike racks, toilets, changing rooms, cafeteria, parking, playground, skating rinks, soccer fields and courts, lake with wooden decks.
3. **Construction of 5 flood control reservoirs:** expansion of retention capacity of flood control system at critical points, as defined in Upstream Tietê Drainage Master Plan.
4. **Implementation of a new road system:** construction of a 10 km road along Baquirivú-Guaçú River, creating the possibility of new links between Arujá, Guarulhos, São Paulo International Airport and São Paulo Metropolitan Ring.

The objectives of this program are:

a) Flood control with storage capacity increase of 2,540 million m^3 and a new channel;
b) Low income families resettlement;
c) Reduction of waterborne diseases;
d) Floodplain restoration and protection;
e) Greater offer of leisure and green areas in Guarulhos;
f) Decrease traffic jams and travel time;
g) Economic and social development.

This paper aims to present a sustainable alternative for major drainage system for a large urban watershed that received necessary investments and will be implemented.

2. THE FLOODPLAIN DIAGNOSIS

During preliminary studies, an extensive field survey was realized to map flooding areas along Baquirivú-Guaçú River and its main tributaries streams as showed in Figure 1.

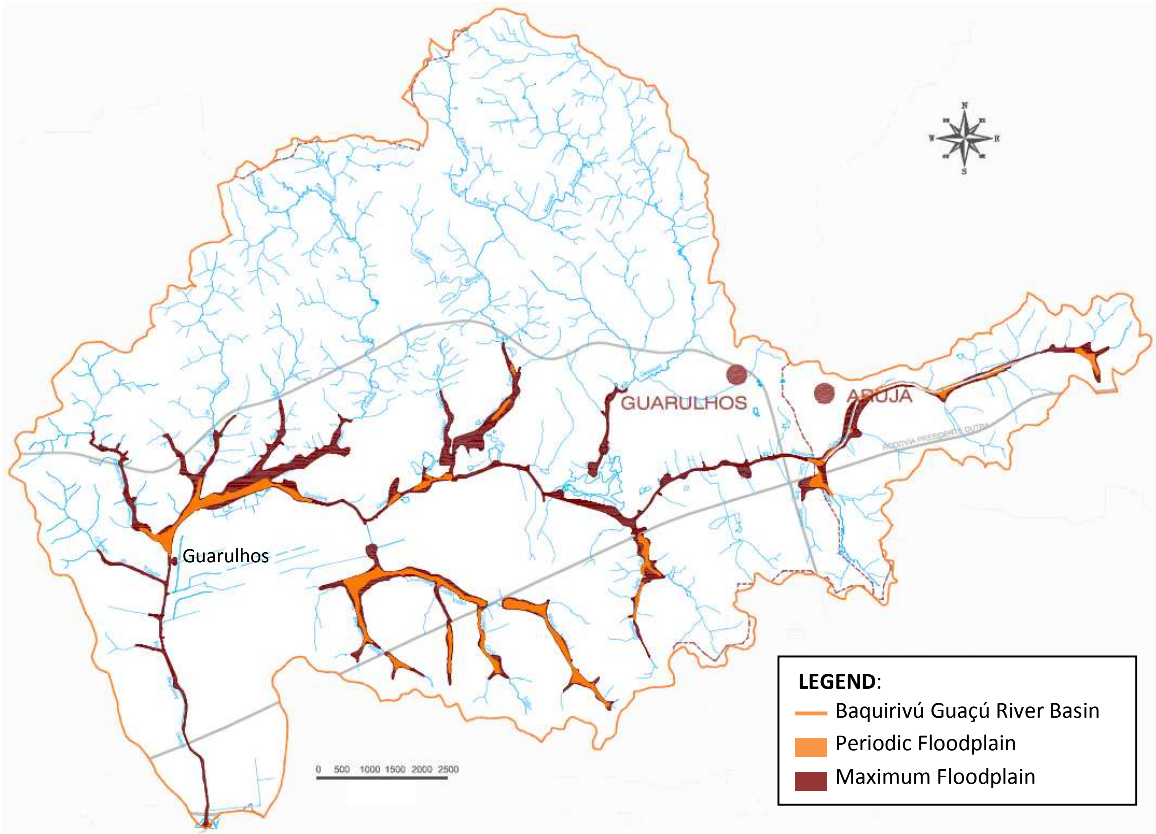

Figure 1. Maximum floodplain area obtained from field survey.

2.1 Hydrologic and Hydraulic Modeling

Rainfall design was obtained from intensity-duration-frequency curve (equation below) for São Paulo city from Martinez and Magni (1999) for a 2 hours duration and 10, 25, 50 and 100 years return levels. Huff distribution (1967) of 1st quartile was applied.

$$i_{t,T} = 39{,}3015(t+20)^{-0{,}9228} + 10{,}1767(t+20)^{-0{,}8764}\left[-0{,}4653 - \ln\left(\ln\left(\frac{TR}{TR-1}\right)\right)\right]$$

For 10 ≤ t ≤ 1.440 min

Where: ***i*** *= rainfall intensity (mm/min);* ***t*** *= rainfall duration (min) and* ***TR*** *= return level (years).*

Table 1**.** Total design rainfall for 2 hours duration in São Paulo city.

	Return level			
	10 years	25 years	50 years	100 years
Rainfall (mm) =	72.3	85.1	94.6	104.0

Rainfall-runoff transformation was performed using Soil Conservation Service (SCS) Model (Natural Resources Conservation Service, 1986). SCS Curve Number (CN) Loss Model was estimated for each sub basin and in completely urbanized sub basins a CN of 86 was used. Time of concentration was calculated using cinematic method and hydrologic modelling was performed using HEC-HMS® software.

Hydraulic modelling to verify actual channel flow capacity and to design projected channel was performed using HEC-RAS® software.

3. RESULTS AND DISCUSSION

3.1 Hydraulic and sustainable solutions

Actually, Baquirivú Guaçú River flows alternately trough natural and artificial channels that don’t have enough capacity for actual 10 years return period flow. In this project, the main objective was to present an integral solution considering SUDS’s principles of quantity control and amenity and biodiversity. So, the readjustment of Baquirivú Guaçú major drainage system was design for:

1. Reduce peak flow using detention basins along the main stream and confluences with significant tributaries;
2. Readjust main channel flow capacity for new 100 years return level flow (after detention basins construction);
3. Protect floodplain areas with a linear park along the main stream, promoting landscaping, creating leisure areas and avoiding irregular occupation.

Table 2. Detention basins volume, type and peak flow attenuation for 100 years return level flow.

Detention basin	Volume (m^3)	Main stream	Tributary streams	Inflow (m^3/s)	Outflow (m^3/s)
RBA-3	260.000	inline	inline	86.1	57.0
RGA-2	1.120.000	offline	inline	85.1	22.2
RBA-5	600.000	inline	inline	144.8	111.4
RAS-2A	410.000	offline	inline	55.5	32.1
RAS-2B	150.000	offline	inline	37.1	23.3

Figure shows peak flow attenuation at Baquirivú Guaçú River mouth for 10, 25, 50 and 100 years return period flow for the designed drainage system.

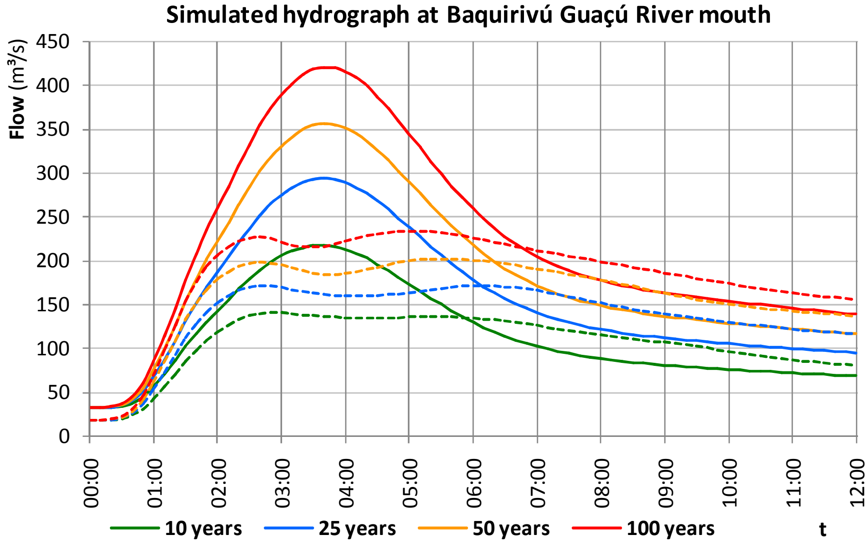

Figure 2. Simulated hydrograph at Baquirivú Guaçú River mouth. Solid lines represent simulated flow for scenario 1 (present) and dashed lines represent simulated flow for scenario 2 (project) considering all detention basins designed.

Due to actual low capacity flow of Baqirivú Guaçú River, it was necessary to design a new channel to improve hydraulic conditions at the same time as linear park to consolidate and preserve floodplain areas. This park will be an important improvement once this region has suffered during a long time with the shortage of public leisure facilities. It's also expected that with this project, authorities will have more control of irregular occupations along Baquirivú Guaçú River.

A hydraulic comparison between scenario 1 and 2, which represents actual and designed systems respectively, is showed in

Table **3**. For each analyzed reach, are presented flow capacity and 100 years return level flow for both scenarios.

Table 3. Channel hydraulic characteristics for scenarios 1 (present) and 2 (project). For each reach, its flow capacity and 100-years return level flow are showed.

		Scenario 1 (present)		Scenario 2 (project)	
Reach	Reach length (m)	Flow capacity (m^3/s)	100-years flow (m^3/s)	Flow capacity (m^3/s)	100-years flow (m^3/s)
A	3,980	36.0	99.2	110	68.6
B	5,840	55.8	264.5	142	116.5
C	2,400	76.8	340.7	186	152.9
D	1,360	123.0	398.0	234	185.9
E	2,000	93.0	421.8	266	213.0
F	2,000	81.3	417.6	300	234.6
G	786.1	360.4	417.6	300	234.6
H	1,714	204.7	419.6	300	254.5

3.2 Landscape solution

Along all main stream of 20 kilometers length, a linear park was designed over both side banks to preserve floodplain areas and promote population interaction with water. In Figure 3, it's showed a typical cross section designed for Baquirivú Guaçú River. Bellow 1 meter of height and on deep, a concrete covering was provided to ensure minimal hydraulic conditions for flowing as velocity and low roughness avoid sediment deposit. Above 1 meter height, when water level must exceed during more extreme events, river banks were covered with grass to reduce flow velocity and promote vegetation growing along stream and it's connection with the park.

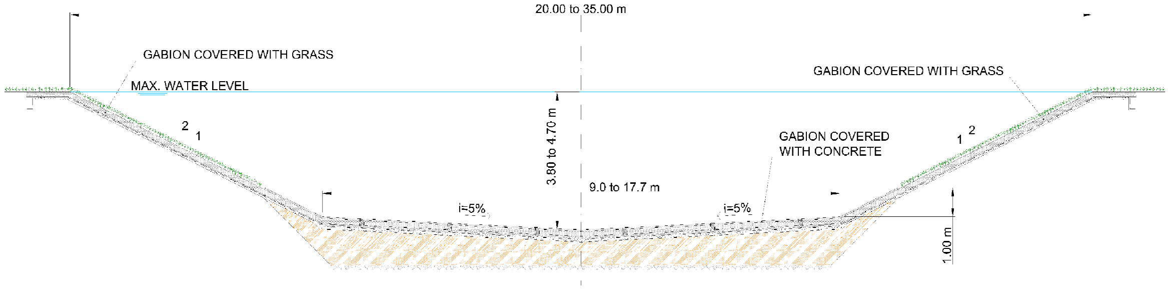

Figure 2. Main typical project cross section for Baquirivú River. Mixed covering, concrete in deep and grass in banks above 1 meter height. Width varies from 20 to 35 meters and height from 3.80 to 4.70 meters.

In Figure 3 it's showed a project general schema with detention basins locations and a detail of RBA-3.

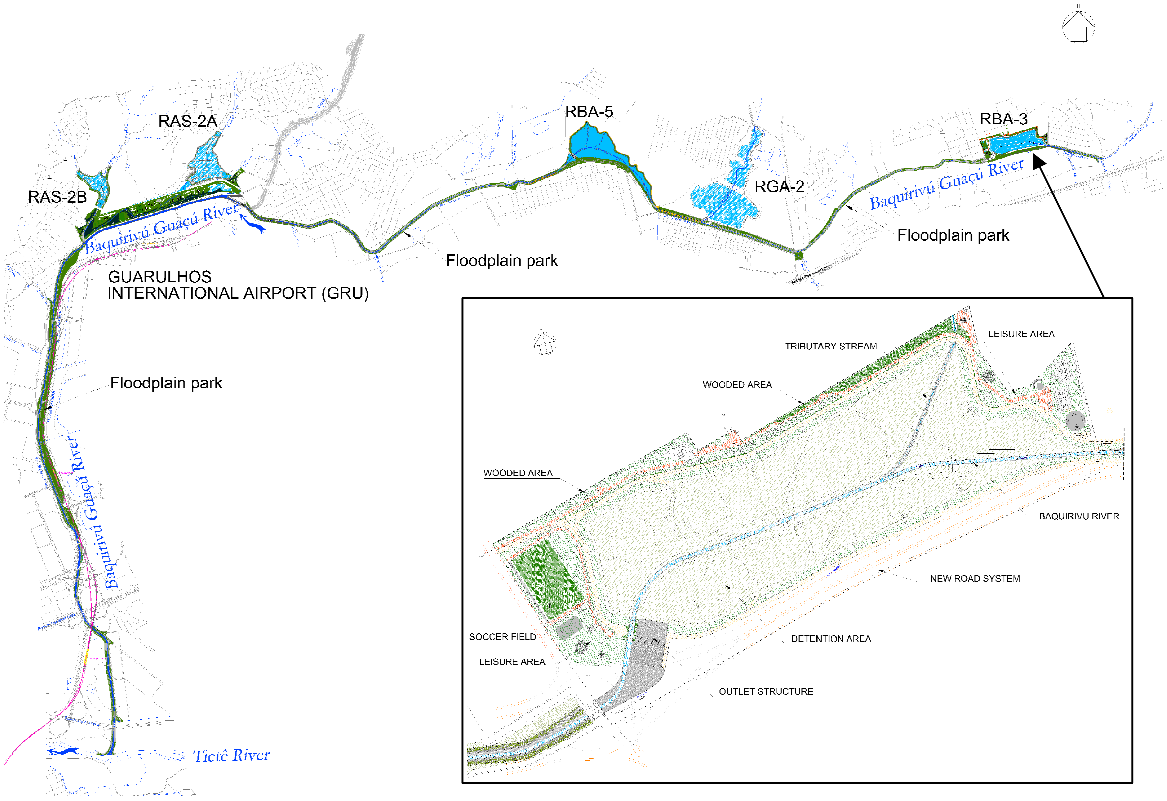

Figure 3. Baquirivú Drainage System, general schema with detention basins localization and linear park extension (green area along Baquirivú River). In detail, RBA-3 design is showed including detention area, leisure areas, soccer field, wooded area, outlet structure and new road system.

4. CONCLUSIONS

After this intervention, it's expected a significant reduction of flood risk on basin urbanized areas and a significant improvement of regional urban infrastructure and green and leisure areas. However, it's highly recommended a second planning stage aiming water quality improvement considering wastewater collection and treatment and source and non-point pollution control. Only after this important step will be possible to have an integral and sustainable solution for this drainage system.

5. REFERENCES

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