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Sustainable Drainage Systems: An Integrated Approach, Combining Hydraulic Engineering Design, Urban Land Control and River Revitalisation Aspects

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1. Introduction

Floods are natural and seasonal phenomena, which play an important environmental role, but when they take place at the built environments, many losses of different kinds occur. By its side, urban growth is one of the main causes of urban floods aggravation. Changes in land use occupation, with vegetation removal and increasing of impervious rates lead to greater run-off volumes flowing faster. Intense urbanisation is a relatively recent process; however, floods and drainage concerns are related to city development since ancient times. Drainage systems are part of a city infrastructure and they are an important key in urban life. If the drainage system fails, cities become subjected to floods, to possible environmental degradation, to sanitation and health problems and to city services disruption. On the other hand, urban rivers, in different moments of cities development history, have been considered as important sources of water supply, as possible defences for urban areas, as a way of transporting goods, and as a means of waste conveying.

Thus, there is a paradox in the relation between the water and the cities: water is a fundamental element to city life, but urbanisation is not always accompanied by the adequate planning and the necessary infrastructure is generally not provided, leading both to urban spaces and water resources degradation. An interesting historical register illustrates the problem of urban land occupation. In the 16th Century, the architect Giovani Fontana studied the Tiber River flood in the Christmas of 1598, in Rome (Biswas, 1970). Fontana's conclusions stated that the severe consequences of that flood were related to the occupation of the riparian areas near the confluences of Tiber River with different tributaries and channels, as well as to the lack of information of the people that settled their houses at those places. This situation is pretty similar to what still occurs today: lack of urbanisation planning and control, poor environmental education and the absence of a major framework to unite technical and socio-economic aspects. The main proposition of Fontana to control floods in Rome referred to the enlargement of Tiber River, in order to improve the general flow conditions – a classic view focusing on fast conveying floods to a safe downstream discharge.

As cities started to grow, especially after the Industrial Era, urbanisation problems became greater and urban floods increased in magnitude and frequency. The traditional approach for the drainage systems, which were important as a sanitation measure in the first times of the cities development, conveying stormwaters and wastewaters, turned unsustainable. Flow generation increased and end-of-pipe solutions tended to just transfer problems to downstream. In this context, in the last decades, several approaches were developed, in order to better equate flow patterns in space and time. However, not only the hydraulics aspects are important. Technical measures do not stand alone. The water in the city needs to be considered in an integrated way and sustainable solutions for drainage systems have to account for urban revitalisation and river rehabilitation, better quality of communities' life, participatory processes and institutional arrangements to allow the acceptance, support and continuity of these proposed solutions.

2. Historical aspects and background of urban floods and drainage solutions

Several ancient civilisations showed great care when constructing urban drainage systems, combining the objectives of collecting rainwater, preventing nuisance flooding, and conveying wastes. During the Roman Empire Age, significant advances were introduced in urban drainage systems. Concerns on urban flooding mitigation and low lands drainage were very important to the city of Rome, which arose among the hills of Lazio region, on the margins of Tiber River. To meet urban drainage needs, a complex network of open channels and underground pipes were constructed. This system was also used to convey people's waste from their living areas (Burian and Edwards, 2002).

During the Middle Ages, urban centres suffered a great decay and people tended to live in communities sparsely established in rural areas, near rivers, with minor concerns about urban drainage. Sanitation practices have deteriorated after the decline of the Roman Empire and surface drains and streets were used indiscriminately as the only means of disposal and conveyance of all wastewaters (Chocat *et al*., 2001). Later, when cities started to grow significantly again, in the Industrial Era, urban drainage found itself regretted to a second plane. The industrial city grew with very few guidelines. The Liberalism influenced urban growth and there was a certain lack of control on the public perspective for city development (Benevolo, 2001). Sanitation, then, became a great problem and inadequate waste disposal led to several sort of diseases and deterioration of public health. The role of urban drainage became very important in helping to solve this problem and, more than often, it was important to fast collect, conduct and dispose securely stormwater and wastewater. Focus was driven to improve conveyance and this was the main goal of urban drainage, until some decades ago. However, considering the fast urban growth of the last two centuries, and the fact that the world population profile is changing from rural to urban, it became hard to simply look at urban drainage and propose channel corrections, rectifications and other similar sort of interventions. Canalisation could not answer for all urban flood problems and, in fact, this isolated action, in a local approach, was responsible for transferring problems more than solving them. The increasing flood problems that the cities were forced to face showed the unsustainability of the traditional urban drainage conception and new solutions started to be researched.

A sustainable approach for drainage systems became an important challenge to be dealt with. Drainage engineers became aware that the existing infrastructure was overloaded.

Focus on the consequences of the urbanisation process, that is, the increase of flow generation, which concentrates on storm drains, should be changed. Source control, acting on the causes of flooding and focusing on storage and infiltration measures, emerged as a new option at the end of the 1970s (Andoh & Iwugo, 2002).

An integrated approach, considering the watershed as the planning unit, may be considered the initial basis for a sustainable system design. The design of an urban drainage system integrated with city development, aiming to reduce impacts on the hydrological cycle, acting on infiltration processes and allowing detention on artificial urban reservoirs, joining concerns, restrictions and synergies from Hydraulic Engineering and Urbanism appears as a fundamental option to treat urban floods. Besides the quantity aspects, the water quality became also a main issue and waste waters and solid waste disposal became matters to be treated together. The first flush and the washing of the catchment also introduced a new perception related to the diffuse pollution. At last, and in a complementarily way, rain water harvesting appears as an opportunity to increase water resources availability in urban environments. Several different conceptions have been proposed in the last decades, with some minor differences among them. All of them, however, tend to consider those questions in an integrated way, trying to rescue natural characteristics of the hydrological cycle, while adding value to the city itself.

Coffman et al. (1998) proposed a design concept of Low Impact Development (LID). LID design adopts a set of procedures that try to understand and reproduce hydrological behaviour prior to urbanisation. In this context, the use of functional landscapes appear as useful elements in the urban mesh, in order to allow the recovering of infiltration and detention characteristics of the natural watershed. It is a change in the traditional design concepts, moving towards a site design that mimics natural watershed hydrological functions, involving volume, discharge, recharge and frequency. The main principles of this approach may be briefly described by the following points:

- minimise runoff, acting on impervious rates reduction and maintaining green areas;
- preserve concentration times of pre-development, by increasing flow paths and surface roughness;
- use of retention reservoir for peak discharge control and improve water quality;
- use of additional detention reservoirs to prevent flooding, if necessary.

In a similar way, another early trend in the drainage system design evolution involved the use of stormwater Best Management Practices (BMP). The term Best Management Practices is frequently used in the USA and Canada and its origin is related with pollution control in the field of industrial wastewaters. Later, it was also referred as a possibility of nonpoint source pollution control and then associated with stormwater management. This way, stormwater BMPs are supposed to work in a distributed way over the watershed, integrating water quantity and water quality control aiming to mitigate effects generated by land use changes, with optimised costs. BMPs are designed to reduce stormwater volume, peak flows, and nonpoint source pollution through infiltration, filtration, biological or chemical processes, retention, and detention. They also may be classified into structural, when referring to installed devices and engineering solutions, or non-structural, when related to procedures changes, like limitations on landscaping practices (US EPA, 2004).

LID and BMP are very often used together and may complement each other.

Batista *et al.* (2005), in Brazil, consolidated the concepts of Compensatory Techniques in urban drainage design, which meant the introduction of several different measures, focusing on infiltration and storage capacity, with the aim of compensating urban impacts on the hydrological cycle.

Another possibility of improving urban drainage solutions concerns the Sustainable Urban Drainage System (SUDS) concept. In this case, the ideals of sustainable development are included in the drainage system design process, that is, impacts on the watershed due to drainage solutions may not be transferred in space or time. Moreover, besides contributing to sustainable development, drainage systems can be developed to improve urban design, managing environmental risks and enhancing built environment. SUDS objectives account both for reducing quantity and quality problems and maximising amenities and biodiversity opportunities, which form the three way concept: quantity – quality – amenity & biodiversity. All of them have to be managed collectively and the desired solution appears in the interface of these three objectives (CIRIA, 2007). The philosophy of SUDS, similar to LID, is also to replicate, as well as possible, the natural conditions of pre-development site.

The key elements for a more sustainable drainage system consider to:

- manage runoff volumes and rates, reducing the impact of urbanisation on flooding;
- encourage natural groundwater recharge (where appropriate);
- protect or enhance water quality;
- enhance amenity and aesthetic value of developed areas;
- provide a habitat for wildlife in urban areas, creating opportunities for biodiversity enhancement;
- meet the environmental and the local community needs.

The continuous evolution of all these concepts and the seek for new urban drainage system solution led also to the Water Sensitive Urban Design (WSUD) concept, initially developed in Australia.

Wong (2006) states that the definition of WSUD appears to be confusing among practioners because of its wide range of applications. WSUD tries to integrate social and physical sciences in a holistic management proposition for urban waters.

Langenbach et al. (2008) define WSUD as the "interdisciplinary cooperation of water management, urban design and landscape architecture which considers all parts of the urban water cycle, combines water management function and urban design approaches and facilitates synergies for the ecological, economical, social and cultural sustainability."

According to Wong (2006): "WSUD brings 'sensitivity to water' into urban design. The words 'water sensitive' define a new paradigm in integrated urban water cycle management that combines the various disciplines of engineering and environmental sciences associated with the provision of water services, including the protection of aquatic environments in urban areas. Community values and aspirations of urban places necessarily govern urban design decisions and therefore water management practices".

WSUD is centred on integration at a number of levels (*ibid*):

- the integrated management of potable water, wastewater and stormwater;

- the integration of the urban water management from the individual allotment scale to the regional scale;
- the integration of sustainable urban water management with building architecture and landscaping;
- the integration of structural and non-structural sustainable urban water management initiatives.

Integration of urban water uses in different spatial scales, with the involvement of different knowledge areas, encompassing hydraulic engineering, urbanism, architecture, social sciences and economy, trying to preserve natural environment and adding value to the built environment, in a participative framework where communities play an important role, seems to be the main point to characterise the WSUD concept. The institutional arrangements are key elements here, in order to manage this process

Furthermore, actions on urban rivers revitalisation or, in a more optimistic sense, actions to allow urban rivers rehabilitation, also arise as a new possibility. The river revitalisation usually includes solutions for the built environment, reconnecting it to the city, but not necessarily recovering natural patterns. The concept of river rehabilitation, however, tries to integrate the river hydrology and morphology, the hydraulic risks associated to the flood control, the quality of waters and the ecological state of the river. These are very complex tasks to be dealt in urban environments, due to several constraints accumulated over time. River canalisation, flood plains disconnection, lack of free spaces, combined sewers (or even uncontrolled wastewaters disposal, as it happens frequently in developing countries), social pressures and other questions appear as difficulties in the way of a river rehabilitation. By the way, one possible decision in urban development may be to state a vision for the river and how to integrate it with the built environment and try to do the best possible to walk in that direction.

Gusmaroli et al. (2011) propose the adoption of an ecosystem approach, in order to supplement or replace the concept of Waterfront Design. The Waterfront Design mainly aims to recover the relationship between river and city around the line where they meet. Stepping ahead brings the opportunity to propose the river rehabilitation concept from the point of view of an environmental improvement, looking at the city as an organism in constant transformation and, therefore, capable of modelling and adapting itself (even only in part) to the demands of recovering more natural features of the watercourses. In this sense, it is a challenge to find ways to recover more natural rivers and rethink the city's growth as a result.

3. Interface between rain waters and the city

The urbanisation process changes significantly the natural water balance equilibrium. Vegetation removal and its substitution by impervious surfaces reduces the infiltration possibilities, increasing superficial flow volumes. Besides, natural retention is reduced and the runoff is able to travel faster over regularised urban surfaces. In general terms, even when the urbanisation process is conducted within planning standards, the superficial volumes are greater. If the urbanisation does not account for more sustainable patterns, the peak flow is much greater than the natural one and the peak time occurs early.

Uncontrolled urban development, especially in developing countries, where later industrialisation led to a very fast process of city growing, frequently faces the occupation of the natural flood plains and even of the river banks, as it can be illustrated by figure 1. This fact worsens even more the problem of urban floods, because the space needed for flood overbank flows is now occupied by houses, streets and amenities. In this situation, floods tend to spread for larger areas, trying to find room, while affecting urban life in several aspects (sanitation, health, traffic, housing,…) and producing great losses. Once the flood space become limited by urbanisation, the flowing waters try to find other paths, inundating areas not subjected to floods before.

Fig. 1. Riverbanks occupation in the metropolitan area of Rio de Janeiro City, Brazil (Photo Miguez, 2010).

Usually, after the first impacts of urban development, changing urban land use and producing the first floods, the drainage canalisation appears as one of the most frequent consequences, both in the allotment level, with the micro-drainage systems, and in the catchment level, with the major works of macro-drainage canalisation. Canalisation works are frequently related to roads and regular grids of the cities. Canalisation, however, as discussed in the previous topic, tends to solve floods locally, with a partial vision of the problem.

In general terms, the occupation process of a watershed normally starts downstream, at the lower and flat areas. The imperviousness effects and the urbanisation towards riverine areas lead to the first canalisation works as a solution for flood control and urban design in these areas, aggravating floods on the basin outfall. With the continuity of the urbanisation process, the upstream areas start to be also occupied, repeating the formulas of the

downstream areas. Thus, when these new developments areas start to approximate of the riverine areas and suffer from flooding, new canalisations are settled, and the older downstream areas, where the city centre lies, become flooded again. At the end of this process, the natural storage areas are now occupied, all the catchment is canalised, there are no more flood plains, the channels do not have more discharge capacity, flood is transferred to downstream and large portions of the urban surface are inundated. Besides, the city strangles the drainage system and there are very few possibilities of new canalisation works.

4. Urban drainage design

Urban drainage design is a relative simple task, when considering the implementation of a project in a new urban area. Channels and pipes are integrated in order to convey the calculated discharge for the design rainfall. Infiltration measures and/or reservoirs may be predicted aiming to keep the generated discharge under a certain limit, and other sort of controls may be imposed, providing a low impact development. In this case, design is made by sub-catchments that are combined and summed in a certain pre-defined order, composing the urban land contribution to the drainage net, in a sequential calculation process. When a drainage system already exists and fails, however, it may become very difficult to propose adequate corrective interventions for the system rehabilitation without considering its systemic behaviour. The combination of superficial generated flows with drainage net flows may be diverse. Waters spilling out of the storm drain system may flow through streets, in an unpredicted way. The streets convey these flows to downstream reaches of the catchment, re-entering the drainage net without control. Sometimes, this superficial flow may even reach a neighbouring catchment, accessing other pipes not yet drowned. Other times, water may be temporarily stored inside lower open areas, like parks or squares, as well as inside buildings, in an undesired way. Urban flood control is a matter of reorganizing flow patterns in space and time (Canholi, 2005). Combination of effects is a difficult question to be assessed in the scale of a catchment and, sometimes, the proposed solutions may not be effective. In this context, mathematical modelling may be an important tool to support the design of integrated urban flood control projects.

4.1 Urban drainage traditional design

Traditional practices of urban drainage design are based on canalisation works, in order to adapt the system to the generated and concentrated flows. This approach equates the undesirable consequences of the flooding process, which are the greater and faster discharges produced by the built environment.

The urban drainage system comprises two main subsystems: micro-drainage and macro-drainage. The micro-drainage system is essentially defined by the layout of the streets in urban areas, acting in collecting rainfall from urban surfaces. The macro-drainage is intended to receive and provide the final discharge of the surface runoff brought by the micro-drainage net. Macro-drainage corresponds to the main drainage network, consisting of rivers and complementary works, such as artificial canals, storm drains, dikes and other constructed structures.

In general terms, the urban drainage system design comprises the following steps: subdivision of the area into sub-catchments; design of the network integrating urban

patterns and natural flows; definition of the design rainfall, considering a certain time of recurrence and a critical time of duration, associated with the concentration time of each sub-catchment considered; step by step calculation of design discharges for each drainage network reach through the Rational Method or another convenient hydrological method; hydraulic design of each drainage network reach. Figure 2 illustrates this approach.

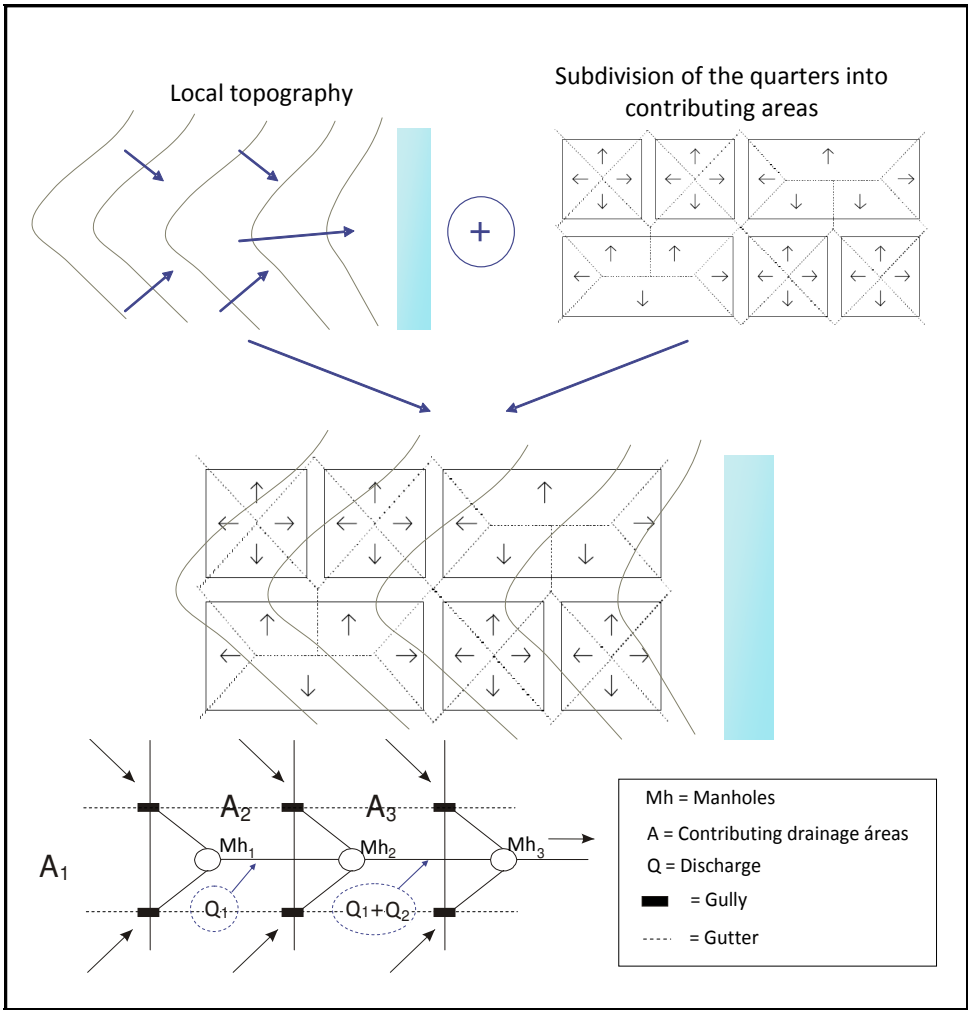

Fig. 2. Schematic urban drainage system classic design.

This approach greatly simplifies the real situation and focus only in conveying discharges. Although it may be useful in certain design situations, spatial and temporal effects combination are main factors to be considered when urban floods occur. It is important to have the assistance of a mathematical model as an assessment tool and solutions should be addressed to the catchment as a whole.

4.2 Urban drainage design trends

The traditional approach for drainage system design is being supplemented or replaced by newer concepts that seek for systemic solutions, with distributed actions over the catchment, trying to recover flow patterns similar to those that happened prior to urbanisation. Storage and infiltration measures are considered together in integrated layout solutions. Moreover, these new trends add concerns of water quality control, as well as enhance rainwater as a resource to be exploited in an integrated approach for sustainable management of urban stormwaters. Besides, the possibility of combining flood control measures with urban landscape interventions, capable to add value to urban spaces, with multiple functions, is becoming an interesting option from the point of view of revitalising degraded areas, as well as optimising the available resources for public investments.

The vision of integrating urban drainage projects with urban development plans and land use and occupation management, provides a better temporal and spatial range of action for flood control projects, as it seeks to intervene not on the consequence of heavy rains, but on the inundation causes. The changing to a point of view of more sustainable solutions on urban drainage requires a commitment with the future consequences concerning the decisions taken today; so solutions must be flexible enough to allow possible modifications and adaptations in the course of urban development (Canholi, 2005).

In urban drainage, sustainability implies that urban floods may not be transferred in space or time. Urban drainage systems have to be planned in an integrated way with urban growth and drainage solutions should be integrated with urban landscape (Miguez et al., 2007). In this context, urbanisation process and urban land use control have both to be thought in order to minimise impacts over the natural hydrological cycle.

This discussion leads to an important point: the understanding on how urbanisation interferes with flow patterns is necessary to develop strategies for stormwater management and urban floods control, by one side, and to establish urban development standards on the other side. Urban drainage planning must consider a broad set of aspects and has to be integrated with land use policy, city planning, building code and all the related legislation. It is possible to say that urban flood control demands the adoption of a varied set of different measures and concepts. Among these measures it is possible to distinguish two greater groups of possible interventions: the *structural measures* and the *non-structural measures*.

Structural measures introduce physical modifications on the drainage net and over urban catchment landscapes, like canalisation, dams, reservoirs, urban flood parks, dykes, among others, intending to change the relations between rainfall and runoff and to reorganise flow patterns. *Non-structural measures* work with environmental education, flood mapping, urbanisation and drainage planning for lower development impacts, warning systems, flood proofing constructions, and other actions intending to allow a more harmonic coexistence with floods.

Structural measures are fundamental when flood problems are installed, in order to bring the situation back to a controlled one. *Non-structural measures* are always important, but are of greater relevance when planning future scenarios, in order to obtain better results, with minor costs.

Under this new perspective, the urban drainage projects, in theory and whenever possible, should neutralize the effects of the urbanisation, restoring the hydrological conditions of the pre-urbanisation, bringing benefits to the quality of life of the population and aiming the environmental preservation.

4.2.1 Structural measures

Structural measures can be classified according to their performance in the catchment. According to Tucci (1995), they can be divided in *distributed measures*, *measures in the micro drainage* and *measures in the macro drainage*, as detailed below and exemplified in Figure 3.

- *Distributed Measures*: these measures act on the lot, squares and sidewalks. They are also known as source control measures.
- *Measures in the micro drainage*: these measures act on the resulting hydrograph from one or more lots.
- *Measures in the macro drainage*: these measures act on the rivers and channels.

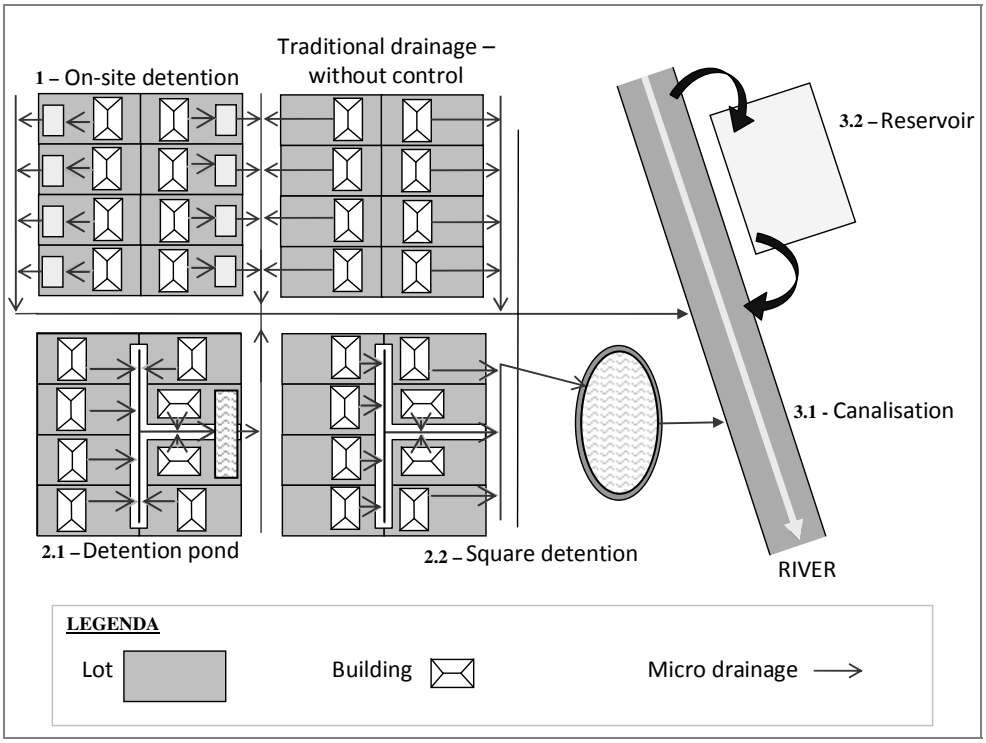

Fig. 3. Examples of flood control measures according to their working principle:
1. Distributed Measures; 2. Measures in the micro drainage; 3. Measures in the macro drainage (Rezende, 2010).

Canalisation is, undoubtedly, the more traditional measure adopted in flood control interventions. Its main objective is to improve the hydraulic discharge capacity of the macro drainage network, through the removal of obstructions to the flow on the main channels, the river channel rectification and the revetment of the riverbanks. Another traditional measure widely used to contain river overflow is the implementation of dykes associated with polders, especially in low areas of the catchment, which allow the protection of the urbanised plains. The protected areas, which remain unable to drain the precipitated water over its own local catchment during the river flood events, are generally linked to the main water body by one-way gates (FLAP gates) or by pumping stations. Thus, it is necessary to preserve unoccupied areas inside the polder to receive and temporarily store these waters.

Another set of measures, as an alternative to the simple improving conveyance, proposes to act with the possibilities of storage and infiltration. Important examples of this set of measures are the *detention ponds*. These measures used to be generally designed at the upstream reaches of the most urbanised regions, where the occupation still is sparser and where there are available areas for the implementation of the ponds. In situations where the urbanisation occupies every available space, the detention ponds have been adapted to other scales, allowing the use of public spaces such as parks, parking lots and squares, in order to temporarily store the rainwater from less frequent events and also add value to the urban environment and region, as can be seen in Figure 4, showing a detention pond implemented in Santiago (Chile), which is associated with a landscaping design. The use of this kind of structure has a very wide spectrum, and it may be used through the implementation of large ponds, or by the distribution over the watershed of several of these devices, where they can act in squares or even inside the lots.

Fig. 4. A detention pond in Santiago, Chile (Photo Miguez, 2009).

Another possibility for stormwater storage measures may be the use of reservoirs that have the goal of improving water quality. These structures are the *retention ponds* and the *constructed wetlands*. It should be noted that the main objective of these measures is the treatment of rainwater, remaining smaller its quantitative effects. This is due, in part, by the need to provide a permanent pool and also a greater time of permanence of the water inside the reservoirs, to enable the treatment processes with the required efficiency. Figure 5 presents a picture of a *retention pond,* constructed in the city of Lagord, France. This pond is part of a drainage plan of the whole region of La Rochelle, which includes the city of Lagord, aiming for the treatment of rainwater.

Fig. 5. A retention pond in Lagord, France (Photo Rezende, 2009).

Measures that aim to favour infiltration processes of the rainwater in the ground, allowing the partial recovery of the natural hydrology of the watershed, are also interesting options in the context of flood control. They may assume different configurations, according to its operation.

An important measure in this context, also because its environmental implications, may be the *reforestation* of degraded areas, such as hill slopes and riverbanks that have been illegally occupied. Miguez & Magalhães (2010) indicate that reforestation prevents soil erosion, preserves the superficial soil layer and promotes the infiltration and, thus, the volume of runoff is reduced, allowing the correct functioning of drainage structures, since smaller amounts of water and sediments reach the system.

4.2.2 Non-structural measures

Structural interventions for flood control do not provide a complete risk protection for the design areas. These areas may be still subjected to flood events with a magnitude greater than that of the protection designed level. So, measures that aim to prevent the population from these risks and help them to deal with flooding are necessary. Unlike the structural measures, which act physically changing flow relations, the non-structural measures goal is to reduce the exposure of lives and properties to flooding. A wide range of possible actions, from urban planning and flooding zoning until individual flood-proof constructions, compose this set of measures.

Johnson (1978) identified the following non-structural measures: installation of temporary or permanent sealing in the opening parts of the buildings, elevation of pre-existing structures, construction of new elevated structures, construction of small walls or dykes surrounding the structure, relocation or protection of goods that could be damaged within the existing

structure, relocation of structures out of the flooding area, use of water resistant material in new structures, regulation of the occupation of the flooding areas, control of new community settlements, regulation of parcelling and building codes, purchase of flood hazard areas, flood insurance, implementation of forecasting and flood warning systems with evacuation plan, adoption of tax incentives for a prudent use of the flood area, and installation of alerts in the area.

5. Sustainable urban drainage systems concepts

The urban drainage system needs to be viewed in an integrated way in the context of the sustainable urban development. It is crucial to understand the crossed relationships between urban growing and flood problems. The aspects involved vary from environmental conservation, land use control, low impact development, and healthy city life. To achieve these goals, related to a sustainable urban drainage, however, it is necessary to construct a framework integrating legal, institutional, social, technical and economical aspects. In this context, it is important to clearly identify the applied regulation in terms of urban zoning and land use control, the water resources policies and the water resources management practices, the integrated environmental sanitation opportunities and constraints, the building standards and limitations, the role of the institutional agents and community participation. Areas to be protected from urban growth need to be delimited, as well as, sometimes, it will be important to recover areas already occupied. This is not simple, due to social pressures against possible dwelling relocation procedures. In developing countries, for example, it is common to have "informal" cities, conforming slum areas growing on risky situation, along riverine areas or hill slopes. Landscape changing should be minimised and original river characteristics could be recovered. In this context, preventing urban land to be heavily impervious is one of the major goals. Minimising impacts on the urban water cycle is of fundamental importance. The development project must comply with natural hydrological aspects or provide compensatory measures for urbanisation changes. The watershed, as a complex and integrated system has to be considered as a whole, not only in physical terms. This must be the unit of planning and design. The documents that integrate urban development and the strategies for a sustainable drainage system, and, therefore, a sustainable city, are the Urban Development Master Plan and The Urban Stormwaters Master Plan.

The non-existence or non-fulfilment of plans for urban development leads to drainage and flood control projects that are restricted to emergency, reactive, and sporadic actions, defined just after the occurrence of disasters (Pompêo, 2000).

This scenario, usually based on the simple and quick removal of water from highly impervious areas by means of canalisations, has become unsustainable and requires a new vision into the problem of urban flooding. Holz & Tassi (2007) suggested that the current drainage system should dismiss the solution of simple removal, as fast as possible, of the non-infiltrated stormwaters that come from the increasing in soil imperviousness, replacing it with measures aiming to mitigate the impacts of this process by facilitating the infiltration and water retention in order to regenerate the hydrological conditions of pre-urbanisation. They emphasize, however, the importance of combining the use of traditional and unconventional drainage structures in order to optimise the system. The fall of the old paradigm should not be simply substituted by a new one. The traditional techniques have to

be adapted to a new use, adding the accumulated knowledge to the sustainable solution. Pompêo (2000) emphasizes the need to think the activities related to mitigation of floods in a preventively way, highlighting the value of planning applied to flood control projects. In this context it is introduced the ecosystem approach, which represents the evolution of the reactive thought of the conventional Drainage Master Plan for a proactive and advanced thought in the form of management of the natural and built environment, considering them as interdependent and integrated components. An ecosystem approach can result in lower costs, since it seeks to reduce the need for costly and complex actions of remediation, emphasizing the orientation and planning decisions on land use changes. This option tends also to reduce costs of maintenance over time, because more natural arrangements tend to work by themselves.

This new vision has been based on the concept of Sustainable Development. It's possible to affirm that these systems are designed to both manage the environmental risks of urban stormwater and contribute, whenever possible, to an improved environment and quality of urban life.

Sustainable drainage projects aim to reduce runoff through rainwater control structures in small units. This way, the runoff control performed on source reduces the need for large structures of mitigation and control on the river channels.

Environmental issues presented today to the cities highlight the failure of technical solutions for urban drainage projects, demanding a new approach which should focus on the problem of urban flooding by incorporating the social dynamics and the multisectoral planning in the search of solutions (Pompêo, 1999).

The urban infrastructure systems are interdependent and the fact of not considering the effects of one system over another, or of a system over the urban environment, can reduce the efficiency of these systems or even turn not viable their operation, as is the case of the relations between Drainage and Flood Control systems and Water and Sanitation, Solid Waste, Land Use and Housing systems. Two trivial examples in peripheral countries are the failure of the drainage system operation by the inefficiency or lack of management of municipal solid waste; or the deterioration of health by the inefficient sanitation conditions which, combined with flood events, provide the proliferation of water related diseases.

Problems associated with urban drainage systems are not exclusively technical, but primarily of institutional nature, such as the lack of cooperation between the different departments responsible for urban management and the communication between the city and its citizens (Stahre, 2005). The lack of cooperation between departments may arise from conflicting interests and priorities.

According to Stahre (2005), the Drainage Department of Malmo, Sweden, sees the approach of the sustainable drainage system as an ideal way to achieve its goals and objectives with a low cost, if compared to the traditional drainage system, whereas the Department of Parks and Recreation sees the sustainable drainage solutions as a good ally for the development and improvement of quality of life in the urban environment by increasing the value of urban parks. As a consequence of this sharing of interests, the costs of structures, deployment and maintenance can be divided between the two departments, and also with others that will share the benefits of implementing this system. Stahre (2005) concluded that

the solution of rainstorm problems can no longer be regarded as a simple technical service supported only by the Drainage Department, because these waters now represent an important positive resource to the population, inserted in the urban environment. It's important to emphasize the value of water in the city as a demanded resource, not wasting its potential uses.

The failure to consider the drainage in the urban development plans may result in more expensive solutions for flood control, often noneconomical. The successful implementation of a Sustainable Drainage System depends on the cooperation among the different technical departments responsible for urban planning and the active participation of the population.

In this context, the existence of compatibility among the Urban Development Sanitation, Solid Waste and Urban Drainage Master Plans, aiming the integrated planning of the city should be ensured.

The design of the Urban Stormwater Management currently presents, according to Righetto et al. (2009), the aggregation of a structural and non-structural set of actions and solutions, involving large and small works and planning and management of the urban space.

The Stormwater Management Plan of the City must necessarily meet the principles of Sustainable Management of Urban Stormwater, and should seek the following objectives (Ministério das Cidades, 2004):

- Reduce the damage caused by floods.
- Improve the health of the population and of the urban environment, within the economic, social and environmental principles.
- Plan the urban management mechanisms for the stormwaters and the municipality river network sustainable management.
- Plan the distribution of stormwaters in time and space, based on the trend of evolution of the urban occupation.
- Regulate the occupation of areas at risk of flooding.
- Partially restore the natural hydrological cycle, reducing or mitigating the impacts of urbanisation.
- Format an investment program of short, medium and long term.

The drainage projects proposed by the plan should provide the most cost-effective relation, covering social and economic aspects, as well as being integrated into the guidelines of the local River Basin Committee, if any.

The plan must also contemplate a socio-environmental work, through the development of a project that addresses social mobilization, communication, training of educators / agents in the area of environmental sanitation and other environmental education activities, aiming a social-economic and environmental sustainability, including the community participation in the phases of design, implementation, evaluation and use of the proposed works and services.

The premises to be considered in the creation of the Stormwater Management Plan are (Ministério das Cidades, 2004):

- Interdisciplinary approach in diagnosing and solving the problems of flooding.

- Stormwater Plan is a component of the Urban Master Plan. As drainage is part of the urban infrastructure, it should, therefore, be planned in an integrated way.
- Runoff cannot be intensified by the occupation of the basin.
- The Plan has as its planning unit each watershed of the city.
- The stormwater system should be integrated into the environmental sanitation system, with proposals for the control of solid waste and the reduction of stormwater pollution.
- The Plan shall regulate the territory occupation by controlling the expansion areas and limiting the densification of the occupied areas.
- This regulation should be done for each watershed as a whole.
- Flood control is a permanent process and should not be limited to regulation, legislation and construction of protection works. A plan to monitor and maintain the proposed measures is needed along time.

It is important to schedule the actions of the Stormwater Management Plan in time, recognizing short, medium and long term actions, to ensure enduring solutions for drainage. Short-term measures intend to correct or mitigate the immediate problems of macro-drainage network, promoting the removal of singularities, desilting and maintenance of the original characteristics of the system. Measures to prepare the required database for the consubstantiation of the plan are also important. The construction of a mathematical model should also be among the initial activities, to provide a systematic evaluation tool. Also among the short-term activities, it is necessary to make a diagnosis for the watershed.

After that initial stage, in the short/medium term, measures should be designed to control runoff at the source and for the recovery of the natural hydrological cycle characteristics. These measures should be scheduled, to be implemented over time. Flood maps should be provided for the evaluation of the proposed scenarios and, also, allow the definition of interactions with land use zoning.

From the developed experiences, it may be possible to produce a practical drainage manual, in the medium/long term, bringing together recommendations for all the developments and future projects. The long-term actions should sustain an adequate operation for the drainage system, through maintenance and monitoring. Environmental education campaigns and community engagement are also needed to help in supporting the proposed solutions.

6. River revitalisation

It is known that self-sustaining river systems provide important ecological and social goods and services to human life (Postel and Richter, 2003 *apud* Palmer *et al*., 2005). River revitalisation is an issue that comes as a necessity to face the progressive deterioration of river ecosystems worldwide. The results can be analysed not only from the aesthetic viewpoint and to improve the environment, but also in terms of hydrologic and ecologic functioning of restored river reaches, increasing the quantity and quality of river resources and their potential use to riverine population (González del Tánago & García de Jalón, 2007). In urban areas, River Revitalisation is more complex, because of the large modifications suffered by the riverine areas, with the construction of buildings and roads, which make it difficult to have the space needed to recover the natural processes of the river bed and its banks (*ibid*). The river revitalisation process needs to be discussed in a particular

way for urban areas and a consensus solution between the natural landscape and the built environment must be found.

In highly urbanised regions, generally the available areas for interventions are scarce, there are numerous socio-economic problems, which make the revitalisation process very complex, because it involves the need of large riparian areas, in order to find space for the river recover its natural course and flooding areas. However, even if these riparian areas were restored to the original natural condition, the heavy modifications that the catchment suffered over the time would probably lead to floods still happening. Thus, the space that would be required to recover the river course functions today is greater than the natural one. Actions in the basin have to be considered, to decrease the imperviousness and to rescue superficial retentions, with the use of reservoirs.

Urban water courses restoration is a challenge for managers, researchers, experts and citizens. In urban environments, the main focus must be on the restoration of the lateral connectivity with the river banks and its tributaries, the restoration of the river natural flow regime, as well as the increase of the degree of freedom of the river. The combination of flood risk management concepts with River Revitalisation measures can be a solution of efficient applicability in urban rivers, in comparison with traditional and localised drainage solutions (Jormola, 2008). Thus, what is expected is the creation of a self-sustainable natural river system, in order to maintain the flood control function after the flow patterns restoration. In this context, a sustainable approach for drainage system should consider River Revitalisation as one of the tools aligned with this major objective.

However, it's important to note that, even when the adopted measures configure only a partial revitalisation, they are important. In addition to reducing the peak flood, they help in the dissemination of this kind of techniques and provide a new perception about the existence of the river for the involved community. They also allow the river valuing and reintegration as part of urban landscape. Finally, it should be pointed out that any process of revitalisation takes time to be fully developed and find it complete. It is necessary to await the responses of the environment, regarding the "new" conditions to which it was submitted. During this time, complementary actions, resulting from the monitoring of this evolution may and should be developed.

7. Institutional aspects supporting the integration of a sustainable urban drainage system and the water resources management – the Brazilian experiences management

The legal framework comprising the different institutional and management levels is probably the first arrangement to be settled in the path of the sustainability. One of the questions that first arise refers to the urbanisation responsibilities. City development is an attribution of the Municipality, while water resources management is something that needs to consider the basin scale and, generally, comprises a regional planning. In Brazil, legislation shows a significant concern in providing tools for guiding the different institutional levels in the path to build a sustainable city. However, Brazilian cities, in general, do not present an adequate quality level for the built environment and the city life. In order to have a general view of the Brazilian legal framework for urban development and, in particular, for the achievement of sustainable urban drainage systems, a brief review is included as an introduction to this section, in the following lines.

The Federal Urban Land Parcelling Act (Brazil, 1979) establishes the minimum standards for urban developing. This Act considers that a plot is a parcel of urban land provided with the basic infrastructure, meeting the urban restrictions. This basic infrastructure refers to urban drainage, sewerage, water supply, electricity and public roads. The Act also states that it is not allowed to have allotments in flooding areas, in environmental protected areas or in polluted degraded areas. Another Federal Act, known as "City Statute" (Brazil, 2001), establishes detailed rules for public land use order and social interest that regulate the use of urban property in favour of the collectivity, the security and well-being of citizens and environmental balance. The urban policy aims to organise the fulfilment of the social functions of the city and of urban property by the application of a set of general guidelines, from which the following topics are detached for the purposes of the present discussion:

- guarantee the right to sustainable cities, meaning the right to urban land, housing, environmental sanitation, urban infrastructure, transport and public services, work and leisure for present and future generations;
- democratic management through people's participation and associations representing various segments of the community in the formulation, implementation and monitoring of plans, programs and projects for urban development;
- planning the development of cities to prevent and correct the distortions of urban growth and its negative effects on the environment;
- supply of urban infrastructure and community equipments, transport and public services to serve the interests and needs of the population;
- ordering and control of land use to avoid pollution, environmental degradation and excessive or inadequate use in relation to urban infrastructure;
- protection, preservation and restoration of the natural and built environment, and cultural, historical, artistic and landscape heritages.

Several important urban management tools are made available in the context of the City Statute. The Urban Master Plan is considered to be the basic instrument for the urban developing policy.

In the field of water resources management the "Water Act" (Brazil, 1997) defines that the hydrographical basin is the unit of planning and design for water resources purposes. Another important reference is the "Basic Sanitation Act" (Brazil, 2007). This Act establishes the first national guidelines for the federal policy of basic sanitation. An important key element of this Act is the integrated conception of the sanitation services and their relation with the efficient management of water resources. For all purposes this Act considers sanitation as a set of services, infrastructure and operational facilities for drinking water supply; sewerage collection, treatment and disposal; urban solid waste management; urban drainage and storm water management.

As it was said in the beginning of this section, although legislation has merits, there are difficulties in urban development and control. This discussion and the possible ways to go further in urban sustainability, concerning urban waters, are the main points of the next topics.

7.1 The local planning and the management level

The jurisdiction of the municipality in federative countries focuses on roles that are generally related to the provision of local public services and to planning, supervision and development functions, which are related, among others, to land use planning, environmental protection and also to a certain level of economic activities regulation (Dourojeanni and Jouravlev, 1999). Considering the Brazilian case, recently the municipalities with larger investment capacity began to incorporate roles related to the provisions of social services that used to be traditionally restricted to the state and federal levels.

It is observed from the 1990's a tendency to extend the role of local public levels regarding the environment management. A lot of factors, however, limit the performance of the municipality in the water management. In Brazil, for instance, there are legal constraints determined by the Federal Constitution, where the cities cannot directly manage the water resources contained within their territories, except for certain formal agreements that transfer some assignments through cooperation arrangements with the State or the Union. Water resources management is a matter of river basin management and cannot be restrained to an administrative territory jurisdiction. Thus the role of the cities is restricted to lower levels of relevance and administrative autonomy (Jouravlev, 2003). Municipality participation in basin organisms for water resources management (called Basin Committees, in Brazil) has been the main stage where the interactions between Municipalities and the other public or private actors occur.

Despite of the fact that the administrative level of the municipality is the closest to social reality, its range of political and administrative roles does not allow a systemic vision of the territory in which it is inserted. In turn, the absence of a clear definition of the extent of local governments functions, in general, linked to the traditional tasks of territorial administration, the supervision and provision of local services, and the fact that most of the municipalities have a reduced financial autonomy, depending on transfers from other government levels, makes it difficult to them to have a more effective participation in the water management. Referring to the financial constraints, Lowbeer & Cornejo (2002) warn that the multilateral financing agencies, except for the Global Environment Facility -GEF, have not yet come to explicit in their agenda the need for integrated management projects of natural resources linked to the territory management and land use, particularly in urban areas. Few are the experiences implemented which have coordination between water conservation/preservation and regulation of the land use against the (dis)functions of urban growth.

Another aspect is that the essentially local nature of the city governments' interests makes them act more like water resources users rather than managers of these resources (Jouravlev, 2003). These aspects are exacerbated in metropolitan areas where local governments have often antagonistic interests and priorities, creating dissent environments with little room for cooperation. The metropolitan question is surely one of the greatest present challenges.

Even if there are restrictions to the municipalities' participation as direct managers of water resources, there is no doubt about the importance of local governments on planning and ordering the territory, due to its consequences on the water resources conservation. It is the

county attribution the elaboration, approval and supervision of instruments related to land use zoning and planning for development purposes, such as the Urban Master Plan, the delineation of industrial, urban, rural and environmental preservation areas inside the municipality, land parcelling criteria, the development of housing programs, among other activities that have impact on water resources and sanitation conditions, especially in predominantly urban watersheds.

According to Peixoto (2006), the history of the production process of the urban space and its impact on natural resources and human dwellings quality demonstrates the difficulties for articulation between urban and environmental issues. At the same time, however, it may be observed a trend of convergence of these issues towards sustainability, expressed on the federal Acts previous described in the beginning of this topic. Nevertheless, what is observed in the country is the disconnection between the practical instruments of water management and of land use planning, reflecting, perhaps, the lack of legitimacy in the planning process of Brazilian cities as well as certain gaps in local legislation. Several cities are marked by a high level of informality and even illegality in land use – social problems arise as a critical element and urban mesh degrades with spreading slums, also favouring several environmental impacts. According to Tucci (2004), the greatest difficulty for the implementation of integrated planning stems from the limited institutional capacity of the municipalities to address complex and intersectoral issues. However, it is relevant to point out that there are differences among cities, depending on its size, geographic position, distance from the metropolitan areas, historical urban structuring and evolution, qualification of the technical public staff. Peripheral districts in metropolitan areas, presents, sometimes, an outdated legislation, aggravated by the absence of reliable information and lack of quality technical support.

7.2 Integrated water resources management: interfaces with sectoral policies and territory planning

The institutional organisation of water resources in Brazil began in the 1930s with the establishment of the Water Code, in 1934. The Water Code represented a milestone in the institutionalisation of the water planning in the country, allowing the expansion of the electricity sector. The granting of hydroelectric developments and electricity distribution services went to the Union with the establishment of this Act. In the same year it was also created the National Department of Mineral Production (DNPN, in Portuguese), within the Ministry of Agriculture, which incorporated the Service of Geology and Mineralogy and the Water Service. During the year of 1938, it was created the National Council of Water and Power, attached to the Presidency that, together with the DNPN, became in charge to decide on water and electrical energy in the country.

Even before the 30's, several governmental committees had been set up in order to coordinate and implement water works. However, the onset of a coordinated action in the water sector has only occurred in 1933, with the creation of the Sanitation Committee of Baixada Fluminense, in the framework of National Department of Ports and Navigation. Baixada Fluminense is an important region, in the metropolitan area of Rio de Janeiro City, characterised by extensive lowlands. This Committee was responsible for the formulation of a comprehensive drainage program for Baixada Fluminense, which was an unprecedented action in the country, with the main aim to make this vast lowland plains of the State of Rio

de Janeiro arable and, secondarily, to eradicate yellow fever and to control the local floods (Carneiro, 2003).

This Committee was the seed of the National Department of Sanitation Works – DNOS (in Portuguese), in 1940, created with the responsibility for implementing the national policy of general sanitation, both in rural and urban spaces, including flooding mitigation, erosion and water pollution control, and the recovery of areas for agricultural or industries uses, as well as the settlement of water supply and sewage systems. Despite the range of assignments given to DNOS, its performance was limited, in its initial phase, to the drainage work for drying wetlands, consolidating and expanding the program prepared by the Sanitation Committee of Baixada Fluminense (*Ibid*).

Dourojeanni and Jouravlev (2001), referring to the experiences of integrated management in Latin America, point out that many of the institutions set up from the 1940's were increasingly incorporating multiple uses of water, even though they used to have as initial particular goals - like flood control, hydroelectric plants, irrigation projects and water supply. Few were those which began their activities by integrating these multiple uses of water.

An important experience in water management in the country, considering the perspective of integrated water resources management, was the creation of the Special Committee for Integrated Watershed Studies (CEEIBH, in Portuguese), in 1978. Supported by CEEIBH, several watersheds committees were constituted. However, despite the important role of these committees on the preparation of studies and investment plans for the recovery and management of the related watersheds, the efforts and experiences have not been able to establish an integrated management of the water resources, nor the implementation of proposed actions could reverse the basins degradation. They also failed to avoid sectoral and fragmented management practices. In part, the low effectiveness of these initiatives was due to the fact that these committees had a merely advisory feature.

Until early 1985, the National Department of Water and Electrical Energy (DNAEE, in Portuguese) was responsible for the management of water resources in the country. Since 1988, however, with the new Federal Constitution, a set of modifications in the water sector was introduced: the definition of Federal/State dominion of the water bodies, the definition of the water as a public good endowed with economic value and the need for the integration of water resources management with land use management policies. In 1995 it was created the Water Resources Secretariat, linked to the Ministry of Environment, with the objective to act in the planning and control of the actions related to water resources in the Federal Government, among others. This institutional change represented the incorporation of the concept of multiple uses of water in the environmental context (CEPAL, 1999).

With the approval of Act 9,433, in 1997, the country received one of the most complete regulatory frameworks focused on water resources managing in the international scenario. The National Water Resources Management System aims to coordinate the administration of water resources in the country seeking to integrate it with other sectors of the economy; administratively arbitrate conflicts related to water uses; implement the National Water Resources Policy; plan, regulate and control the use, preservation and restoration of water resources; and charge for water use, among others. This Act establishes that the watershed is the territorial unit for the National Water Resources Policy implementation and for the National Water Resources Management System actions.

The principles adopted by the Water Act, as the Act 9.433 became known, are adherent to the statements of the major international conferences that have dealt with the water issues and which substantially contributed to the concept of development on a sustainable basis. However, as several authors emphasize (Dourojeanni & Jouravelev, 2001; Cepal, 1999), the integrated management of water resources requires a change on planning paradigms, in both public and private levels. Integrating these variables implies on operate in various fields of public policies, especially in those related to regional and urban development and the institutional arrangements that shape those policies. According to Silva & Porto (2003), the institutional planning and management of water resources system faces four types of integration challenges:

- Integration among activities directly related to the water use in the basin: water supply, wastewater depuration, flood control, irrigation, industrial use, energy production, in order to optimise the multiple use under the perspective of a joint management of water quality and quantity;
- Regulatory articulation with sectoral systems that do not use directly the water resources, such as housing and urban transportation, in order to prevent excess of imperviousness or urban pollution impacting water sources;
- Territorial integration with the instances of urban planning and management, in order to apply preventive measures in relation to the urbanisation process, avoiding the increasing demand of quantity and/or quality of existing water resources, including flood occurrences;
- Articulation with neighbouring basins, celebrating stable agreements on the current and future conditions of imported and exported flows of the waters used in the basin.

7.3 New institutional arrangements: watersheds and metropolitan areas

The current approach for the water resources management in urban areas presupposes an inseparable and integrated planning for urban development projects. Tucci (2004) proposed an approach where aspects related to watershed protection, sewerage collection and treatment, solid waste collection and disposal, urban drainage, river floods and land use are treated in an integrated way, considering the Urban Master Plan as the central point.

Gouvea (2005) stated that the dynamics of the urban growth, often disordered and even chaotic, was gradually showing the ineffectiveness of many programs and projects implemented in isolated modules and developed from the mistaken idea that the urban reality could be divided and treated in a compartmentalised way. The author notes that actually the city must be seen not only as a specific and complex system, but also as part of a larger system, regional or even national, made up of several subsystems, such as habitation, public transportation, sanitation, natural environment, etc., which are closely related and require an integrated and multidisciplinary approach.

Tucci (2004) lists some factors that hinder the application of the integrated management concepts in cities, as follows:

- absence of adequate knowledge on the subject: the population and professionals from different fields and levels who do not have adequate information on the problems and their real causes. The decisions usually result in high costs. For example, the use of canalisation works as drainage solutions is a widespread practice in Brazil, even when

they represent high costs and impacts. Generally, the channels transfer flood downstream, affecting another part of the community. These works can reach an order of magnitude of 10 times the costs of on-source control measures;
- inadequate design for urban systems control: an important part of the technicians who work in urban issues is outdated about the environmental concerns;
- fragmented vision of the urban planning: urban planning and development do not always incorporate integrated aspects related to water supply, sewage, solid waste, flooding and urban drainage;
- lack of management capacity: the cities are not designed for proper management of the different water aspects in urban areas.

The situation is even more critical in the metropolitan areas that have a high level of conurbation. It is no coincidence that new institutional arrangements for the cities management have aroused the interest of technicians and researchers who identify the need for the resumption of planning on a regional basis, without neglecting, of course, issues that could and should be treated locally. Therefore, the challenges related to urban waters management combined with the intense process of territory occupation, develop into specific problems of the built environment that require a tailored approach. The following sub-items discuss the new institutional arrangements and the perspectives they bring to fill the institutional gap left by the absence of metropolitan instances for intensely urbanised cities planning in Brazil.

7.3.1 Watershed committees

The central figure in the water resources management system is the watershed committee. The committees are public political organisms of decision making, with legislative, deliberative and advisory powers, concerning the use, protection and restoration of water resources, involving a wide representation of organised sectors of civil society, governments and water users.

The committees work as a decentralised locus for discussion on the water uses issues of a watershed, acting as a mediating instance among different interests. These committees are seen as "water parliaments", playing the role of the decision maker within the basin context. The committees composition, as provided by Act 9,433, comprises the Union, the States and the Cities located, even if partially, in the respective basin; the water users within basin area; and the civil water resources entities with activities in the basin.

Nevertheless, it is a fact that the committees established in the country have found great difficulties in fulfilling their decisions and in executing their investment plans. Two main aspects can be identified as constraints to the action of the committees. The first one is that the revenues from charging water uses, which is the only funding source of the committees, are not enough to make the necessary investments for the watersheds recovery. Thus, the committees remain dependent on the traditional sources of investment, which have their own mechanisms for eligibility and prioritisation. The second aspect is that the committees have not gained the necessary political and institutional legitimacy for the public policies coordination related to the watershed, nor could it guide the investments to target actions of its interest. This last aspect stems from the fact that the basin does not constitute a political space reference for Brazilian institutions

Without disregarding the committees importance in the public policies decentralisation and in the society participation, the above pointed aspects restrict the possibilities of the committees working as integrators of public regional policies.

7.3.2 Public consortia

The possibility of forming consortia in Brazil dates from the late nineteenth century; however, there were, over time, numerous configurations and autonomy design of these instances of inter-municipal cooperation. Table 1 summarises the forms of consortia planned in Brazil for over a century.

Period	Organisation Model
1891 - 1937	The consortia were contracts celebrated among municipalities whose effectiveness depended upon state approval.
1937	The Constitution recognises that municipalities association in consortia are legal public entities.
1961	It is created the first Brazilian inter-federative autarchy.
1964 - 1988	Administrative consortia arise as collaboration agreements without legal personality.
From 1998	Creation of several public consortia. The Constitutional Amendment n^0 19 changed the art. 24 of the Constitution of 1988, introducing the concepts of public consortia and the associated management of public services.
2005	Public Consortia Act
2007	The Decree 6,017, of 17-01-2007, regulates the Public Consortia Act

Source: Adapted from Rieiro, 2007.

Table 1. Consortia Models provided in Brazil in the period 1891-2007.

As it can be seen, between 1964 and 1988 administrative consortia arose as simple collaboration agreements, without legal personality, reflecting the period of centralism of the military government. From the 1990s, based on the Constitution of 1988, a great number of public consortia appeared in Brazil, especially in the health field. Consortia were also formed around specific themes, being the most common the regional development and the environment, water resources and sanitation.

Most of the consortia established in the country involve small and medium communities. Only 5% of the consortia include cities with more than 500,000 inhabitants (Spink, 2000, apud Gouvea, 2005). Gouvea (2005) states that the main obstacle to the formation of inter-municipal cooperation is still the autarchic aspect of the Brazilian municipalities, in a 'compartmentalised' federalism context, which rigidly separates the counties. Thus, the Brazilian federative framework does not ease the cooperation between municipalities.

The discussion about the new Public Consortia Act began in August 2003, aiming to regulate the Article 241 of the Constitution and give more legal and administrative security to the partnerships among the consortium parts. In 2005, the Congress approved the new Act. The public consortia, according to this Act, are partnerships formed by two or more entities of the federation to achieve common interest goals, in any area. The consortia can

discuss how to promote the regional development, manage solid and wastewaters disposal, and build new hospitals or schools. They have their origin in the municipalities associations, which were already established in the Constitution of 1937. One of the purposes of the public consortia is to enable and make viable the public administration of the metropolitan areas, where urban problems solutions require joint policies and actions.

The consortium also allows small municipalities to act in partnership and, with a gain in scale, improve their technical, operational and financial capabilities. It is also possible to make alliances in areas of common interest, such as watersheds or regional development poles, improving public services. Indeed, the new Act brought to the public scene a promising tool for the management of common problems in urban areas, offering to the public entities a viable alternative for cooperation at the supra-municipal level.

7.3.3 Sanitation sector regulation

After a long period without a regulatory mark for the sanitation services, it was approved, on 5 January 2007, the Basic Sanitation Act, nº 11,445. With this Act, the country established a modern regulatory mark for the sanitation sector, integrated with the National Policy of Water Resources Management, and establishes the national guidelines for the basic sanitation sector.

This Act considers as basic sanitation the public supply of potable water services; the collection, transportation, treatment and adequate sewage final disposal; the collection, transportation, transfer, treatment and final disposal of household waste and garbage originated in the public streets and open areas; the drainage and urban storm water management, considering the conduction, detention or retention of the flood flows and the treatment and final disposal of the rainwater drained from the urban areas.

The Act states in its fundamental principles, among other things, the need of making the sanitation services available for all urban areas, preserving citizens health and public and private structures. The sanitation services need to be articulated with urban and regional policies of development and integrated with water resources management. These principles clearly demonstrate the integrative perspective of the Act, fleeing from the traditional view of the sanitation sector in the country, especially when compared with the actions of the former National Department of Sanitation Works (DNOS).

The Basic Sanitation Act also provides several innovations, among others, the possibility of the holders of public sanitation services delegate these services to Public Consortia.

Another unprecedented advance is the possibility of including in the contracts some progressive and gradual goals for services expansion, increasing in quality, efficiency and rational use of water, and energy rationalisation.

Members of the Federation are also allowed to establish funds, separately or together in public consortia, which may be composed, among other resources, by a portion of the revenue from the services, in order to cover the costs of the universalisation of the public sanitation. These funds, in addition to traditional funding sources, can solve the chronic lack of financing for the sector, especially in relation to urban drainage, where resource allocation is more uncertain.

The Act consolidates the possibility of formation of the Public Consortium for providing regionalised public sanitation services, as stated in the Public Consortium Act.

The Decree nº 6,017 of 17 January 2007, that regulated the Public Consortia Act, details the way public bodies may constitute consortia. The first aspect to be noted is that the public consortium will be constituted as a legal entity formed solely by members of the Federation, organised as a public association, with legal personality under public law and autarchic nature, or as a legal entity of private law with non-profit aims.

The goal of the consortium will be determined by the associated public entities, assuming, among others, the following possibilities:

- associated management of public services;
- services provision, including technical assistance, structures construction and goods supply to the direct or indirect administration of the consortium members;
- sharing or common use of the equipments or instruments, including those for management, maintenance, data processing;
- technical studies production;
- water resources rational use promotion and the environment protection;
- performance of functions in the water resources management system that have been to them delegated or authorised;
- local and regional policies and actions for urban and socio-economic development.

The prevision for the exercise of the multi-sectoral functions opens the way for the establishment of a technical agency with legal competence for integrating the public policies involving environment, water resources, sanitation and land use planning within a regional scope.

7.4 Integrated perspectives: water resources, sanitation and urban development

Probably, the most urgent and complex task of the agenda of public managers really committed to build a sustainable future for the cities refers to promote the integration of public policies concerning water resources, sanitation and urban land use ordering.

The metropolitan question is an issue of increasing importance, and the built environment worsens with the growing of the cities and the conurbation process. At the moment, in Brazil, there are available tools for building institutional arrangements that resume the management in metropolitan basis, replacing the model that prevailed in the last twenty years, which focused in local and fragmented policies. Thus, there are reasons to believe that the new institutional arrangements figuring in the country offer alternatives for the shared management between states and municipalities, especially in the larger urban agglomerations. The public consortia may have more political and legal legitimacy to plan the interventions that could cause better impacts in the territory, in an integrated manner, interacting with all the levels of government and society. It is strongly needed the long-term planning resumption, based on effective cooperation mechanisms.

Specifically regarding the action of the municipalities, there is a vast field of possibilities to be sought, especially after the approval of the City Statute. The new Master Plans, previewed in this statute, can and should incorporate mechanisms for a more effective

management of land use, using a wider range of legal, economic and tax-oriented instruments for the urban development on a sustainable basis.

Finally, the improvement of the technical management of cities and metropolitan areas challenge remains. Again, it is stressed the need for creation of cooperative structures, not only among the various municipalities of the same metropolitan area, but also between these municipalities and the state, for the definition and implementation of policies in an integrated manner.

8. Case study: the seek for sustainable solutions for urban floods in Iguaçu-Sarapuí river basin at Rio de Janeiro state, Brazil

A case study regarding the Iguaçu-Sarapuí River Basin, located in the western portion of the Guanabara Bay Basin, which lies in the Metropolitan Region of Rio de Janeiro is discussed. Figure 6 shows a map of this area, with the Cities that are in this basin. This is one of the most critical areas in the state regarding urban flooding. This region is densely occupied and presents great urban and industrial development areas, as well as wide rural zones in an urbanising process, and reminiscent areas of natural vegetation on the upstream reaches of the basin. This case study intends to illustrate and complement the conceptual discussion held in this chapter and to show how complex the interaction of urban drainage problems and the city growth can be in a context of an unplanned and non integrated reality. In this region, urban expansion dynamics is, in general, marked by irregular occupation, in terms of land tenure and urban regularisation, and lack of sanitation.

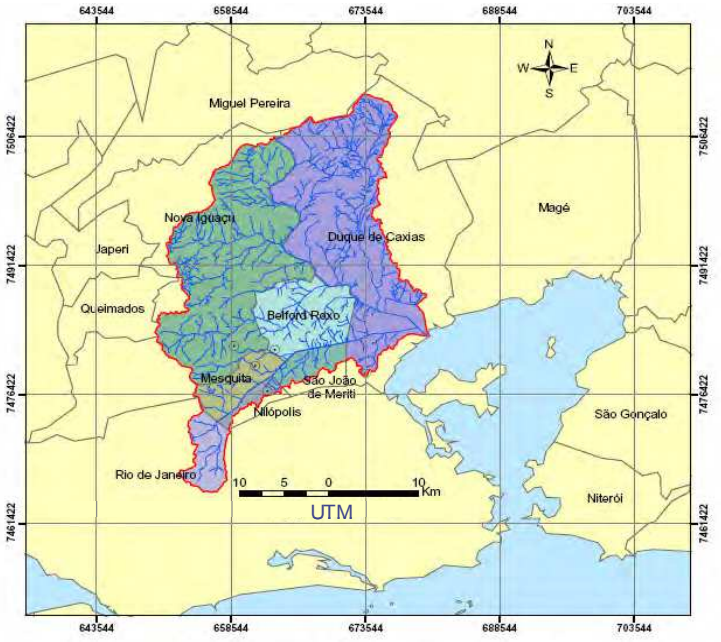

Fig. 6. Iguaçu-Sarapuí River Basin at Baixada Fluminense Lowlands in the Metropolitan Area of Rio de Janeiro.

The region under consideration has a great portion of Baixada Fluminense Lowlands. Interventions for flood mitigation were supported by Federal Government on 1930's (canals construction, dams, floodgates and pumping stations). At that time, the hydraulic structures were projected for agricultural uses. A migratory process for this area began on the 1950 's and accelerated from the 1970's on. In the beginning of the 1990 decade, Baixada Fluminense Lowlands sheltered more than 2 million inhabitants in 6 counties. More than 350 thousand of these inhabitants suffered the effects of significant floods. The chaotic process of urbanisation resulted in the occupation of the main rivers bed, what has made almost impossible the maintenance of the watercourses; the acceleration of the process of rivers and canals sedimentation due to deforestation of the slopes and inadequate solid waste disposal; and the increase of the runoff, due to uncontrolled vegetal removal and consequent substitution by impervious surfaces.

The basin of Iguaçu-Sarapuí River, in the past years, became a stage for articulated actions focusing on flood control and environmental recovery, in the context of the revision of its Water Resources Master Plan, in a study made by the Federal University of Rio de Janeiro for the State Institute of the Environment (INEA, in Portuguese). This study was supported by a mathematical model, called MODCEL, capable to represent the system in integrated terms (Mascarenhas & Miguez, 2002). Figure 7 shows the mapped flood conditions for present situation, represented over the modelled area of Iguaçu River Basin.

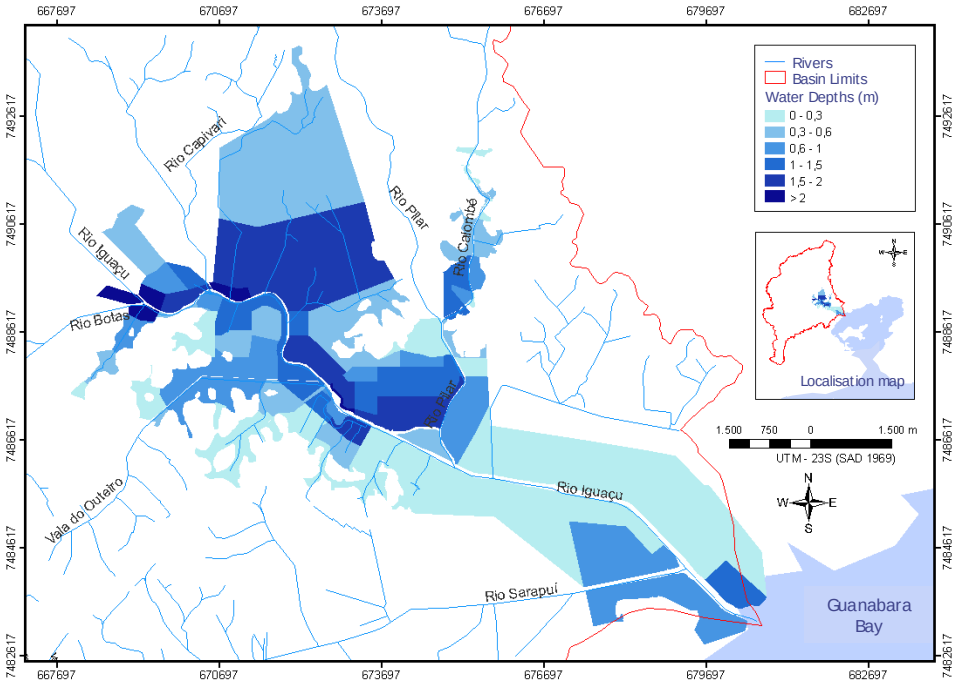

Fig. 7. Flood map of Iguaçu River Basin, for a design rainfall of 20 years of return period, calculated with a mathematical model aid.

Some of the proposed actions were:

- maintenance of spaces free of urbanisation, preventing the aggravation of flooding at the consolidated urban areas;
- land use regulation and control, by means of the establishment of Environmental Preservation Areas;
- implementation of urban parks;
- creation of public consortiums for integrated planning of policies for multi-counties interests (recognising the importance of the metropolitan planning);
- revision and adaptation of the municipalities urban planning instruments.

Three kinds of parks were designed:

1. Fluvial Urban Park – longitudinal parks along rivers, with the purpose of protecting water course banks, also avoiding their irregular occupation by low income population.
2. Flooding Urban Park – longitudinal parks implemented in low elevation areas to allow frequent inundations, which will help to damp flood peaks.
3. Environmental Urban Park - parks with greater dimensions, flat or not, with the purpose of environmental preservation and land use valuing, aiming to minimise runoff generation and maintaining a buffer of pervious surfaces.

Figure 8 shows the general propositions for Iguaçu River Basin, while Figure 9 shows two more detailed examples of the proposed parks.

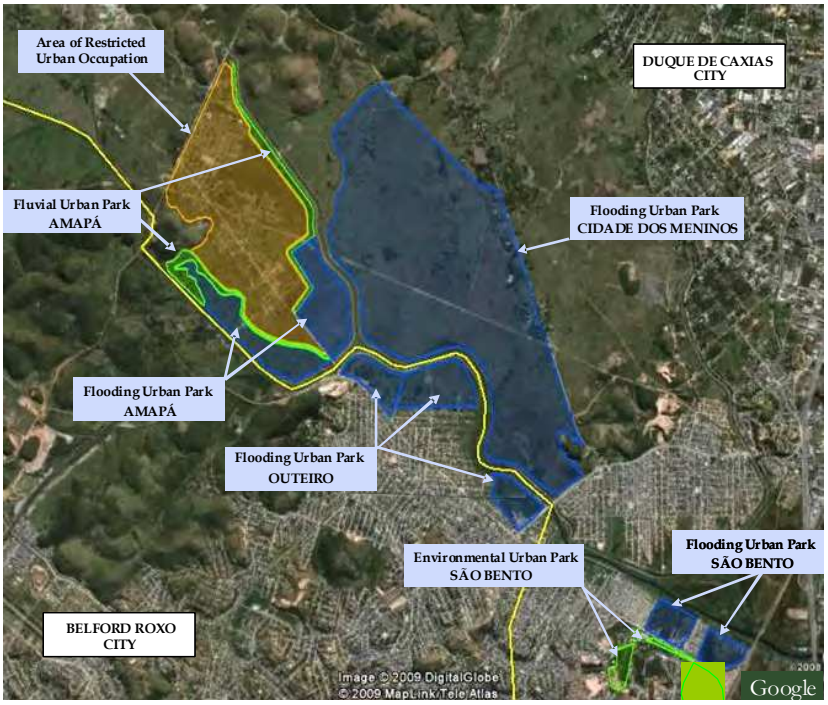

Fig. 8. Flood control measures proposed for Iguaçu River Basin.

Complementary actions held by the State include the articulation with every Municipality in the basin, in order to implement the proposed measures, create local conditions for urban land uses control and develop environmental education campaigns, with the financing of the Federal Government, through a specific Program of Developing Acceleration.

Fig. 9. Fluvial Urban Park and Flooding Urban Park examples.

According to INEA information, these interventions will benefit directly and indirectly, around 3 million inhabitants of Baixada Fluminense and, encompassing: the recovery of 80 km of degraded riverbanks, promoting the resettlement of 2,200 families from risk areas to new housing developments at neighbouring areas; the implementation of parks and recreational areas to protect the recovered riverbanks from new occupations and for storing temporarily floods; the definition of new areas for environmental preservation purposes; the construction or recovery of approximately 70 km of streets along the areas of intervention, as well as the recovery of narrow crossings, bridges, aqueducts, gates and polders. It is also estimated the planting of more than 200,000 trees along the riverbanks. In order to sensibilise and mobilise the local communities for social and environmental problems and the importance of participation and social control, INEA has been developing the process of monitoring and evaluating this project through local committees and through the regional forum of participation and social control.

9. Conclusion

City growth is a world trend and sustainability is a central point to be considered in the next times to come. In a general way, however, great cities present lots of problems to deal with: land use control needs, sub-habitation, unemployment, poverty, inefficient transportation, insufficient public services, lack of infrastructure, among others. The question of water resources management and sanitation aspects are of fundamental importance in this scenery. The urban flood problem is certainly one of the most important challenges that cities will have to face. The urbanisation process is one of the man-made actions that most affect floods. On the other side, in the context of a city, the flood process is one of the facts that most degrades it. Considering urban drainage in the context of the integrated city development, however, the sustainability perspective opens a diversified set of

opportunities to be explored as integrated solutions, in the fields of hydraulic engineering, architecture and urbanism, city planning and management, social disciplines and economy concerns.

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