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URBAN DRAINAGE PLAN IN BRAZIL

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ABSTRACT: Planning an urban infrastructure is especially difficult where the increase of urbanization is rapid and where the Urban Master Plan does not take into account its impacts. In the major cities of Brazil, one of the main impacts has been increased peak flows which also increase flood damage. In Brazil there are more than 12 cities with population greater than 1 million.

The main difficulties are: (i) lack of an urban drainage master plan; (ii) uncontrolled invasion of public green areas by the poor; (iii) illegal developments near the city boundaries and; (iv) unplanned public drainage works. These actions created a large cost for the population and the township investments.

This paper describes these main problems, the impact of the unplanned procedures and outlines action which cities can follow to reduce the impacts of the urbanization on drainage. The paper also describes the flood control strategy being implemented in the Metropolitan Area of Curitiba in Brazil.

URBAN DRAINAGE DEVELOPMENTS IN BRAZIL

As the beginning of this century, only 15% of the world's population lived in cities; by the year 2000, it is estimated that this percentage will rise to 50%. In Latin America and Caribbean countries, urban population growth is from 3 to 5% a year. At the turn, from century of about 30 to 35 cities in the world are expected to have above 10 million inhabitants (Foster, 1986). In most developed countries the urban population is above 70%.

In recent decades, Brazil has had a high urban population growth mainly in the Metropolitan Regions which are usually the State capitals. The present urban population in Brazil is about 80%. This population growth in the major cities occurred without any Urban Drainage Planning. It had, as consequence, the followings impacts:

* occupation of the river flood plains by the population, which increased the flood damage;
* increase in flood frequency due to the basin urbanization.

One of the main examples is the Tiete River in Sao Paulo city. The river valley has been occupied since the beginning of the century. The government has increased the river flow capacity, and the flood frequency decreased for some years, so that population density increased in the flood plain and upstream. Flood peaks and their frequency increased again following urbanization, and flood damage also increased. Today during the rain season there are more than five events creating large damage (to private property and public infrastructure), high cost (traffic jams) and lost income due to difficulties in mobility. The actual cost of improving the capacity of the main channel is more than US $ 1 billion.

Brazilians cities have been developed according to Urban Master Plans, which usually do not take account of the impact of urbanization on drainage flow. The impermeabilization associated with upstream development transfers its effect downstream, causing flood increase. Usually the cities engineering departments do not have the hydrologic support to cope with this problem and engineering works such as channels, pipes are designed without taking account of possible downstream impacts, where built-up areas leave no space for impoundment during flood events to decrease peak flows.

The concept basic to the design of stormwater drainage works is to drain water from urban plots as quickly as possible through pipes and channels networks; but this increases the peak flow and the cost of the drainage system. There is no control of peak increase at microdrainage level and most of these impacts will appear in the major drainage.

To cope with this problem, city and state administrations have developed many works such as channels in the major drainage and pipes in the secondary drainage network. This type of solution has only transfered the flood problem from one section of the basin to another, with costs from 2 to 50 US millions dollars/km of channel.

Besides this lack of planning in the drainage network, the municipality has many difficulties to enforcing legislation. These difficulties are due to the following:

* due to the high urbanization increase, most of the new developments in the city boundaries are not approved by the township and do not have the required facilities such as stormwater and sewer networks. This arises from lack of control.
* there are public areas, such as planned open spaces, which are invaded by slums due to the social pressure from the poor population.

These urban constructions usually creates less impact to downstream, but they are developed in risky areas. Usually these areas are: (i) near to the rivers with high flood frequency; (ii) in the hillslope with risk of lanslide during the rainy season.

IMPACT OF URBANIZATION AND ITS EVALUATION

The Brazilian procedure for calculation urban discharge is to use the Rational method for small areas (DAEE, 1979, McCuen, 1989) and the SCS model (SCS, 1975) for major drainage. The evaluation of urbanization impact in the major urban rivers requires a projection of the future urban occupation of the area, which is difficult because of the lack of legislation enforcement in the city boundaries. Since in most major cities the developments are in the downstream to upstream direction, there is the possibility of conflict between the upstream population, which causes the flood frequency increase, and the donwstream one, which suffers its impacts. The solution will come through public budget , supported by all the population.

To plan for this future impact, the real impact of developments must be evaluated in advance. Motta and Tucci (1984) evaluated the impact of the Master Plan Developments in Porto Alegre (Brazil) using a hydrologic model and a relationship of urban density to impermeable area (Figure 1). The urban density is the tool of urban planning and the impermeable area is the important parameter of the model. The relantionship obtained was for a residential type of occupation and the values obtained by measurements of aerial photographs. Tucci et al(1989) used a hydrologic and hydrodynamic model to simulate the Tiete river and evaluated the future cenario of 2005 in São Paulo. The relationship of density and impermeable area was updated with data from São Paulo city which gave similar values.

Campana and Tucci (1994) using remote sensing techniques through fuzzy mathematics calculated the impermeable areas (above 2 km2) for three major Brazilian cities, São Paulo (16 million), Curitiba (2,5 millions) and Porto Alegre (3 millions) using Landsat images and field observation. The values are presented in Figure 2, which shows, a good relationship between these two parameters. Most of the areas used are mainly residential and most plot sizes are around 300 to 400 m2. As can be seen, the asymptotic value is around 65% of impermeable area, which is the value recommended by SCS (1975) for lot size development less than 500 m2. This curve cannot be used for small areas of non-uniform developments such as high concentration of commercial and industrial occupation or green areas surrounded by high population density.

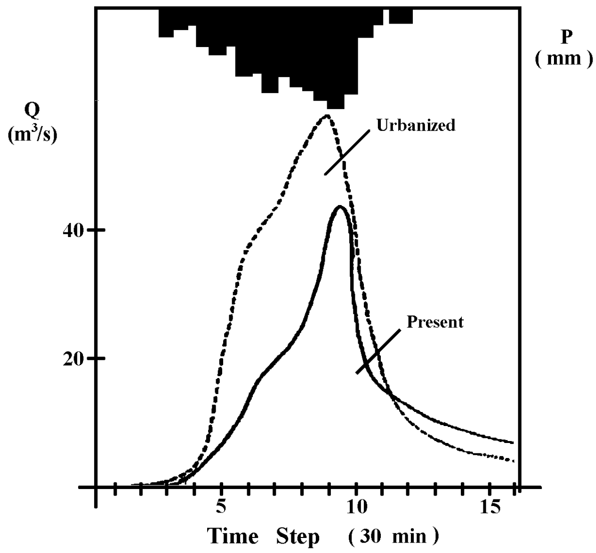

Figure 1 Urbanization flow increase in Diluvio Basin, Porto Alegre,Brazil (Motta and Tucci, 1984)

The curve can be used together with the forecast density to estimate the impermeable area. Another important parameter which changes markedly during urbanization is the time of concentration. Campana (1995) used GIS techniques to calculated in each sub-catchment of Diluvio Basin in Porto Alegre, the change in time of concentration, and used the curve of Figure 2 to estimate the impermeable area. The future scenario was given by the City Master Plan Development Plan and the simulation used a hydrologic-hydrodynamic model.

Those figures are estimated by modelling and Tucci (1995) used data on the metropolitan area of Curitiba to evaluate the natural mean annual flow of Belem river (42 km2), which has about 60% of impermeable areas with residential and commercial concentration. The drainage sewers covers most of the basin area. Figure 3 shows the relationship of mean annual flood and basin area. By extrapolation, the estimated natural flow is 12,0 m3/s and the present (urbanized) condition, based on recorded data of the last 10 years from which the basin had no major change is 71,7 m3/s. The increse is about sixfold.

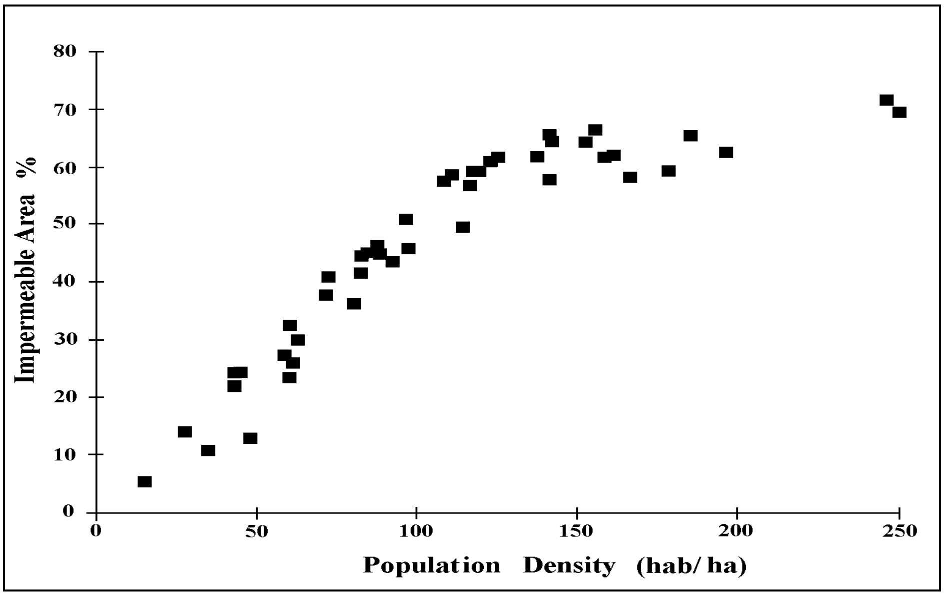

Figure 2 Impermeable area and population density (data from São Paulo, Curitiba and Porto Alegre, Campana and Tucci, 1994)

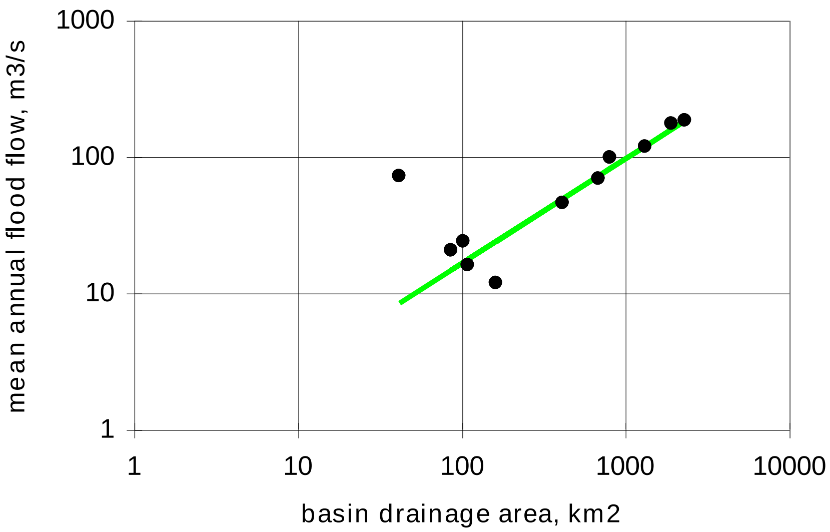

Figure 3 - Mean Annual Flood and Basin area for basin in Iguaçu River near Curitiba (the point which is far from the fitted curve is from urbanized Belem Basin)

URBANIZATION CONTROL AND MASTER DRAINAGE PLAN

One of the major difficulties in the urban developmen is to enforce legislation. To control the urbanization impact on flow, it is necessary to create new regulations for urban developments, defining, for example a limit to peak flow resulting from new developments. But since invasion of public undeveloped areas by squatters often occurs and the developments in the city boundaries are made without formal approval by administrations, how can this process be controlled?

In the first place, these difficulties are not a excuse for not passing the regulation and the Drainage Master Plan. Some strategies can be followed to develop the drainage volume control:

Sub-catchments of the urban cities have to be planned for the future development by evaluating its natural capacity and the limits of the developments in order to cope with this conditions. It can be done through limits in the peak flow increase and by implementing public facilities as parks with urban detention ponds. The uncontrolled flow of the cities can be damped by these ponds. These area have to be occupied with public facilities before they are invaded or developed by private users.

It is possible to create permeable index in the plot construction and public space;

Increase the public usage of the green area in order to prevent invasion: create physical difficulties for space invasion. In some cities invasion of public spaces has been discouraged by the existence of barriers such as river channels, roads or railway lines.

An example of flood control strategies is presented by Tucci (1995) for Curitiba. The Metropolitan Area of Curitiba (State of Paraná, Brazil), population about 2,5 million, is developed in the Upper Iguaçu

River Basin which has a basin area of 1000 km2 in J. Belem (Figure 4). The tributaries are about 100 km2 in size and the highest density of population is in Belem Basin.

The Iguaçu River has a large natural flood plain due to the small river conveyance because of the small river section area and slope. During the flood season the hydrograph is damped by the storage capacity of the valley. During the past decades the regional administration rulled against ocupation of the floodplain, but there were invasions and unapproved developments and occupation. In July 1983 and January 1995 two major floods occured with severe damage. The 1995 flood had a seven day rainfall with more than a 100 year of return period (largest in the 110 years of data). The duration of the main river hydrographs is seven days.

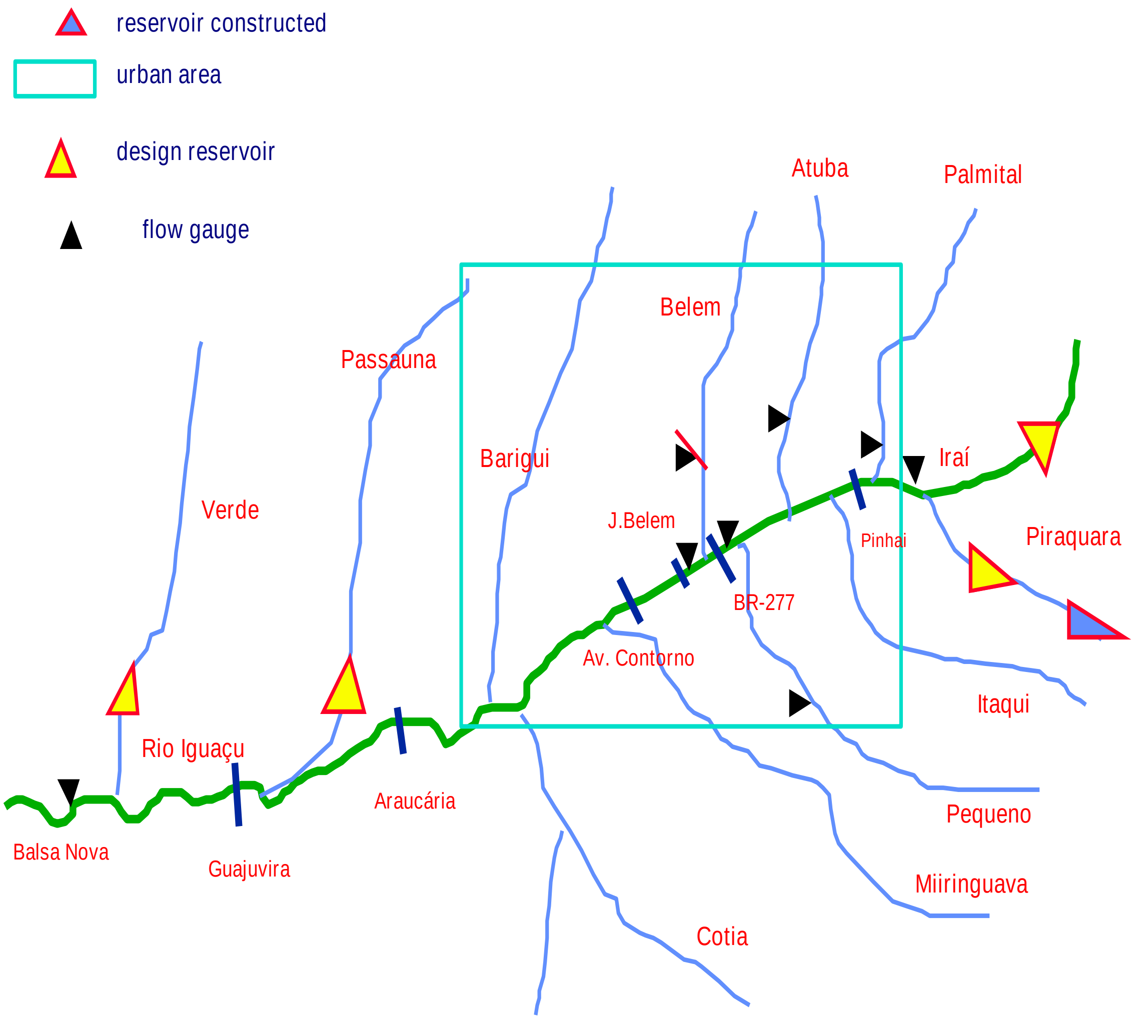

Figure 4 Curitiba Metropolitan Area and Iguaçu River

The usual approach would be to increase the Iguaçu river capacity to cope with the 50 or 100 year flood. But if this were done, the population would occupy the floodplain and upstream areas, increasing again the peak flow. In this scenario the cost of control would be of the same order as that undertaken at São Paulo.

The main approach to flood control was therefore taken to be the following:

Create a storage area in Iguaçu river in the Metropolitan Area in the form of a major park (area about 20 km2). This park is defined by a channel which creates a limit to urban settlement pressure (Figure 5);

The park to be designed and implemented together with the channel construction. In addition there must be an important control of this area;

Development of the Drainage Master Plan for the Region using the strategies presented before: (i) developments of urban parks in the tributaries to hold the peak increase of the uncontrolled upstream area; (ii) regulation for the controlled area.

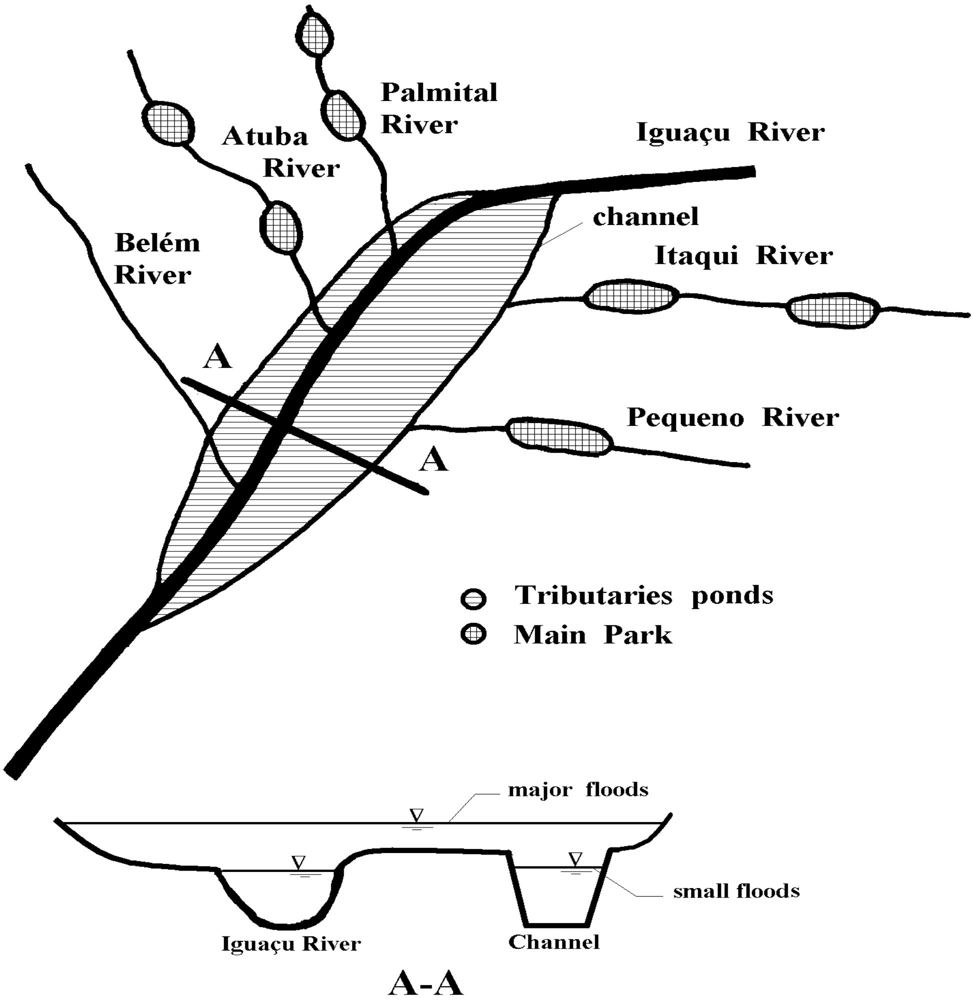

Figure 5 Flood Control in Metropolitan Area of Curitiba

CONCLUSION

The problems of urban development in developing countries like Brazil different from those in developed countries in terms of : (i) density of occupation; (ii) regulations and mainly (iii) social impacts of urbanization through illegal occupation of land, whether public or private.

Each problem has its own solution and each situation may require a different approach to minimize the impact on the standard of living of the communities. This requires a good understanding of the urbanization pressures and the waters resources of the area. This paper presented some general proposals illustrated using the flood control of Curitiba Metropolitan Area which now being implemented.

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