Climate Change Impact on Flood Control Measures for Highly Populated Urban Watershed

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Abstract: Flooding and overflows are recurring problems in several Brazilian cities, which usually undergo disorderly development. Their causes vary from increased impervious surface areas, deficiency/inefficiency of drainage structures and their maintenance, siltation of rivers, channel obstructions, and climatic factors. This situation is aggravated in the major cities. The *Anhangabau* watershed lies in the central portion of the city of Sao Paulo – Brazil and covers a drainage area of 5.4 km². The region is highly urbanized and crossed by a major north-south road connection. During heavy rain events, portions of this interconnection passage become compromised, disrupting the flow of vehicles, creating a chaotic situation for the population, as well as losses to the national economy. Observed rainfall records and an existing IDF (intensity duration frequency) curve for the region are used to obtain design storms. To account for climate change, a well know procedure, the equidistance quantile matching method for updating IDF curves under climate change, was applied to the existing historical data. Several different global climate models (GCM) and one regional model were applied to obtain and update rainfall design storm. The GCMs and future scenarios used were from the IPCC Assessment Report 5 (AR5) and two future projections: RCP (representative concentration pathway) 4.5 and 8.5. Alternatives previously proposed to solve to flooding issue are briefly reviewed. On one of the latest studies [1], a few modern concepts of water resources management are presented, and the linear retention measure was found to offer higher potential to mitigate the flooding problem in the lower valley of the watershed. Therefore, this alternative was used to evaluate different design storms scenarios combined with return periods of 25 and 100-years as well as the updated IDF under climate change for RCP 4.5 and RCP 8.5. To model the complex network, representing both road and drainage systems and their interconnections, PCSWMM/SWMM software was applied. Results are presented as flooding maps and show the impacts of the proposed linear retention measure based on the existing IDF curves and the updated IDF curves under climate change for two different drainage system conditions, current and improved with the use of linear retention reservoirs. Results show that the prosed changes on the drainage system help reduce the risk and damage to flooding. The climate change scenarios, however, impose a significant threat and need immediate attention from city planners and stakeholders.

Keywords: Urban flood, Hydrologic and hydraulic modeling, Retention structures

1 Introduction

The *Anhangabau* watershed lies in the central portion of city of Sao Paulo, Brazil, emptying into the *Tamanduatei* river, which arises from other municipalities in the metropolitan region. The city of

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Sao Paulo was established in a flat area between the *Tamanduatei* and *Anhangabau* rivers. For over 300 years, life in SP existed only because of these two rivers: the *Anhangabau* was a smaller one with clean drinking water, while the larger *Tamanduatei* was served to navigation. With consequent urban development, the rivers, which were the reason for the city existence, have become obstacles to its growth. The construction of the *Chat Viaduct* in 1892, upon the valley of *Anhangabau* river was the first achievement in overcoming the barriers that rivers imposed on the city expansion. In the 1920s, the *Anhangabau* park was created, upon its river, which was already rectified and buried. In the late 1930s, a city road plan was proposed aiming the use of valley bottoms for the construction of new avenues. This avenue plan started a practice that has been established as a model in the city structuring, where the path of waters gave way to cars [2]. Floods in the *Anhangabau* Watershed have become a critical and chronic problem for the city, which has been studied for decades. The region is highly urbanized and is crossed by important road connections. During heavy rain period, portions of this road network become compromised, due to floods at the bus terminals, main streets and tunnels, completely disrupting the flow of vehicles, creating a chaotic situation for the population, as well as losses to the national economy.

Climate change has known to affect cities and urban center around the word. It heavily influences flood risk in cities, especially highly urbanized and populated centers. Many authors have been studying and try to understand the phenomena using a variate of techniques and methodologies, such as [3, 4, 5, 6 and 7]. The review presented in [9] emphasize that public spaces are among the areas most vulnerable to climatic hazards and question the specific social potential of the adaptation of the public space in the processes of vulnerability, namely considering the need for alternatives in the current flood management practices.

Two previous studies completed between 2004 and 2006 [1] proposed different alternatives to the problem in the *Anhangabau* watershed. Both alternatives were discarded and not implemented by the city for cost-benefit reasons and technical limitations. The alternatives are briefly described on the methodology section.

This objective of this study is to evaluates a new alternative, based on modern concepts of water resources management such as linear retention reservoir and LID control measures and its performance under climate changing conditions. A complex modeling network employing PCSWMM [10] was elaborated, attempting to represent all road and drainage system and their interconnections. With the assessed model, the alternative that intended to mitigate the flooding problem in the lower valley is evaluated with different designed rainfall storm scenarios.

2 Materials and Methods

The *Anhangabau* watershed is located in the central region of Sao Paulo, covering an area of approximately 5.4 km². The *Anhangabau* river is formed by the confluence of three streams: *Saracura, Itororo* and *Bixiga*. The basin macro-drainage's system consists of a set of buried galleries that drain waters of these tributaries under the main roads that cross the basin, joining other under *Praca da Bandeira*. It is noteworthy mentioning *Moringuinho* river is in fact a tunnel as part of the drainage system, which was built as an initiative to reduce flooding in the *Anhangabau* valley region, diverting part of the *Itororo* river flow directly to the *Tamanduatei* river. Figure 1 illustrates the basin location in the city of Sao Paulo, its main hydrographic and road main points of interest.

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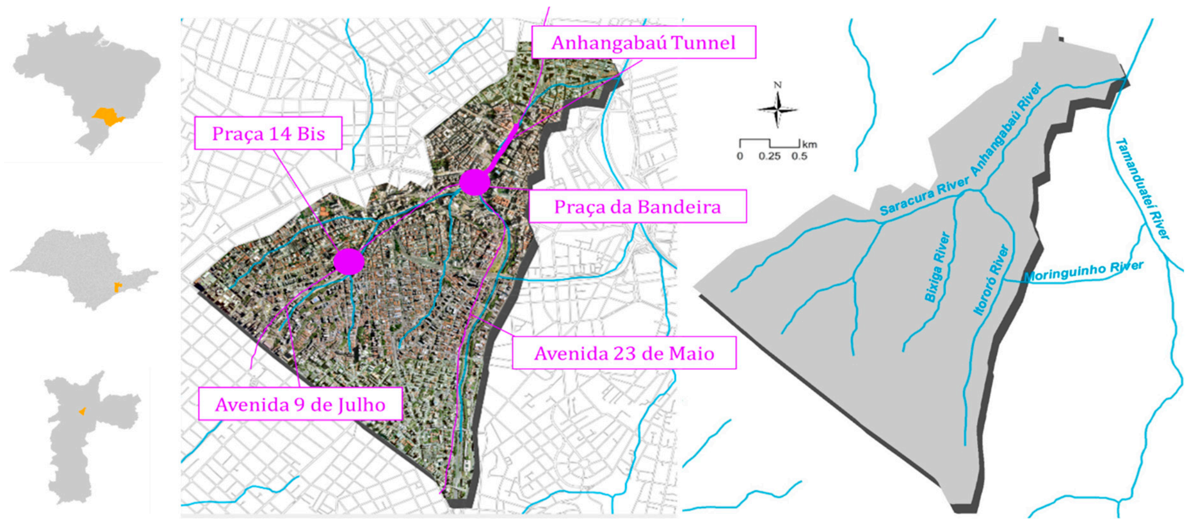

Figure 1: Location, main rivers and points of interest at the *Anhangabau* watershed

The floods that occur on public roads and private areas of the Anhangabau watershed are extremely frequent. Data provided by Center of Emergency Management of Climate of the City of São Paulo / SP [11] showed that the occurrence of floods between January and April 2018 was 1 time in the *Anhangabau* tunnel, 7 times in the *Praca da Bandeira*, 2 times in the *Av 23 de Maio*, 2 times in the *Praca 14 Bis* and 1 time in the *Av 9 de Julho*.

The previous mentioned studies (form 2004 and 2006) proposed for the region are briefly presented as follows:

- **Alternative proposed in 2004:** This alternative was completed in 2004 and consists of a reservoir under *Praca da Bandeira* (46,000 m³), a reservoir under *Praca 14-Bis* (36,000 m³), their interconnection galleries, overland flow catchment and partial reinforcement of existing galleries under *Avenida 9 de Julho*. The reservoir under *Praca da Bandeira* was designed with 2 wells and adjacent circular format. According to the project, only those structures would protect *Anhangabau* tunnels against events of about 5 years of recurrence. In a second phase of constructions, it is proposed a reservoir under *Praca 14-Bis* consisting of two adjacent polygonal wells and the replacement or repair of existing galleries along *Avenida 9 de Julho*, ensuring protection against originally planned 25-year return period events.
- **Alternative proposed in 2006:** The main objective for this alternative was to cause as little interference with the transportation system of the region as possible, being projected for a 100-year recurrence time. The project was proposing derivation of the full flow of the catchment area upstream *Praca da Bandeira* (estimated at 137.6 m³/s) in a tunnel with about 1.6 km long and 6.2 m in diameter, in addition to providing a system of galleries at *Avenida 9 de Julho* by the application of non-destructive methods. Similarly, considering the position of the bypass tunnel upstream *Praca da Bandeira*, it would not be necessary to extend the galleries along *Avenida 9 de Julho* until the existing galleries in *Anhangabau* valley.

For the current study, we modified another alternative proposed in 2011, that uses of tunnels and large transverse dimension galleries to be deployed along the basin valley bottoms, in order to linearly soften discharges generated by heavy rainfalls. In our analysis we introduced the concepts of and retention distributed over the basin, projecting conduits to be spread in small watersheds (less than 50-ha catchment area).

The interventions proposed for the basin consist of the replacement of existing drainage network pipes for conduits with larger section, constituting a network of linear distributed reservoirs. Tunnels and galleries distributed along public roads and watercourses were designed, seeking to follow, wherever possible, existing minor drainage networks. In addition to promoting flood control over wider areas, this proposal allows the reduction of constructive impacts on the most critical regions of

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the basin. Among the planned measures are substitutions and / or reinforcement of existing galleries under *Avenida 9 de Julho* and *Avenida 23 de Maio* and other main streets. Flow control over various segments of linear reservoirs should be possible through discharge control elements. For this purpose, fixed orifices were chosen, complemented by weirs that would drain all the excess volumes after filling the segment.

Logically, the entire network construction method (to implement the proposed interventions) in *Anhangabau* watershed should adopt both construction methods, depending on several local factors. From the hydrological point of view, both systems would present equivalent performance. The implementation of the linear retention system would result in a network extension 19 as presented in Figure 2, that shows the area of the *Anhangabau* watershed with the layout of the proposed linear retention system.

Figure 2: Proposed linear retention reservoirs under city roads.

2.1 Model development

The hydraulic efficiency of the three alternatives was evaluated using a computational model for hydrological and hydraulic simulations with identical criteria for all alternatives. The model used was the Storm Water Management Model (SWMM), available by US Environmental Protection Agency (EPA), with the PCSWMM interface, developed by Computational Hydraulics International.

The study used the Soil Conservation Service (SCS) curve number (CN) method to calculate the infiltration process, and the dynamic wave method to route flows through the drainage system, which is the most complex and accurate model to simulate the occurrence of conduit overflow through manholes. The proposed solutions were evaluated with the application data outputs, provided in the form of hydrographs or velocity and water depth diagrams, corresponding to overland flows. The modeling is related to the physical characteristics of the watershed in order to represent the dynamics of natural phenomena:

- Simulated rainfall represents observed rainfall events or defined design storms and future projected storms modified due to climate change;

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- Subcatchments contain the information necessary to represent the processes of infiltration, interception and surface runoff;
- Buildings act as obstructions to overland flow;
- Pathways temporarily store and drain runoff according to surface information; and
- Drainage grates and curb inlets make the connection between the surface flow and subsurface drainage network, which can also work under pressure.

For the assessment of surface water depths generated above the underground gallery network, a representation was created on two levels, connected by orifices, known as dual network. The first level is composed by the surface drainage system, which is represented by the ground surface directly above the galleries, i.e. roads and terrain that receive sub-catchment runoff inputs. These inputs enter the second level of modeling according to established rules for the interconnection between these levels. The second level is made of hydraulically underground galleries that once surcharged, may cause the energy grade line to surpass the ground level, generating floods just above the ground, again respecting the rules of communication between the underground network and routes. Figure 3 illustrates the processes described.

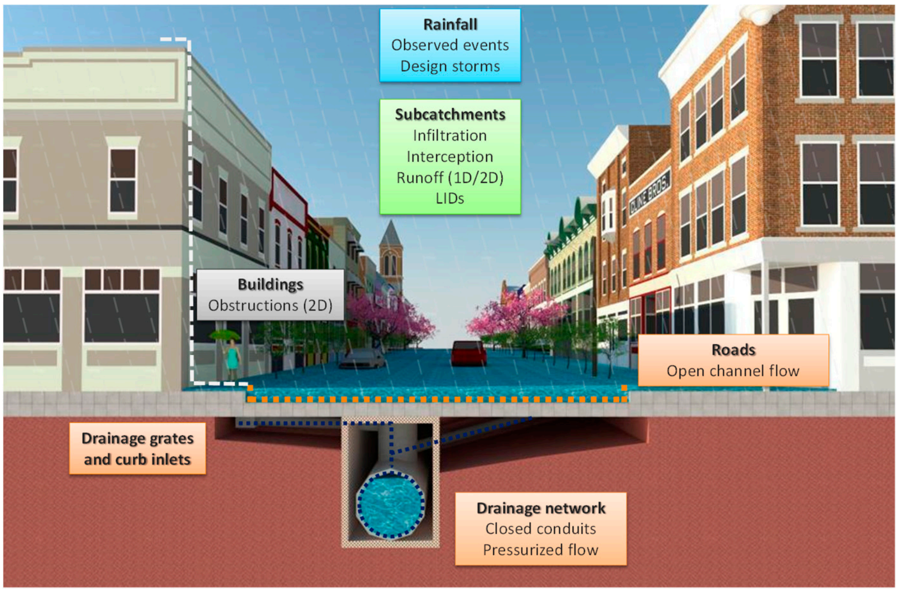

Figure 3: Schematic modeling representation for PCSWWM

The city of Sao Paulo official cartography basis – the Digital City Map (MDC) – was applied to represent the relief, geometric conformation, land occupancy, buildings, sidewalks, public roads and streets and other (plazas, gardens and green areas, for example), as well as the sub-catchments natural drainage elements that influence the inflows to the macro-drainage system. The MDC is the result of an effort from the city to standardize its database, developed through modern aerial survey techniques with flights performed in 2004, which generated maps in the scale of 1/1000 and contour lines of 1 m vertical intervals.

To ensure more homogeneous sub-catchment contributions, the basin was divided into small catchment areas, discharging into superficial nodes from the hydraulic network, following the discretization of the road network. The surface road system (excluding tunnels) was represented by 2,196 nodes, and then the basin was divided into an equal number of sub-catchments.

The geometric characteristics of the basin main macro-drainage system, consisting of underground galleries and all its singularities and manholes, were obtained from previous studies and projects developed for the city. Data from surveys performed in the 1990s were used, supplemented by surveys conducted by recent gallery inspections. The minor-drainage system is formed by a set of storm sewers with diameters up to 1.2 m, which slopes were estimated trying to

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follow surface slopes wherever possible, considering a minimum cover of 1 m. The connection between underground and surface networks is made through orifices that obey rules proportional to the characteristics of structures such as drainage grates and curb inlets, which were acquired from municipal records, supplemented with field surveys. These representative structures are not only consistent with the inflow entry process in storm sewers, but also meet in case of overflows from underground network to the road system channels. The rules of entry and exit of such structures have been defined for each type of drainage grates or curb inlets, with estimated parameters such as height, width and runoff coefficient, based on the studies of [12].

The existing network features were initially introduced into the model, followed by those of the designed systems. The basic hydraulic model represents, altogether, 110 km of roads, 50 km of drainage networks and 2,802 joint structures as curb inlets and drainage grates. Figure 4 shows the distribution of model elements in the region.

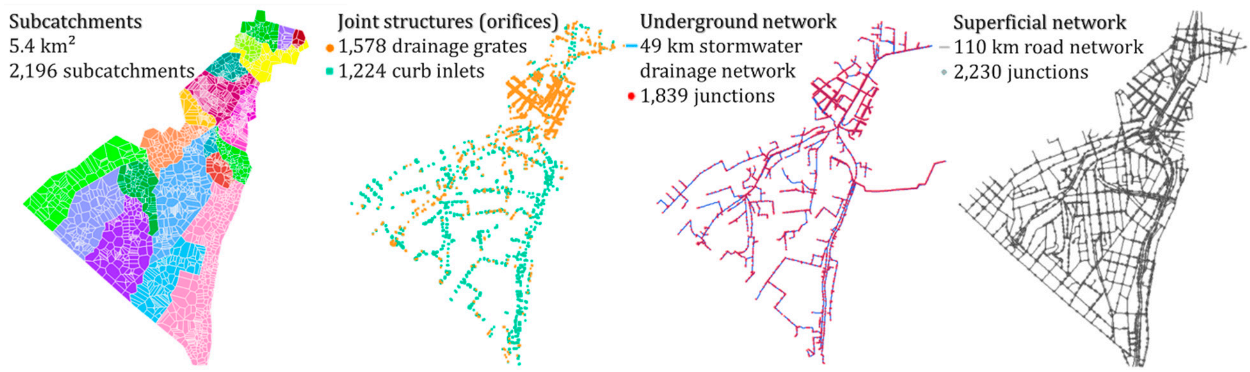

Figure 4: Modeling network for PCSWWM model and current drainage system

One should also consider the influence of the *Tamanduatei* river flow regime, which could worsen the conditions of the *Anhangabau* watershed discharges during events of critical intense rainfall in *Tamanduatei* watershed. On the road system outfalls, spread around the basin, free boundary conditions were chosen, while the outfalls at *Tamanduatei* river have fixed levels depending on the simulated return period, estimated from older hydraulic studies of *Tamanduatei* river. Additionally, the drainage grates and curb inlets had their capacities expanded along the linear retention tunnels (*supertubes*). Furthermore, the dimensions of the orifices and weirs that control the flow between tunnel reaches were optimized aiming to maximize the linear storage and minimize the effects of flooding on roads and tunnels.

2.2 Simulation scenarios

Hydrologic and hydraulic modeling of the *Anhangabau* watershed was made considering its current situation and the scenario with the implementation of the distributed linear retention reservoirs. Each scenario corresponds to a combination of drainage system, urban occupancy, adoption of LID controls, modeling dimension and rainfall time series:

- The land use and occupation features in the *Anhangabau* watershed were gathered from the interpretation of the MDC. Average rates of imperviousness were assigned for each type of identified land use. Considering the whole *Anhangabau* watershed, an average of 77.5% impervious areas resulted for current conditions. The trend imperviousness scenario was generated according to the Regional Strategic Plan to the local borough, which establishes a minimum rate of permeability of 15%. In order to obtain a critical scenario, a minimum imperviousness rate of 85% was adopted, persisting higher values estimated in the current scenario. Therefore, the basin average impervious rate would be 86.1%. Alternative situations also considered an increase in the stormwater retention capacity at the allotments, applied in

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25% and 50% of the building areas in reference to a municipal law, considering the trend occupancy condition.

- Low Impact Development (LID) controls were selected considering limited space availability for retaining and runoff infiltration structures. The resulting simulation parameters were estimated through a combination of porous pavements, bio-retention cells and infiltration trenchs.
- Beyond one-dimensional (1D) conventional modeling, PCSWMM application is able to generate models of urban flooding that combine SWMM model outputs to a two-dimensional (2D) model that represent the formation of flood spots, allowing an easily understood visual analysis of the results. 2D modeling considers a dense superficial mesh, which demands precision land representation data and requires significant processing time.

2.3 Rainfall and Climate Change Scenarios

The design storms applied were characterized through the intensity-duration-frequency (IDF) relations, which assign the average precipitation intensity at a given duration and probability of occurrence, usually expressed as a period that is the inverse of frequency. These relations are obtained by a series of intense rainfall data, sufficiently long and representative. The IDF curves used for our studies are inferred from the station IAG / USP - E3-035 (23°39'S, 46°38'W) fitting a Gumbel probability function [13, 14] and using the method of moments to estimate its parameters [13, 14, 15]. This station as a long observation record, from 1933 to 1997 (65 years), as described by [16]. The alternating block method is applied to the temporal distribution of rainfall obtained using IDF relations, adopting a 2-hour critical duration. This distribution is not related to physical phenomena, but it is an empirical method that characterizes a critical condition. Return periods selected correspond to 25 and 100 years and an areal reduction factor of 0.992.

For the climate change scenarios, the IDF tool [17, 18 and 15] was used to create the updated IDF Curves. The tool allows users to generate IDF curve information based on observed data as well as future climate projections using projected precipitation series from the GCMs. Multiple future greenhouse gas concentration scenarios (RCPs) are available within the tool for 24 GCMs that simulate various climate conditions that affect local rainfall data [17, 18].

The IDF_CC tool adopts a quantile-matching (EQM) precipitation downscaling method for updating IDF curves, proposed by [19] and described in [15]. It is based on (i) similarity of the distribution of changes between the projected period and the baseline period (temporal downscaling), and (ii) spatial downscaling of the annual maximum precipitation (AMP) derived from the GCM data and observed sub-daily data. The quantile-mapping functions are directly applied to AMP to establish the statistical relationships between the AMPs of GCM generated precipitation data and sub-daily observed data. The relationship built between the GCM baseline and the station's historical observations are assumed to remain the same in the projected future IDFs. The IDF_CC tool offers multiple GCM choices for updating IDF curves for future climate scenarios. The user can select all models (ensemble option) or an individual GCM and a projection period. The gridded GCM data for both baseline period and projection period are spatially interpolated to station coordinates using the inverse square distance weighting method.

The presented results refer to simulations with design storms with a return period of 25 and 100 years, considering the current occupation of the basin and drainage system and the proposed retention interventions. Table 1 summarizes the simulated scenarios.

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Table 1: Drainage system and climate change scenarios simulated

Drainage system	Design Storm	
	Return Period (years)	**Methodology**
Current	25	Observed IDF
		ENSEMBLE RCP 4.5
		ENSEMBLE RCP 8.5
		CanESM2 – RCP 4.5
		CanESM2 – RCP 8.5
	100	Observed IDF
		ENSEMBLE RCP 4.5
		ENSEMBLE RCP 8.5
		CanESM2 – RCP 4.5
		CanESM2 – RCP 8.5
Distributed linear retention	25	Observed IDF
		ENSEMBLE RCP 4.5
		ENSEMBLE RCP 8.5
		CanESM2 – RCP 4.5
		CanESM2 – RCP 8.5
	100	Observed IDF
		ENSEMBLE RCP 4.5
		ENSEMBLE RCP 8.5
		CanESM2 – RCP 4.5
		CanESM2 – RCP 8.5

2.4 Hazard indices and vulnerable assets

The storm water projects and floodplain management have to be concerned about the safety of people in flooded urban areas. In the last years of intensive research on the risk of analysis in flood areas many works have been published [19, 20, 21 and 22].

In [21] the human size characteristics (H.M) are used as an independent variable in defining general flood flow safety guidelines is not considered practical given the wide range in such characteristics within the population. To define safety limits which are applicable for all persons, hazard regimes are defined. Low hazard regimes are indicated where D.V < 0.4 m^2s^{-1} for children (H.M = 25 to 50 mkg) and D.V < 0.6 m^2s^{-1} for adults (H.M > 50 mkg). A moderate hazard zone which is dangerous for some adults and all children is defined between D.V = 0.6 to 0.8 m^2s^{-1}. Between flow values of D.V = 0.8 to 1.2 m^2s^{-1} is a zone of significant risk (dangerous to most), with a flow value of 1.2 appearing to provide an upper limit on tolerable flow for all experiments and across all human size [21].

The comparison of the various scenarios was done with the assessment of the water depth on roads and sidewalks and the use of hazard index. The methodology aims to contrast hazard areas at distinct levels of hydraulic risk, considering the depth of water on the roads and runoff velocity. The classification of various levels of hazard is shown in Figure 5, which was adapted from the work of [23] and compered with hazard bands are defined in [21].

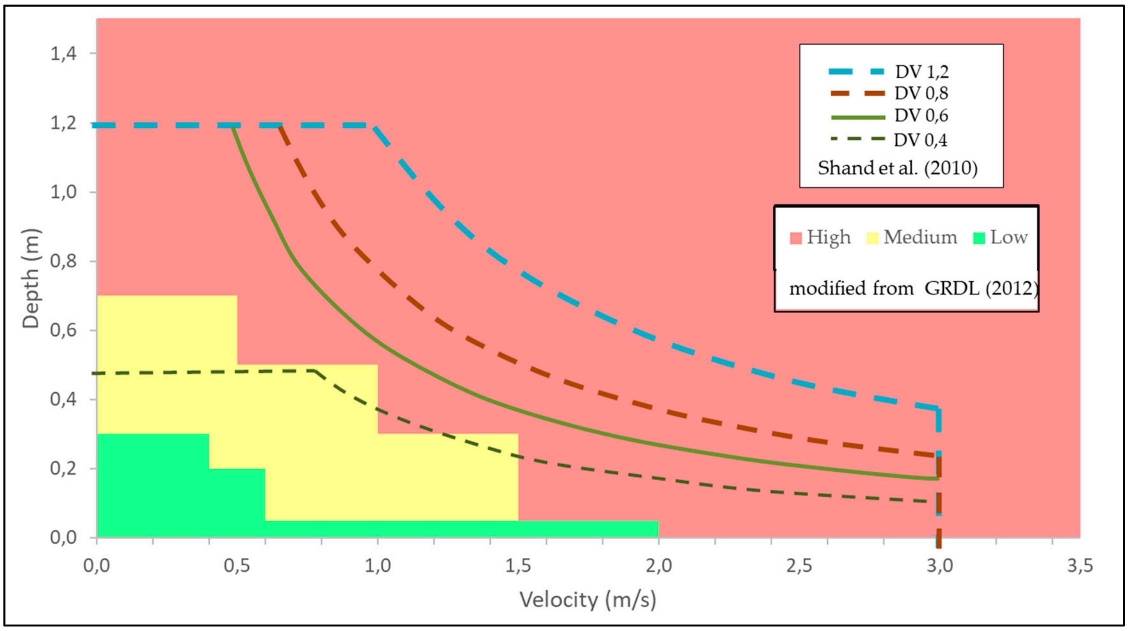

Figure 5: Hazard analysis criteria use in this paper modified from GRDL (2012) and hazard regimes presented in Shand et al. (2011)

From the surface flood levels, a flood risk analysis of buildings was carried out, quantifying the risks into low, medium and high. In total 10,730 buildings were evaluated. This analysis was conducted from a flood elevation assigned to the building, originating from the DTM, compared to the water head in the road segment closest to this building. This analysis tool is part of the differentials of the PCSWMM interface. Low risk was classified when the flood level is restricted to street level, average risk was rated for situations where the water depth reaches 15 cm on the sidewalk and high risk was assigned to locations where the water depth reaches up to 15 cm on the sidewalk.

3 Results and Discussion

Through the model output analysis, it was intuited that the events chosen for the calibration process should not cause significant impacts, but little vestiges of flooding. By analyzing the volume and intensity of such events, it was found that these were not critical storms with high return periods, so the floods caused by them may be linked not only to the small flow capacity of hydraulic structures, but to the current situation of galleries and the drainage system efficiency, which is significantly reduced in urban basins due to several obstructions. The high levels observed in *Tamanduatei* river also reduce the flow conditions in the *Anhangabau* and *Moringuinho* rivers, causing flooding upstream.

This behavior suggested several questions and an interpretation of what would have happened in the days of these events was sought. One of the feasible hypotheses to explain the phenomenon occurred is the loss of efficiency of the drainage network, due to the accumulation of waste in the galleries, trash clogging drainage grates e curb inlets and conduits in poor condition. Given this interpretation, the model was structured with some additional energy losses in the ducts and hydraulic elements. The results showed that, with the introduction of energy losses, it was then possible to represent the events occurred. The simulation with energy losses sought not to truly represent what happened in the events, but to show that, depending on the condition of the drainage

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system, it is indeed possible that smaller rains cause significant impacts in the basin. These exaggerated loss coefficients, however, were not maintained in the simulation of the scenarios presented in this paper, which should not pose any harm to the comparison of the alternatives, since they all were analyzed under the same conditions. The results are presented in terms of water surface levels and hazard indices for the current drainage system, the proposed retention system and the climate change scenarios.

3.1 Surface water levels

The water levels are presented in 5 different levels (colors) as in Figure 6, and the roads are colored according to these classes. Figure 6 shows the results for the 25-years return period storms under different climate change scenarios for the current drainage system, and Figure 7, the results for the proposed retention system with the same storm design scenarios. Both figures show clearly the increase in projected water levels for the future scenarios, with a maximum of 24% of the roads affected by 0.5 m of water depth or more for CanESM2 model and RCP 8.5 scenario, increase from 11% to the historical design storm. The lower regions of the watershed, in the valley bottoms along *Avenida 9 de Julho, Praca da Bandeira* and tunnel *Anhangabau*, concentrate higher water levels as expected.

With the interventions on the drainage system using the proposed linear storage, the improvement in reducing the water depths on watershed is evident comparing the current and projected interventions on the drainage system in Figure 8 for each of the design storms including the climate change projections. What can be noticed however, is that with the more extreme climate change scenarios, specially RCP 8.5, the water depths are comparable to the scenario with the current drainage system and the observer historical storm. This fact raises concern and should alert the decision makers on the city that immediate action is needed.

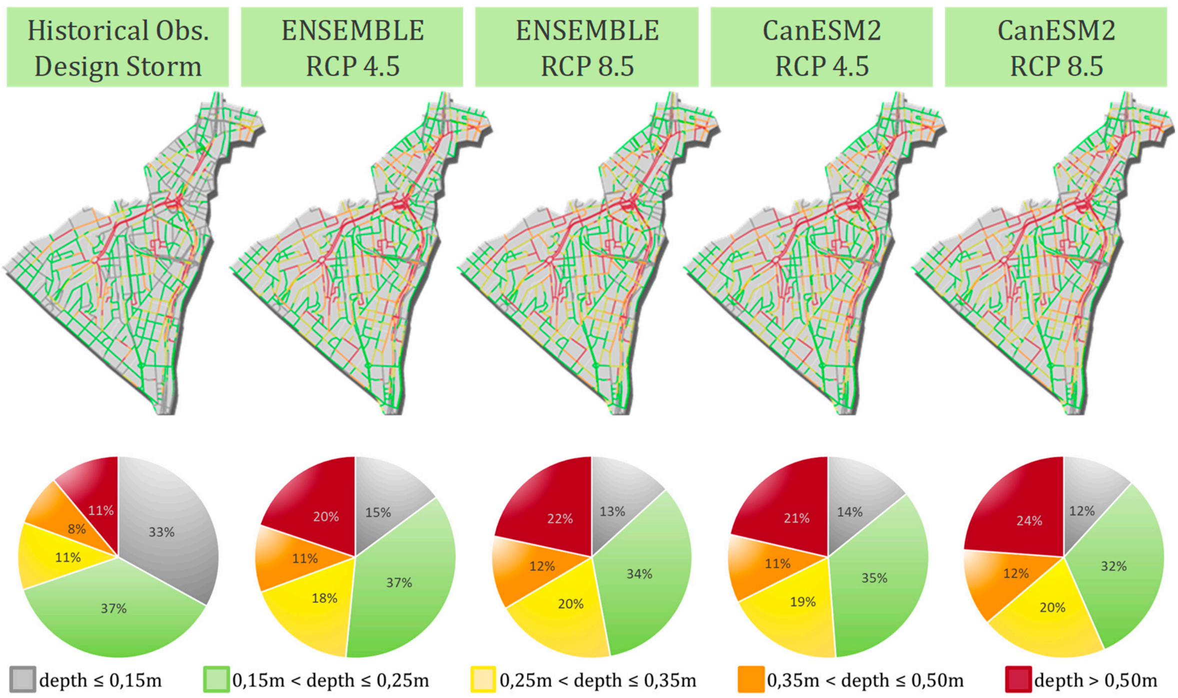

Figure 6: Surface water level results – Current drainage system – 25-year return period storm

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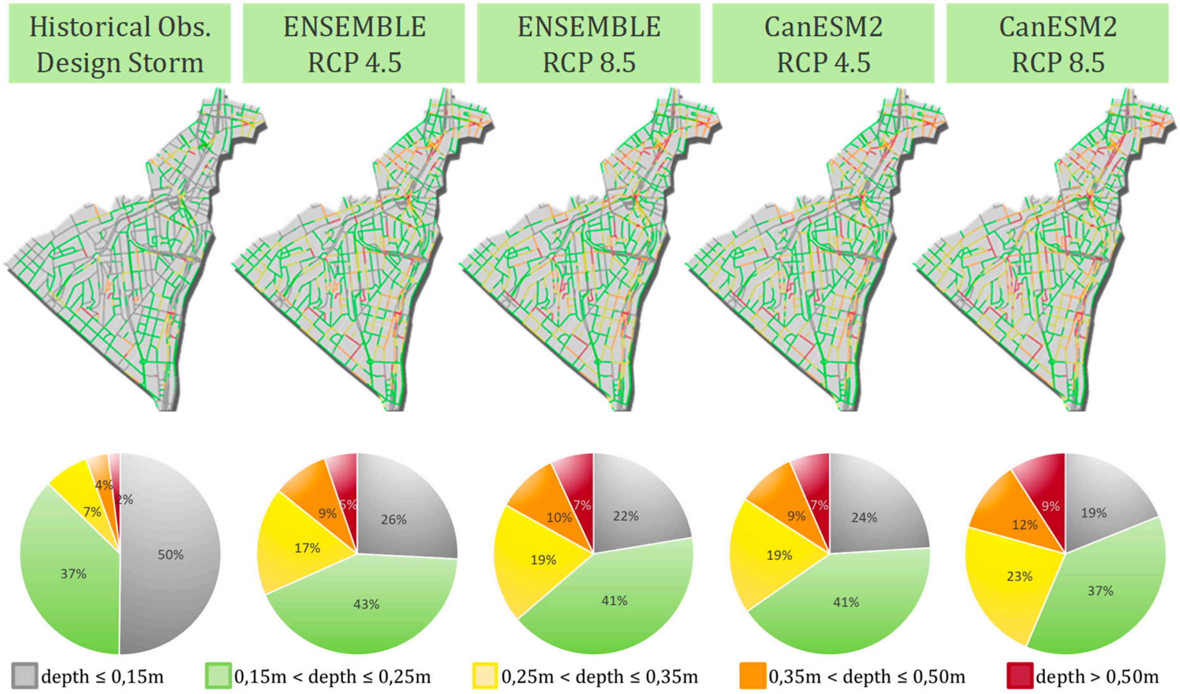

Figure 7: Surface water level results – Distributed linear retention – 25-year return period

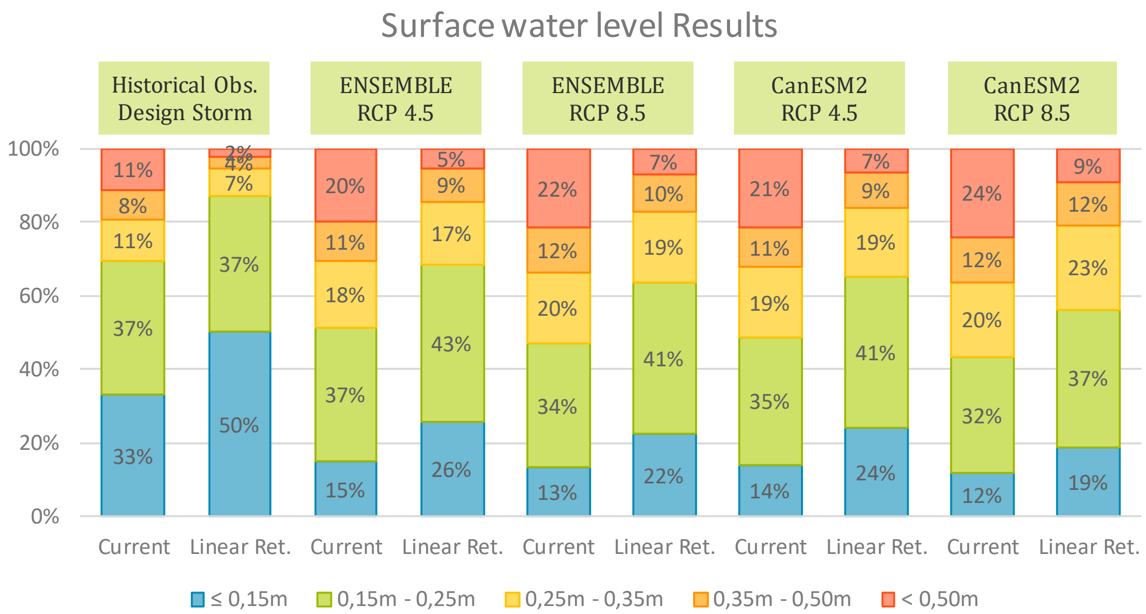

Figure 8: Surface water level result comparison – 25-year return period

3.2 *Hazard indices*

The results of the hazard analysis for selected historical and climate change design storm scenarios are presented in Figure 9 for the current drainage system, and on Figure 10 for the drainage system incorporating the linear retention strategies. From both maps, what is clearly noticeable is the fact that the climate change scenarios increase the percentage of the high-risk levels. For the current

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drainage system, the high hazard index increases from 17% to 34%, for the CanESM2 RCP 8.5 model. The lowest increase in the risk index is for the Ensemble approach and RCP 4.5, where the high-risk level reaches 29% (Figure 9). With the implementation of the linear retention

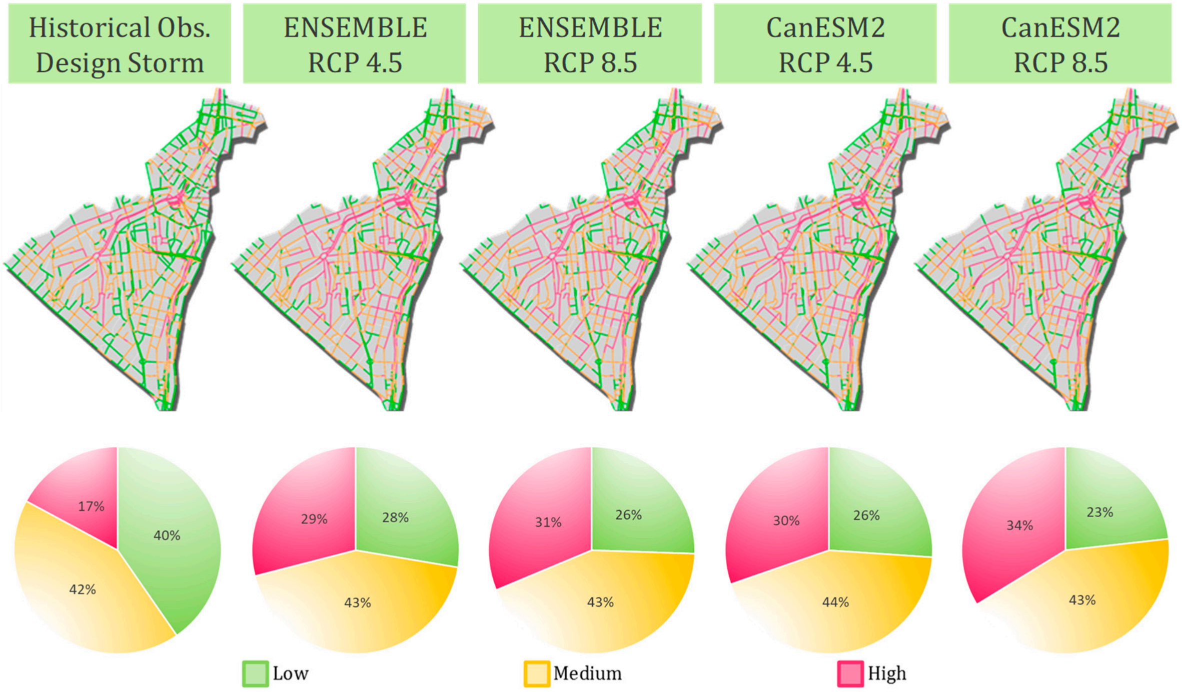

Figure 9: Hazard analysis results – Current drainage system – 25-year return period

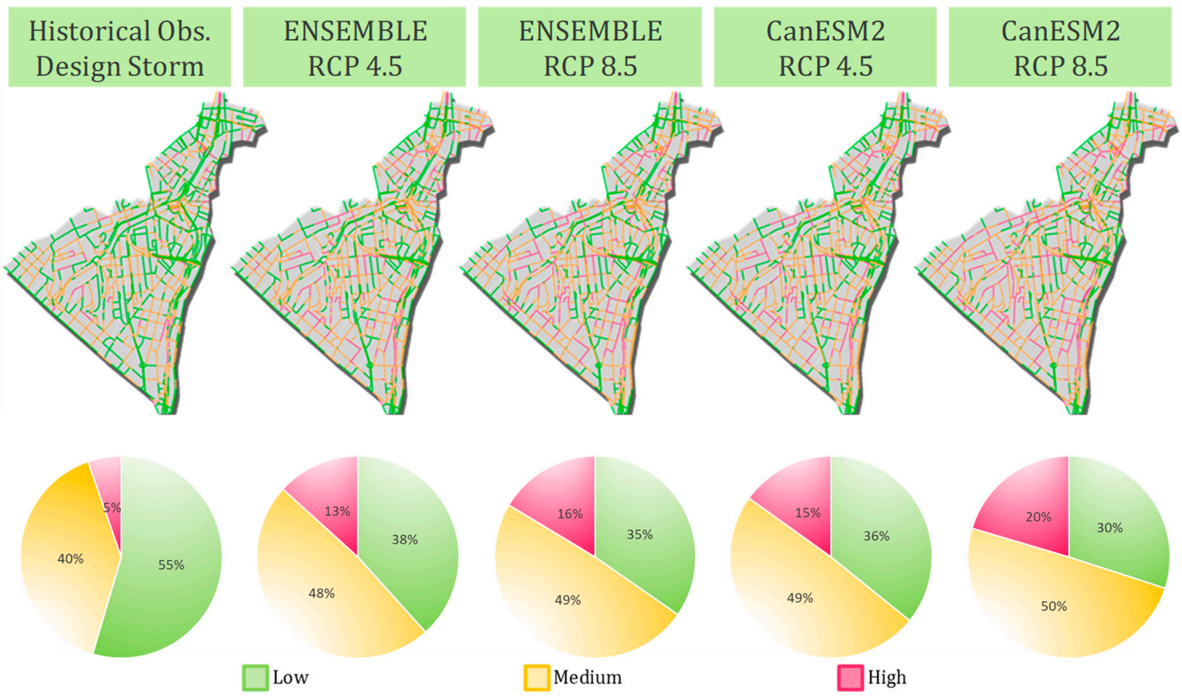

Figure 10: Hazard analysis results – Distributed linear retention – 25-year return period

The summary of the results of the hazard analysis, for both drainage systems (current and proposed), are presented for comparison purposes in Figure 11. From the results it is clear that the

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linear retention is effective in reducing the areas on the watershed exposed to high-risk on all the design storm scenarios. For the historical observed storm, the areas subject to high levels of hazard are reduced to 5% with the proposed drainage system, from 17% that occurs with the current system.

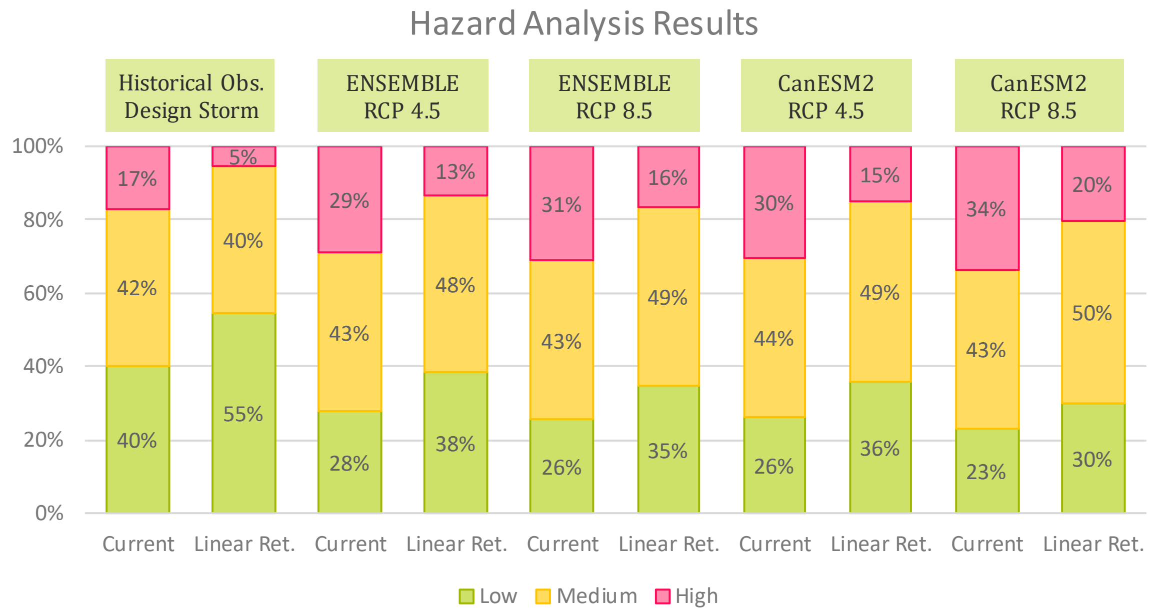

Figure 11: Hazard analysis result comparison – 25-year return period

4 Conclusions

For the basin current situation, floods with a high hazard levels are centered in the valley bottoms along *Avenida 9 de Julho*, *Praca da Bandeira* and tunnel *Anhangabau*, however, the problem is also distributed along several avenues and points throughout the basin.

To mitigate flooding on the watershed presented in this study, a linear retention measure implemented using a simulation model, SWMM with very detailed representation of the drainage system and urban elements. The alternative was used to evaluate different design storms scenarios combined with return periods of 25 and 100-years as well as the updated IDF under climate change for RCP 4.5 and RCP 8.5.

The results presented have shown that the linear retention system is an effective tool for reducing flooding on the region, especially for the scenarios based on the existing IDF curves. However, the scenarios where the updated IDF curves under climate change were applied, have shown that, even with the implementation of the proposed improvements on the system, the flooding and hazard conditions will not be drastically reduced, especially for the scenarios with higher emissions, such as RCP 8.5.

This fact may be deceiving for the population who is fully aware of the dramatic effects of climate change on highly populated urban areas. The linear retention system proposed is not sufficient to mitigate the flooding issue in the presented study, should the changing climatic conditions occur. As mentioned, city planners and stakeholders need take immediate action to prevent further increasing and frequent flooding on the regions. Other alternatives should also be explored, such as further extending the retention system and implantation of LID control measures. Population awareness is not doubt necessary at key to improve the community resilience due to the recurrent and unavoidable flood events on the basin.

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