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► **To cite this version:**

Flavio Conde, Andre Sosnoski. Low impact integration of drainage infrastructure on a highly urbanized area - A case study on Tiquatira basin Sao Paulo Brazil. Novatech 2023, Jul 2023, Lyon, France. hal-04184752

HAL Id: hal-04184752

<https://hal.science/hal-04184752>

Submitted on 22 Aug 2023

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Low impact integration of drainage infrastructure on a highly urbanized area - A case study on Tiquatira catchment Sao Paulo, Brazil

Intégration à faible impact des infrastructures de drainage dans une zone fortement urbanisée - Une étude de cas sur le bassin Tiquatira, Sao Paulo, Brésil

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RÉSUMÉ

Cet article présente la conception et la proposition de plusieurs dispositifs de drainage vers un bassin urbanisé consolidé dans l'un des plus grands espaces verts de la ville de São Paulo, au Brésil, une mégapole de plus de 12 millions d'habitants, avec d'énormes capacités sociales, techniques, économiques et problèmes environnementaux. Dans le but de réduire l'impact des inondations, l'intégration transparente de la proposition à l'infrastructure existante est essentielle pour réduire les conflits lors de la planification des futures interventions de drainage. L'étude est placée sur le bassin de Tiquatira, un bassin versant urbain de 17 km², qui abrite d'importantes infrastructures de loisirs, de logement et de mobilité et sujet à de fréquentes inondations pendant la saison des pluies. Dans le cadre d'un plan directeur plus large, l'étude envisage de réduire les impacts des inondations tout en ne causant pas de conflit majeur avec la zone urbaine déjà verte et manquante en installant deux réservoirs d'inondation à faible impact et en rénovant une zone de loisirs existante avec des structures à l'épreuve des inondations pour agir un réservoir en ligne.

ABSTRACT

This paper presents the design and proposition of multiple drainage devices to a consolidated urbanized basin in one of the largest green areas in the city of São Paulo, Brazil, a megacity with more than 12 million inhabitants, with enormous social, technical, economic, and environmental problems. With the aim to reduce the impact of flooding the seamless integration of the proposition with existing infrastructure is key to reduce conflict when planning future drainage interventions. The study is placed on Tiquatira basin, a 17 km² urban catchment, home to important recreation, housing and mobility infrastructure and prone to frequent flooding during the rainy seasons. As part of a larger masterplan, the study envision to reduce flood impacts while not causing major conflict with the already green lacking urban area by installing two low impact flood reservoirs and retrofitting an existing sport center with flood proof structures to act as an in-line reservoir.

KEYWORDS

(Development concept, Flood proofing, Flood resilience, Landscape, Urban drainage)

1 INTRODUCTION

Integrating drainage structures to the city environment with little to no impact is one of the multiple challenges faced when structuring modern urban drainage infrastructure, especially in megacities like Sao Paulo.

Sao Paulo is a megacity with 12 million of inhabitants and a total area of 1,521km² (IBGE, 2010). During the rainy season, from October to March, the city suffers with floods. This problem has been studied repeatedly considering structural and non-structural measures (Alves Filho & Ribeiro, 2006; Jorge, 2011; Oliveira & Figueiroa, 1984). The recurring floods in the city can vary from local to generalized, having an impact on citywide traffic, buildings and personal assets.

When approaching flood control strategies, recommendations rely on avoiding structural measures that could increase downstream flows and velocities, therefore, storage measures, e.g., in-line/off-line reservoirs are frequently applied to mitigate the impact downstream.

Nevertheless, there is a usual prejudgment that associates flood control reservoirs with negative aspects in the urban environment, such as total reservoir site impermeabilization, degradation and disuse of public space, accumulation of solid waste from diffuse pollution and bad smell. Therefore, new proposals should revolve around changing and adapting new structures to avoid these problems.

More recently, cities are implementing complementary measures for flood management integrating design, architecture and water management (Novotny and Brown, 2007; Bertrand-Krajewski, 2009). These measures aim to reduce the impacts of pluvial events in urban areas and help create areas that mimic “pre-development” dynamics and encourage ecosystem development, whilst providing an amenity to urban residents (MCGRANE, 2016).

In the case study described in this article, Tiquatira catchment needed a drainage system reformulation due to the main channel dimensions being insufficient for 100-year return period events and reduced area to apply further interventions. Therefore, in 2007 an in-line reservoir (217.000 m³) was design and initially proposed the removal of a large part of the existing linear park (54.000 m²), and the removal of a sport center located inside the park area to mitigate the insufficient drainage.

This proposal was criticized by local leaders and general population that lives and uses the aforementioned areas to be replaced by the drainage structure. In the search for a better integration with the environment and community needs, the flow deficit in the system could be extinct with the proposition of two underground off-line reservoirs (90.000 and 122.000 m³).

While testing this alternative the research team noticed that by leaving some areas flooded in 100-year return period events, the size and costs of the reservoirs could be reduced. In addition, the cost reduction could be used to retrofit the existing sport center and adapt it with flood resilient structures.

This paper presents the case study of these two reservoirs and the flood resilient park in the Tiquatira Catchment, located in the urban area of São Paulo, considering its interference with the urban landscape. Aside from the conventional concrete reservoir, it aims to present and analyze a more sustainable approach with their implementation.



Figure 1 - Localization of Tiquatira catchment and current view of the study site

2 METHODOLOGY

In order to simulate the catchment’s conditions, an extensive research was necessary, including information from

city plans, GIS, field research, among others. This data consists, primarily, in geometrical and physical characteristics, such as surface slope, conduit's length, slope, transversal sections and depth, among others.

The information gathered was then utilized in the hydraulic and hydrologic modeling (SWMM) as parameters to estimate actual and future flow hydrographs, flood volume and extension. Rainfall data for each storm event was estimated through the Intensity-Duration-Frequency Curve adjusted for the city of São Paulo, with temporal distribution according to the studies of Rocha Filho et al. (2021), considering several rain gauges time series. For the Tiquatira basin, a three-hour duration event was chosen due to the basin's concentration time and area (17km²).

Utilizing the 2D simulation from the software PCSWMM, it was possible to estimate the floods in this basin for extreme events and test multiple solutions that could be implemented. By using an array of possible interventions linked with their cost, benefit, impact and integration to urban and social needs, it was chosen a group of interventions which provide simultaneously economic, social and environmental benefits.

3 RESULTS

The “Tiquatira drainage handbook”, a planning tool developed by Fundacao Centro Tecnologico de Hidraulica (FCTH) to the Sao Paulo Municipality (PMSP, SIURB), studied the catchment and proposed 12 drainage interventions needed to solve flooding for a 100 year return period events which include the 3 interventions that are the main focus of this article. Some modifications in the urban drainage system were necessary, such as adding new drainage conduits, implementing storage units and cross-section expansions as part of a major drainage masterplan. This article focuses on the catchment's lower region that contains the three proposed structures to mitigate flood impacts in this area.

The major drainage proposition is presented in Figure 2 (a) and show the main interventions proposed. Also, Figure 2 (b and c), shows a representation of an estimated flooded area from the diagnosis and a projected flooded area restricted to the park area after installing the proposed interventions.

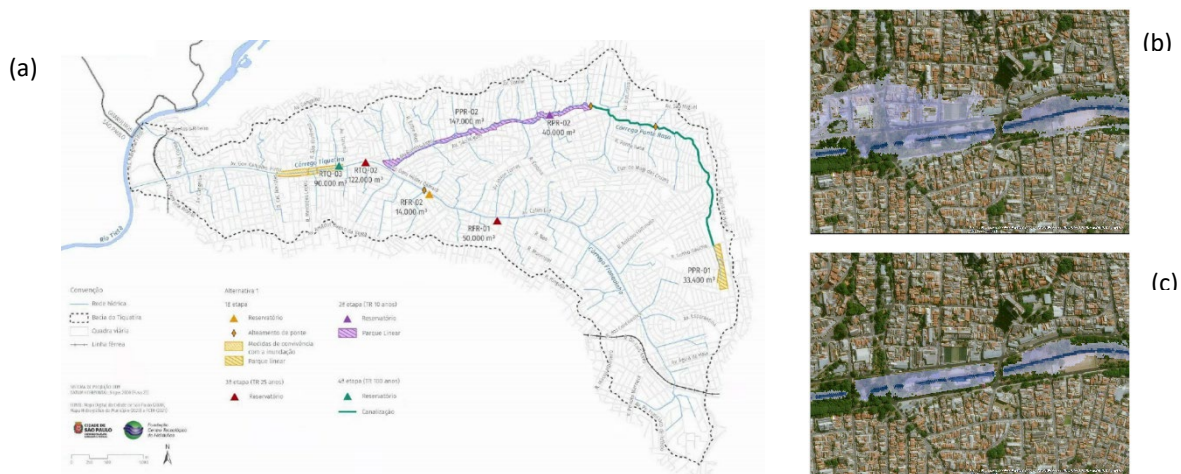


Figure 2 - (a) Tiquatira’s drainage handbook; (b) diagnosis of the projected flooded area; (c) estimated flooded area after proposed interventions

As Figure 1 (a) shows, there are 12 interventions required to provide security for 100 year return period events, some of those are designed to mitigate less critic events such as 5, 10 and 25 year return periods events, therefore they were imagined to be integrated in 4 implantation steps. The implantation steps were imagined to gradually improve the catchment safety. The first step focuses on mitigating 5 year return period events, the second 10 year return period events, the third 25 year return period events and the fourth and last one to mitigate 100 year return period events. For the 3 interventions studied in this article, located in the park area, the two underground off-line reservoirs were divided to be implemented in the second and fourth steps as the flood resilient infrastructure was proposed for the first step.

With the flood resilient infrastructure, dedicated to adapting the structure of the sport center inside the park

with flood proof measures, the interventions costs are reduced as well as the flood impact on the sport center. It aims on reducing the impact of recurrent flooding (5-year return period) but not eliminating the flooded areas. The second of the studied interventions, a 90.000 m³ off-line underground reservoir is constructed to provide security for a 10 year return period event, that after installed will reestablish its current occupation with landscaping and integrating a soccer field in its premises. When subjected to 100-year return period events, at this stage the flood levels would still impact the park area, but with facilitated and rapid recovery. The same design method was used for the third studied intervention, the 122.000 m³ off-line underground reservoir, protecting downstream for a 100-year return period event and leaving the park area still susceptible to flooding.

The next images presented in Figure 2 present the before and after of the interventions and also a dry and wet expected result.



Figure 3 - Perspective illustrations on (a) current site configuration; (b) future site configuration; (c) Current site overview; (d) future site overview; (e) dry view of the proposition; (f) flood view of the proposition

4 CONCLUSION

In recent years, the trend in stormwater management is to approach the traditional engineering methodology, that focus on the hydrological and hydraulic quantitative criteria, to an integrated and holistic view that links stormwater design with other city stakeholders. On the presented case study, the change in the approach has been a result to multiple initiatives from the city's secretariat, academic research teams and popular demand. It shows that the participation of the city stakeholders on the design process is key to provide more sustainable and livable cities. Tiquatira's proposition combine two traditional off-line reservoirs applied in a multi-step order to protect lives, traffic, buildings and personal assets as well as maintaining other area use restrictions.

As part of a major project that plans Sao Paulo's urban drainage infrastructure, this example is one of various initiatives that are changing the way city planners, engineers and decision makers view the flood issues, moving towards an integration between environmental, ecological, social and governance issues.

5 ACKNOWLEDGEMENT

The authors of this article would like to acknowledge the help of the research team of FCTH and Sao Paulo Municipality for providing all relevant data and informations. Also Guajava architecture team for designing the images and project presented.

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