Real-time storm water management during flood events in highly urbanized areas

Gestion des eaux pluviales en temps réel lors d’inondations dans des zones fortement urbanisées

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RÉSUMÉ

Il est courant d'appliquer des données historiques et de simuler des tempêtes pour planifier et gérer le fonctionnement d'une infrastructure d'eaux pluviales. En utilisant un système de surveillance et de prévision en temps réel, les installations hydrauliques peuvent être exploitées plus efficacement et obtenir de meilleurs résultats.

Cet article examine les opportunités et les possibilités d’exploitation de systèmes de drainage prenant en compte des ouvrages hydrauliques complexes pour la protection contre les inondations dans les zones fortement urbanisées et sensibles aux fortes précipitations.

L’étude de cas porte sur la mégapole de São Paulo, au Brésil, en tant que modèle pour le fonctionnement de la gestion des inondations en temps réel. L'article conclut que des progrès peuvent être réalisés dans la gestion des inondations avec le système d'alerte d'inondation en temps réel.

ABSTRACT

It is usual to apply historical data and simulating design storms to plan and to manage the operation of storm water infrastructure. In a real-time monitoring and forecasting system, water works can be operated in a more efficient way with better results.

This article discusses the opportunities and possibilities to operate drainage systems considering complex hydraulic works for flood protection in highly urbanized areas that are sensitive to intense rainfall events.

The case study is the megacity of Sao Paulo, Brazil, as a model for real-time flood management operation, and the products used to manage its drainage infrastructure during flood events.

The article concludes that using data provided by a real-time flood forecast alert system, and using flood zoning, operating flood gates, reservoirs and channels, advances can be made in reducing flood impacts.

KEYWORDS

Infrastructure, Management, Modelling, Real-time, Storm water, Hydraulic Operation

INTRODUCTION

The objective of this article is to discuss a real-time control strategy for storm water management in order to reduce the impact of flood events in highly urbanized cities. This study has focused on the city of Sao Paulo, Brazil, a large global city that periodically suffers with floods. This is the case study for data analysis and contextualisation.
A flood control system in a megacity is designed to protect densely populated areas. The traditional design method is to modify and to adapt the natural urban basin characteristics with artificial channels, reservoirs, etc. The efficiency of this traditional method is very questionable as it leads to unexpected environmental changes and produces considerable impacts in the urban environment. In recent years this concept has changed and is gradually being replaced by the sustainability concept of green flood control system. Basically, the new proposal is to design flood control systems minimizing changes in the natural condition of the urban basin. It is very difficult to use this concept in a megacity considering its complex occupation in terms of infrastructure and housing. So, there is a paradigm between urban occupation and green flood control systems.
A set of projects can be used in a green flood control system, for example, LID's, Linear Parks, Channels, Reservoirs, etc. A promising method that uses the concept of living with water, is the flood zoning which considers different uses and soil occupation. This methodology enhances the resilience of cities subject to floods. A real time hydrological monitoring system (telemetry, radar, etc.) and a set of forecasting models can implement the efficiency of a green flood control with zoning. Love et. al (2018) and Kerkez et.al (2018) developed methods that focus in applying real-time monitoring of water quality and quantity that are used to operate drainage systems in real-time.
By using these approaches, Sao Paulo municipality intends to improve storm water management and promote security to its citizens.

METHODOLOGY

The forecasting hydrological model used in this research is the PCSWMM model, developed by CHIWATER (2018), which applies the method originally proposed by the SWMM model from EPA (2015). The city of Sao Paulo real time flood monitoring system is called SAISP (São Paulo Flood Alert System). SAISP operates a telemetric network with more than 300 stations around the city of São Paulo. The system operates two meteorological radars, a S-Band and a X-Band. The flood forecast model use this data to run every five (5) minutes, continuously. SAISP flood alerts are done as a result of a set of processes which begins with the monitoring and ends with the hydrological model. In order to simplify the alerts, the system produces two levels of information:

- Water level alerts – done in function of the water level in rivers stations located in certain interest regions where floods occur.
- Flood maps – estimated by the flood model, this information is in use by flood control managers.

This kind of information on hydrological events and its impacts are essential to establish flood zone maps considering different hydrological risks. Depending on the relation between flood and damage, urban zoning and occupation can be defined. This analysis is done in parallel with the design of hydraulic works mainly in the areas where the flood damage is very intense, and where it is necessary to reduce the risk of flood.

Figure 1 shows the relationship among different projects in a green flood control system and a real time flood alert system. The diagram describes a timeline of actions that are a product of real-time data applications. The flood alerts are an important source of data which gives the basic information to plan and to operate the flood control system.

This article describes data, structural and non-structural actions that are a product of Sao Paulo's real-time flood forecast system for flood management.

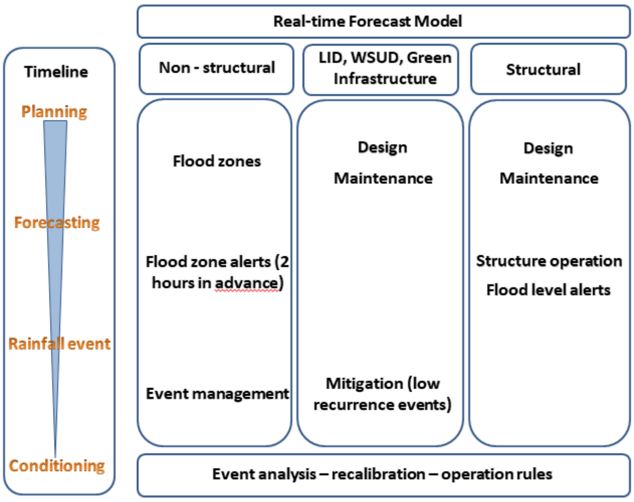

Figure 1 – Relationship among green flood control projects and a flood alert system

Flood zones – Once the flood forecast model is operational, flood maps are generated to indicate risk levels and susceptible areas. Flood zones are previously defined with design storms, but once forecasted radar rainfall is detected and hydraulic simulations diagnose a possible flood event using radar rainfall data, and specific zone alerts are deployed. This process is optimized as observed data volume on the relationship between radar rainfall spatial distribution and flood extents increase.

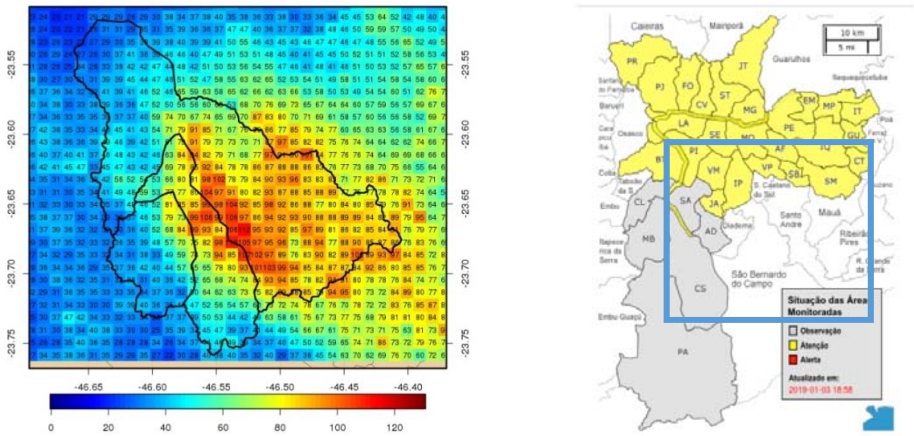

Figure 2 – Relationship between radar rainfall identification and flood alerts

Event management – With flood zoning it is possible to identify areas that need direct management during intense rainfall. When flood events are identified, managing traffic, deploying traffic control officers to block streets and advising citizens to leave their houses are a few of the event management tasks that are active in Sao Paulo. SAISP and CET are deploying hundreds of alerts annually for São Paulo.

Design and maintenance – Since a large number of events are observed in real-time, maintaining stormwater infrastructure is facilitated. The model represents how the ideal catchment will behave during an event. When observed results are different from the ones predicted by the modeling tool, the maintenance team is deployed to verify network conditions and identify if there is a blockage or provide feedback for a model revision. If a structure is not working as expected there is also the possibility to give feedback for network designers to update their design or the design criteria. Water rises in different rates on different catchments, and level alerts take this into account to define alert, attention and emergency status. With this information, effective measures can be taken to protect citizens and properties (Sosnoski, 2018).

Structure operation – Once crucial aspects of the catchments are calibrated and the real-time model can properly predict floods within an admissible range, proactive measures can act in advance and during the events to prevent/ reduce flood impacts. Stormwater infrastructure can be operated to better respond on solicitation. As an example, reservoir inlets can be opened and closed, and the operation will be indicated by model predictions. Some of Sao Paulo catchments have multiple reservoirs that are operate together as a whole system to avoid floods.

Figure 3 – Flood level alerts during intense rainfall and Perspective of a real-time modelling product for green flood control

The operation is part of an iterative process that improves catchment protection as a hole, not leaving vulnerable areas unprotected for future events. As a proposition to gather these important solutions, SAISP alongside Sao Paulo municipality created a Notebook that compiles indications to manage major basins in the city. These Notebooks are accessible tools to help decision making and presenting a modern view to city environment perspectives, and create guidelines on flood protection during intense rainfall.

RESULTS

The real time flood alert system is a planning tool essential to diagnosis the hydrology and its impacts in the urban environment. It is important to test dimensions and to maximize the efficiency of future infrastructure including optimal rainfall return period to minimize costs, (Fortunato, 2014). Furthermore, non-structural measures can be designed from the model, providing flood alerts in two levels, water levels and floodplain zoning. All those possible management solutions are the result of model implementation and its constant development. It is crucial to highlight the importance of continuous calibration and revisiting urban basin structures to build a more efficient flood control planning and management.

CONCLUSIONS

Storm water management in Sao Paulo, is being improved with its real-time flood forecasting system. The city of São Paulo flood alert is supported by the municipality since the seventies. During this period important flood alerts were done and in function of this long period of observation it has been possible to review plans and to design new flood control systems for the city, more recently green flood control systems. There are many research publications about São Paulo flood alert system like Sosnoski et al. (2018) and Conde and Barros (2018). The experience gained by the FCTH research group on this subject is very relevant today, few cities in the world have systems like this in operation for so many years. Therefore, there is a range of possibilities still to be developed in this area. Machine learning integration, rainfall identification and new design rainfall are a few of those future developments that are encouraging this research group.

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