

Flooding in the city of Belém-PA, Brazil: causes and mitigation measures

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Abstract

The city of Belém is located in Pará State, northern Brazil, in the continent of South America. This municipality is located in the great delta of the Amazon River, more precisely at the mouth of the bay from Rio Guamá Guajará, and is divided into several basins. Geomorphologically, it is a floodplain whose level is 4 feet lower than the river level, suffering the influence of high tides and having difficulty in disposing the rainwater. Against the background of considerable human and material losses, priority is the development of tools for assessing the vulnerability of flooding in the region that will assist in the planning. The main objectives are to study the municipality in respect to occurrences of past and current flooding so as to predict the future floods. This will help to organize the alert systems and adapt them into the Brazilian law.

Keywords: Belém, management, flood

1. Introduction

The flood volume has increased considerably in Brazil mainly due to the increase of impervious areas, population density and poorly-planned urban settlement, including the occupation of water meadows. The soil sealing (in urban areas) prevents infiltration and removal of vegetation increases runoff. Other aggravating factors are blocking device (manholes, hydrants inlet and other minor drainage devices), inappropriate sizing of projects, population density in areas of risk, inadequate works, physical interference, and high level of the water table. Such factors associated with rainfall patterns characteristic of the tropics and subtropics with events localized and of short duration, cause flooding of large impact.

The problems resulting from flooding depends on the areal extent of floodplain, the population and frequency of occurrence. Tucci (2009) states that improper occupation of urban areas can be avoided by planning the land use of wetlands, which must be set in the master plan of urban

cities. Such measures may help reduce the impacts of flooding, giving people in risk areas more time to be taken to the safety as well as to protect their property.

One analysis study area was performed to identify the main causes involved in the problem. Objective of this study was to evaluate the impermeable area of the city, identifying their causes and evaluating the measures for the control of floods, and emphasizing the social, environmental and economic aspects.

1.1. Characteristic of the study area

The city of Belém is located in Pará State, northern Brazil, the continent of South America. This municipality is located in the great delta of the Amazon River, more precisely at the mouth of the bay from Rio Guamá Guajará, and is divided into several basins. Geomorphologically, it is a floodplain whose level is 4 feet lower than that of the river, suffering influence of high tides and having difficulty in disposing the rainwater.

Geologically, Belém, since it was situated on an alluvial plain near the sea, has its nature fluvial sediments predominantly marine deposits from wind and sea. The predominant lithology is sandy-clay, sometimes conglomeratic levels or levels of silt. The climate is hot and humid with average annual rainfall reaching 2,834 mm. The average temperature is 25 ° C in February and 26 ° C in November. It is a tropical rainforest climate with no cold season and cooler temperatures of the month, above 18 ° C.

The lowland or flooded lands reaches virtually all the urban city of Belém. These introduce marsh land to a typology originally quite segregated, with high population density based on self-built dwellings (type stilts) on public lands and/or unfit for occupancy. There are 28 channels that cut through the city of Belém (Pinheiro et al, 2001).

1.2. Environmental, social and economic aspects

Belém is the 10th largest city in Brazil, with 1.5 million inhabitants, has 40% of its urban area four feet below the sea level. When the tide reaches 3.80 meters, and great part of the city is underwater. When this tide level coincide with heavy precipitation, the problem of flooding increases, resulting in a concern for the population. Belém is one of the capitals in the world where it rains more, with average annual rainfall of above 3000mm.

From the 1980s, with macro projects and micro drainage watershed, advanced intervention of public policies on sanitation structures of urban lowlands, caused its residents to move to the areas most distant from urban centers and supplied new spaces and infrastructured the housing market (Pinheiro et al, 2001).

This work is based on a vision in the management of flood risks. For Defra, (2004); APFM (2008) the flood risk management aims to reduce the likelihood of flooding or impacts of floods in order to minimize the threat to human life and property. At the same time making use of natural resources to beneficiaries and well-being of people. It is important to note that the measures of flood management cannot ensure complete elimination of flood risks, but can at least mitigate them.

In relation to social characteristics, including conflicts of interest among stakeholders, a plurality of values and responsibilities diffuse (Kenyon, 2007). For as the streams were being filled, new areas have emerged, which received the name of marsh land that are floodplain area, and are located on the lower portion of the city. In 2002 these marsh land reached 40% of the municipality of Belém, with a population of approximately 550 000 inhabitants, which accounted for almost 38% of the population in the municipality.

2. Flood event: causes and measures

2.1. Causes

The occurrence of floods in urban municipality may be due to both natural aspects, depending on the hydrogeological characteristics of the region and climatology, as anthropogenic, due to changes in the environment caused by man. The anthropogenic causes recognized to date in the city are: The soil sealing; The removal of the canopy; The rectification of channels; The urban sprawl; The absence of a system for collection and treatment of sewage, which is released directly into the drainage system; Inefficient performing projects pushing drainage problems to other basins; The lack of data on drainage of the municipality; The inadequate legislation.

The city has a large part of its area below the elevation of 4 meters, subject to constant flooding events for much of the year. Due to the city to present an intense precipitation, the amount of water that reaches the river simultaneously can often be exceeding its drainage capacity, which tends to result in flooding of floodplain areas.

A major problem with the municipalities of Belém is also that their management is not very comprehensive, so it does not take into account many specific data, which leads to a disorganized and poorly structured planning. It is necessary to understand the physical face characteristics of drainage basin, with emphasis for channels that influence the main channel.

The poor drainage of a considerable number of cities today represents an important source of injury to the urban population. This injury is characterized by frequent flooding, traffic congestion and environmental deterioration. Very little has been done in the sense of seeking to control this process in Brazil. The position is that usually it has the opposite fate of resignation of an event to be "natural." When in reality, the impact was generated by

inappropriate urbanization, which requires preventive measures of control and regulation. For this to happen, it needs the technical and administrative measures that are implemented through the Urban Master Plan (TUCCI and Collischonn, 2010).

Specific floods and other natural disasters also present their risks, requiring a thorough analysis of affected area, as well as a good management. For a single risk can cause various impacts and the sum of severities. The risks can then be ordered or prioritized, enabling the decision maker a more appropriate placement of their expectations and aspirations. The process identifies floods, by a list of systemically checking, such as: Management and acceptability of the project, Environmental, Financial, Knowledge and information, Legal, Managers, Policy, Quality, Means, Strategy and Technique.

2.2. Measures

The measures can be addressed from the point of view of planning the drainage, the instruments of management and tool-making decisions are administrators, which aims to reduce the use of financial resources needed for correction of losses and social impacts arising from absence of this practice.

Against the backdrop of huge human and material losses, reveals a priority in the development of tools for vulnerability assessment of flooding in the area assisting in planning. Against this background, it is crucial the determination of limits of flooding, as well as their frequency, checking the confidence intervals and their return time.

Figure 1 intends presents the main points of flooding in the town of Belém.

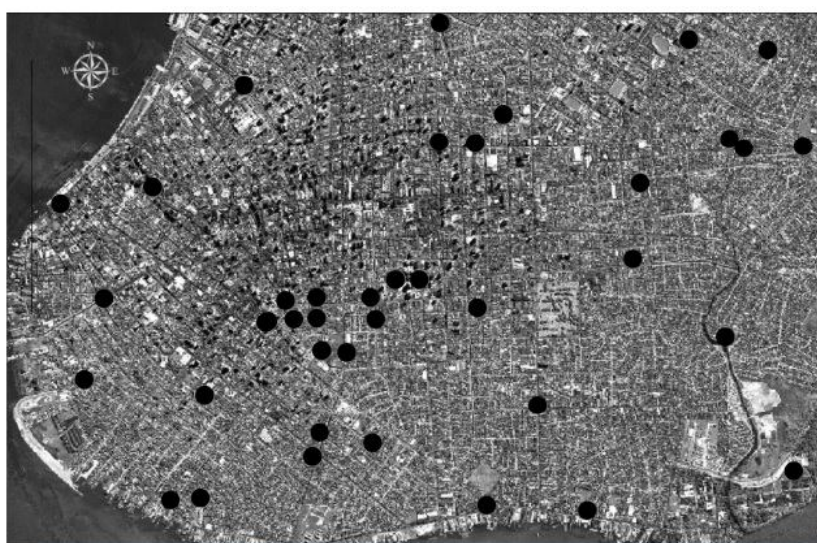


Fig. 1. Principle flooding points in the city of Belém Source: PEGADO (2012).

Obtaining all information of the study of flooding is fundamental in which preliminary should build to the limit of flooding areas based on existing topographical maps and checking the

height of mark of exceptional floods always allowing a refinement of topography in more detail, raising bathymetry of the river to ensure accuracies of the calculations.

Another aspect to consider is drawing the maps of vulnerability that support decision-making about the possible uses of watershed areas. The zoning maps are aimed at regulating of land use or zoning of land areas prone to floods, which will possibly be established by flood risk, being inserted in the master plan of the city. These maps can be displayed in two ways; one is to define the area affected by the flooding, with its return time and the other is a chosen map alert that will allow monitoring of the evolution of the flood, based on a hydrometric scale installed in different parts of the city. The data transmission is done via mobile phone.

A site visit is indispensable for zoning and aerial photography analysis and verification of points floods in order to analyze a set of rules for the occupation of the highest risk areas in order to minimize future losses of materials as well as human. It is good to note that this zoning to be used with better success is of great importance that it is integrated into the municipal laws, with emphasis on sector subdivision, construction and housing, to enable better interaction with the population in the floodplain area.

The development of a method for modeling of an indicator system for identification, quantify and evaluate indicators of climate changes that interfere with urban flooding in the basin tends to place materialized in numbers, odds or possibilities of occurrence of undesirable events or design flaw, and quantifies, where appropriate and feasible, the consequences of these events, in physical, economic, social or environmental terms.

One way to mitigate this effect of flood is to create an early warning system, which has a feature to anticipate the event through flood warning message. This causes the organs and population managers to better manage the population problem to avoid major disasters. To Tucci (2005) prediction systems are designed to avoid alerting the surprise factor, which often causes fatalities and major damage by flooding of roads, trapping vehicles, floods in buildings and equipment. The warning system facilitates the preventive isolation or removal of people and property subjected to floods, as well as diversion of the traffic.

These measures would create a system of data collection and precipitates water level and flow during the occurrence of the event. This estimation can be accomplished through the use of mathematical model representing the behavior of the different phases of the hydrological cycle, with which installs a service and predicted flood alert warnings and evacuation plan of the area. This will support civil defense and creates a full emergency plan when the flood hit a populated area, classified as emergency operation.

It is important to note that the control of floods, should be based on the sum of measures which are structural and non-structural, allowing the population located in the floodplain, minimizing losses and maintain the living environmental of river.

The adaptation of the study results to local urban development plan (Plan) and the Brazilian Legislation seeks to organize the growth and functioning of the city, to ensure that all citizens of the city have a place to live, work and live with dignity and security.

Although the master plan in its guidelines to address the control of environmental hazards, this cannot be identified in practice as the Departments of Sanitation (SESAN) Secretariat and Urbanization (SEURB) in the city, do not have a drainage management plan for Urban flood risk that might support the work of Civil Defence and the Firemen.

Belém should have in one of its offices a system of water resources manager, who has the task of predicting water scarcity, degradation of water bodies, areas of flooding and other issues relevant to decision-making more effective.

Finally, the adjustment of the new data obtained for Alert System Institutional Plan and the National Civil Defense must have as an example the new European Directive of floods (Floods Directive 2007/60/Ec), the latter being a landmark for the management of flood risk in Europe.

3. Final Thoughts

According to some authors, a consistent planning of this actions and control systems of urban drainage should be provided within suitable combination of human resources and materials, always linked the structural and non-structural measures. Unfortunately, this management is not yet possible as seen in municipalities of Belém, for what they have, works with solutions which are costly and are often characterized by unfeasible for the affected area always causing inconvenience to the public.

In general, to mitigate the problems of floods it is important to diagnose existing problems the predictable within a Logistical adopts the project, determine, qualify more appropriate technical standpoint, economic and environmental solutions.

Thus, the study seeks to contribute a source of descriptive events in Belém inundations, which have, directly or indirectly, interfered in most human activities performed.

List of Illustrations

Fig. 1. Principle flooding points in the city of Belém Source: PEGADO (2012).

List of Literature

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