Urban Floods and Case Studies Project: An Overview

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Prologue

Urbanization in developing countries doubled from less than 25% in 1970 to more than 50% in 2006. It is widely accepted that proactive disaster management is a necessity for maintaining the environmental integrity and economic functions of the city. Rapid and uncontrolled growth, bloom in number of vehicles, and financial constraints leading to diminishing investment of infrastructure, have worked together to make our cities highly vulnerable to known natural and un-known so-called natural disaster that are actually man-made for their origin and impacts. Flood disasters are now the most frequent and devastating natural disaster in monsoon Asia. Their impacts have grown in spite of the improved ability to monitor and assess the hazards. The expansion of urban areas into flood plains and wetlands is one reason as it places additional people and infrastructure at risk. Besides this, land-use changes have altered the run-off characteristics of watersheds. Diversions, storage dams, irrigation schemes and inter-basin transfers have altered river flows. The onset, duration, distribution, speed and quality of flood waters has already been changed by human activities. Changes in climate is further altering the flood regimes.

By 2020, seven of the world's ten largest economies will be from Asia. At the same time, Asia is one of the fastest urbanizing regions in the world. In 2000, 37% of its population lived in cities and the proportion is projected to reach more than 50% by 2025. Urbanizing societies usually spend increasing amounts to protect or rebuild damaged flood protection structures, and also respond through land-use regulations, early warning system, etc. Structural intervention to protect valuable urban-based assets, like city commerce & business, however, may shift risk of flood disasters onto other people and places. The actions during and immediately after major floods may exacerbate or limit disasters, while inappropriate recovery activities and policies can

recreate the conditions for the next, even worse, flood disaster. Institutional capacities to manage floods and flood-related disasters are major determinants of vulnerabilities and risk of disaster. Changes in the Asian monsoon system compound the challenges of managing floods in urban regions.

Urban Floods

Recent phenomenon has highlighted the human-made causes that are responsible for recurring and prolonged nature of floods in South Asian cities like Dhaka, Mumbai, Chennai, Bangalore, Ahmedabad, Surat, Patna, Rawalpindi and Islamabad, etc. Flood hazards result from the overflow of land areas, temporary backwater effects in sewers and local drainage channels, creation of unsanitary conditions, deposition of materials in stream channels during flood recession, rise of ground water coincident with increased stream flow, and other problems (State of Kentucky, III-4).

Mumbai is the largest and most economically important city in India, contributing annually about 17% to the nation's income tax and 37% in corporate tax. The flood of 2005 was truly a disaster as it receded only after seven weeks and affected 20 million. The floods killed 1,200 people and 26,000 cattle. It destroyed more than 14,000 homes, damaged more than 350,000, and about 200,000 people had to stay in relief camps. The agricultural sector was heavily hit as 20,000 hectares of farmland lost the topsoil and 550,000 hectares of crops were damaged. The damage to roads and bridges was estimated at EUR 214 million. Much of the drainage system collapsed and there was a continued risk from water-borne diseases. It took several weeks before basic services were restored.

Figure 1. Continued water logging in Varachha area of Surat even after eight days of flood.

All cities face risks from a range of natural and human-induced disasters, including disasters arising from extreme weather events, fires and industrial accidents. There can also be very large differences in the capacity of city authorities and of city-based households and organizations to take measures to limit an increase in risk and to ensure rapid and effective responses when flooding or some other disasters occur. Coastal hazards can be most disruptive to settlements on coastal and estuarine areas and this is where a considerable proportion of the world's population lives. One estimate suggested that 60 percent of the world's population live within 60 kilometers of the seacoast (Scott, et al, 1996, cited in Hardoy, et al, 2001). Ports and other settlements on the coast or estuaries are also most at risk from any increase in the severity and frequency of floods and storms induced by global warming.

Several factors have immensely increased the difficulty in designing an effective and sustainable flood mitigation policy for urban areas. Severe flooding occurs in many Indian cities during the monsoons every year. Global climate change is now resulting in changed weather patterns and affecting the monsoons. Increasingly heavy rainfall occurrences are causing larger incidences of flooding in urban areas resulting in severe disruption to the urban infrastructure. Also, the urban drains are increasingly being used for wastewater / sewage disposal and the overflows result in epidemics. Principal phases of urban water cycle are shown in figure 2.

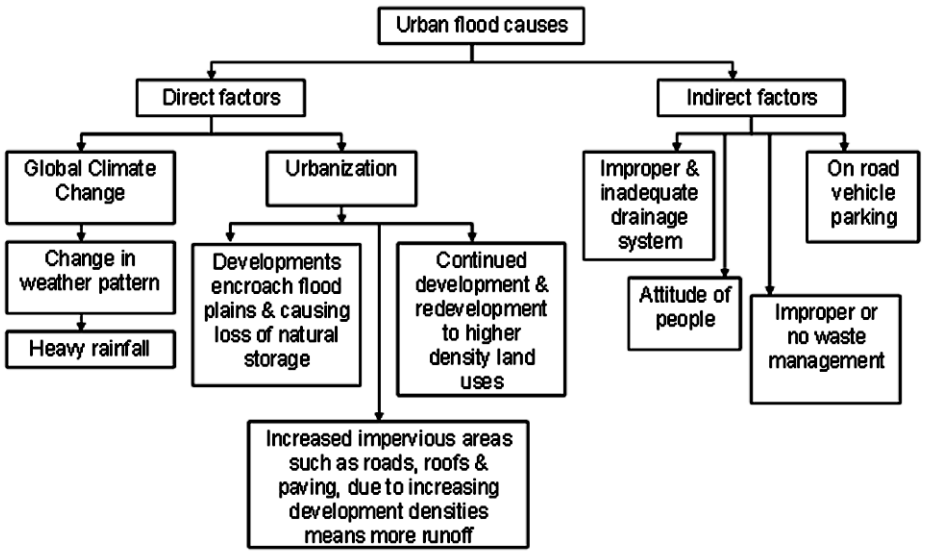

Figure 2. Causes of Urban Flooding.

Flooding in the urban areas may occur when heavy rainfall causes:

a) creeks or channels overtops their banks
b) drainage systems back up because they can not cope with the volume of water or are blocked by rubbish
c) sewers overflow because of illegal connections and the sewer system can not cope with the increased volume

The worst flooding occurs after prolonged rainfall when the soil is saturated and the water levels in creeks elevated. Then, if an intense rainfall burst occurs, causing a large amount of rain within a brief period, flash flooding may occur with little or no warning. Flooding occur because of:

a) developments encroach floodplains, obstructing floodways and causing loss of natural flood storage
b) continued development and redevelopment to higher density land-uses by high costs in major cities
c) increased impervious areas such as roads, roofs and paving, due to increasing development densities means more run-off

Urbanization: Takahashi (1964, 1971) examined flooding events in Japan and showed that floods were not a purely natural phenomenon and that social conditions played an important role that varied from region to region and from time to time. Floods are related to the increase of the impermeable areas and man- made drainage such as conduits and channels. Usually the land use surface in small urban basins are made of roofs, streets and others impervious surfaces. Runoff flows through these surfaces to the storm-sewers. It changes the hydrologic cycle, increasing the overland flow and decreasing the groundwater flow (figure 3). Under these circumstances the peak discharge increases together with the flood frequency.

On-road vehicle parking especially in commercial areas and during night time in residential areas aggravates the blockage of flow of rainfall runoff during heavy rains. With changes in the social structure of post-industrial society, urban space is becoming denser and more complex. The urban facilities, information systems, and networks that are now being built are particularly vulnerable to flood damage. Recent urban floods are examples of a new type of disaster that causes a new type of damage in urban areas. In Chennai City 40 per cent of the population lives in slums - there are 69,000 families who have been identified to be living on government land and they are to be relocated to areas far removed from the city. Delhi, where sub-standard settlements house as much

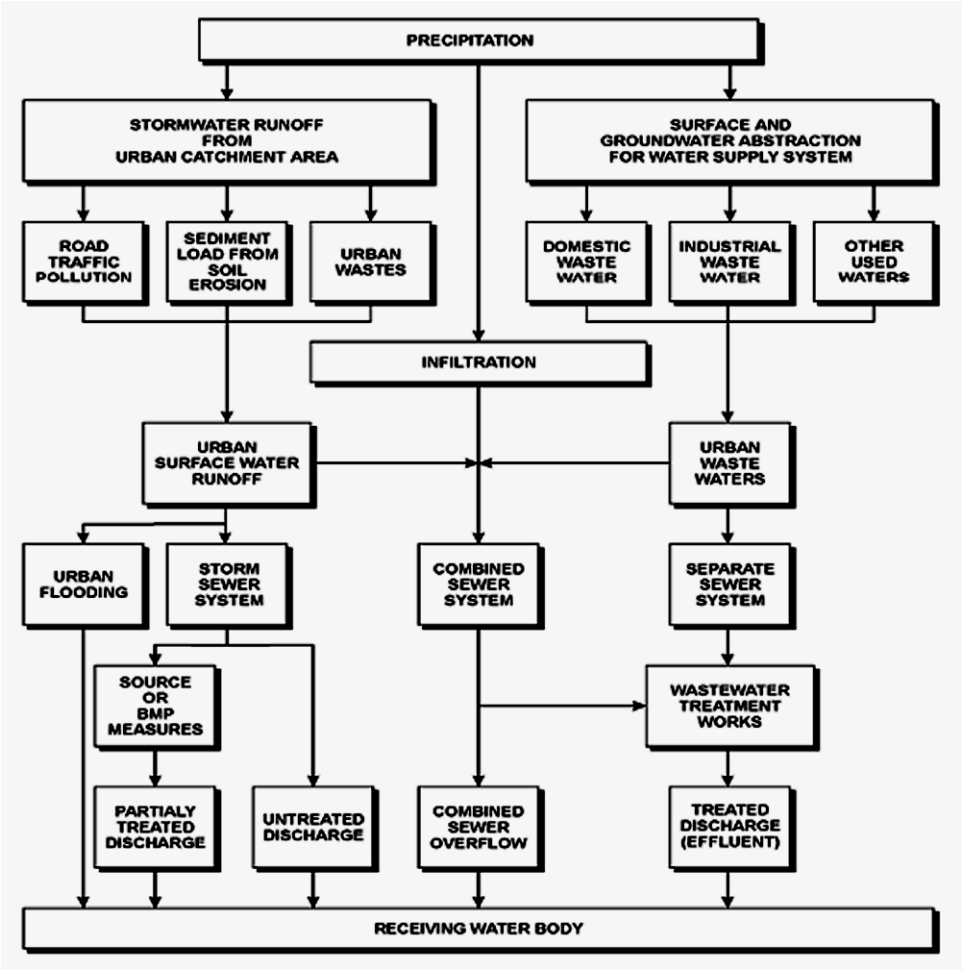

Figure 3. Urban water courses

as 70 per cent of the city's population, leads the way in environmental activism.

In the developed countries the source control of urban drainage has been practiced by detention and retention ponds, permeable surfaces, infiltration trenches and others source control measures. In developing countries usually this type of control does not exist and the impacts are transferred to downstream in the major drainage. The cost to control of this impact is transferred from the individual to the public, since the county has to invest in hydraulics works structures to reduce the downstream floods impacts.

(a) Flood plain occupation: Natural floods mainly occur in medium and large sizes rivers. When no reliable urban plan and regulation exists, the population occupies the flood plain after a sequence of low flood years, because these areas have a flat topography and are near to valuable city land and have a low cost. However, when a larger flood occurs, flood damage increase and the municipality is requested to invest in flood protection in the area.

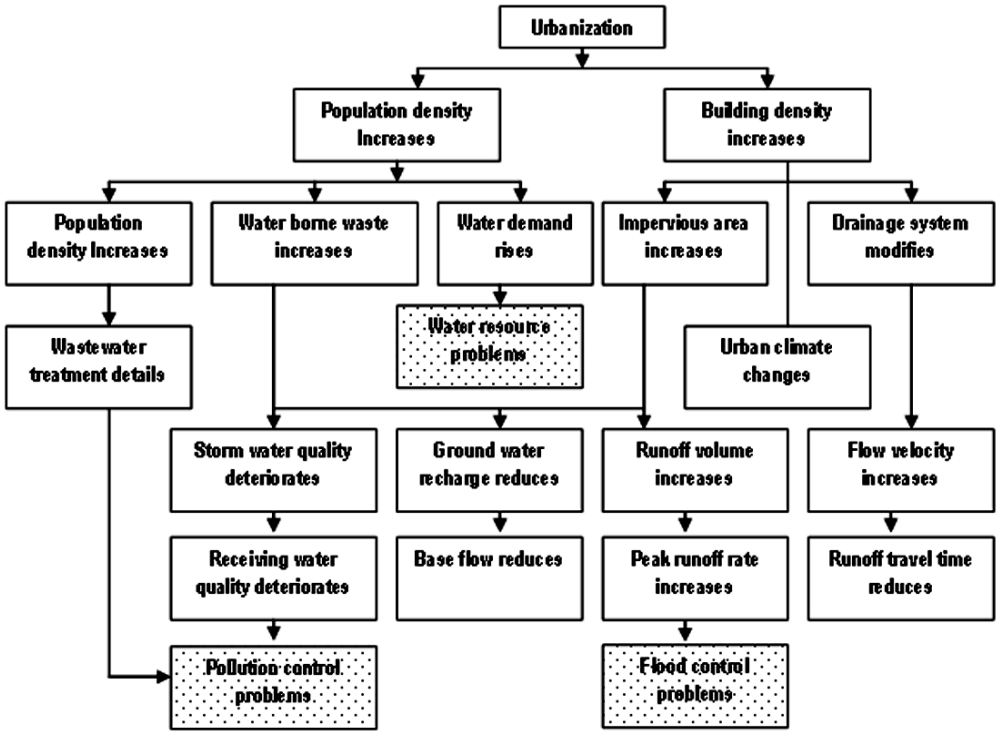

Figure 4. Hydrological impacts of urbanization

Urban flooding is significantly experienced in watersheds of all sizes, wherever the community has occupied locations, which are susceptible to inundation by floodwater. In watersheds which are hydrologically small, it results from cyclonic or storm rainfalls falling on local areas, within or adjacent to urban settlements, where the process of urban development itself has dramatically altered the runoff-producing characteristics of the catchment.

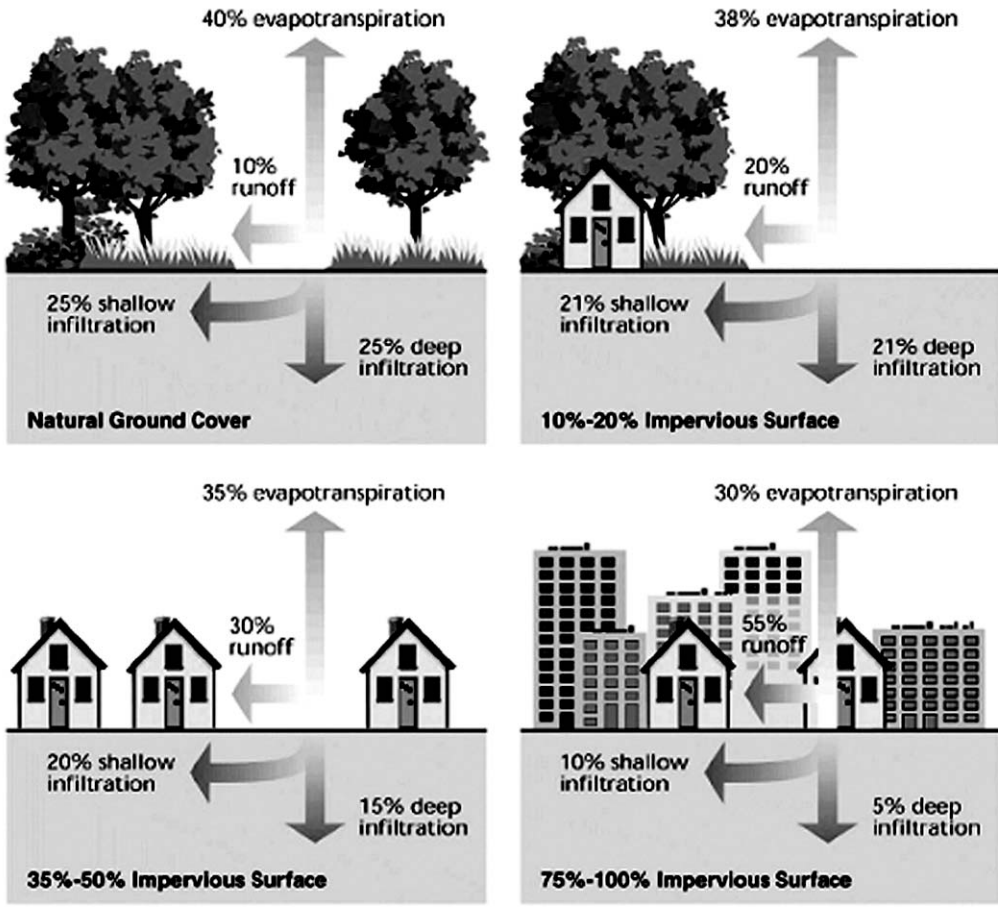

Figure 5. The influence of urbanization on different components of the water cycle

Present Flood-management Practices & Shortcomings

In general, floods cannot be prevented but mitigation and emergency planning can reduce the risk and catastrophic consequences. Flood management is broadly integrated water resource activities aimed at reducing flood impacts on people, infrastructure and economy. It is an irony in the planning that economic considerations and short-term political goals often outweigh long-term but often very serious environmental and social risks. Despite of high impact urban-flood incidence in many cities during recent past, there are still serious flaws in the city planning and governance

in relation to flood risk management.

- The increase in paved ground surfaces, together with the installation of a more efficient drainage system, greatly reduces surface depression and detention storage, reduces the time of concentration and delivers runoff to the nearest watercourse in a fraction of the time that this would have taken prior to urbanization.

  The result is a much sharper rise in the rate of flood runoff, which greatly increases the peak discharge rate from the catchment and substantially increases the subsequent depth and severity of flooding. For these reasons, urbanization can significantly increase the peak discharges in smaller, comparatively frequent storms. Even in larger, rarer storms the peak discharges can be double those of an equivalent rural catchments.
- The current flood management lacks appropriate predictions as the past data for statistical and probabilistic models is often unavailable. The fact that a particular outflow can result from the combinations of hydrologic conditions and is often neglected. Influences of antecedent conditions in the drainage basin are prerequisite considerations and the combination of sound engineering with mathematical modeling can work well.
- An often neglected fact is that change of natural water storage as a consequence of urbanization, also causes significant changes to the temporal characteristics of runoff from an urbanized area, such as shortening the runoff travel time and giving to the event a flashing appearance. Destruction and degradation of urban wetlands has aggravated the risk of urban flooding.
- New buildings on the floodplains are not only at risk of flooding themselves, but also unless care is taken with their design and location, can worsen flooding. Inappropriate new developments can reduce floodwater storage and increase surface runoff.
- Total flood protection is unrealistic and unwise. The ultimate goal of flood loss prevention is the improvement of the quality of life by reducing the impact of flooding and flood liability on individuals, as well as by reducing private and public losses resulting from the flooding. The objectives of the urban flood management are to provide answer to the question of how to deal effectively with the possibility of flooding in urban environment and how to cope with the associated uncertainties.
- An additional present problem of cities is sewerage flooding. Apart from where sewers break, these floods are normally caused by the overflow of 'combined

sewerage overflow' which are common across Indian cities. They carry both sewerage and surface-run-off. The existing capacity is failing to meet growing levels of run-off as discussed above and the increase of sewage as we use more waters.

- Present planning process is weak in addressing on how planning authorities should taken into account the level of flood risk when deciding whether to grant permission for new developments, and to avoid building in flood risk areas, and reduce vulnerability.
- Limited resources for flood mitigation and land-use regulation enforcement in terms of finances and more importantly the staff for field assessments is one of the major problems leading to inefficiency
- Rainwater harvesting structures and facilities, also play significantly additive role in rain-water retention that otherwise shall form the greater amount and velocity of runoff. Insufficient emphasis on promoting such measures has also been a weakness
- Solid waste management in urban areas especially the peri-urban parts is still far from satisfactory, and the garbage including polythene, etc., causes blockage of drains, sewers, and run-off mechanisms, thus aggravating the problem. Incapacities to deal adequately with SWM is additive to urban flooding risk
- Vehicle parking on road is out of proper regulation and enforcement, whereas in case of heavy rainfall resulting in high runoff it leads to retention of greater amounts of water for inundation due to parked vehicles on runoff routes and later floating vehicles create embankments for the flooding waters

Improving and shortening the river channels, constructing high and continuous embankments to keep flood waters in river channels, and expanding storm-water drainage systems, Large-Scale Flood Control Structures (LFCS) have increased a potential of creating new flood hazards. LFCS change the way flood waves propagate in rivers, shortening the time-lag between the rainfall and the peak discharge, thereby increasing the flood discharge flowing down the channels (Takahashi, 1971; Sato, 1998). Moreover, the volume of flood runoff has increased as a result of the loss of water detention capacity of urban catchments. These days, a particular quantity and pattern of rainfall results in a flood discharge of greater volume and with a higher peak discharge than ever before. Moreover, the number of heavy rainfalls, the primary external force of a flood hazard, has been increasing in urban areas in Japan, according to statistics for Japan (JMA, 2005). If this trend continues, it might become a major factor in increasing the flood risk in urban areas.

Framework of City Studies

In order to study the phenomenon of urban floods in India in a comprehensive manner, the National Institute of Disaster Management has taken up a research project, primarily based on case studies on the mega cities of Mumbai, Delhi, Kolkata, Hyderabad, Chennai and Bangalore and two smaller cities of Bhopal and Surat, which have faced floods in the recent years. The basis of selection of above cities is occurrence of regular floods in these cities that caused immediate as well as long after effects like damage to life and property, disturbance in normal routine life through destruction of infrastructures, communication and eclectic facilities etc. Among them five are metro cities so loss due to floods has been on large level that also influenced other parts of the country. For example, the flood incidence of Mumbai 2005 affected all trade activities throughout the country. Other two cities are also important as Bhopal, known as Lake City, is the capital of Madhya Pradesh and Surat is a historically known port and an industrial city. The chapters based on the city-wise studies are organised as per the following structure:

Profile of the City

History – topography – hydrology & water bodies – vegetation - rainfall pattern - demographic and settlement pattern - socio-economic and cultural profile related to flood

City Infrastructure with special reference to drainage

Roads – sewerage – solid waste management – drainage system, Land-use changes

Floods in the City

a) Brief historical account of recurrent and abnormal floods in the city and their impacts, including human dimensions
b) Recent floods in the city – detailed accounts, immediate and long-term impacts
c) Various factors responsible for the floods – natural, physical, environmental, managerial, developmental, etc.

Efforts made to mitigate and manage the floods

a) Master plan provisions in relation to city drainage / sewerage and carrying capacity management – extent of their implementation including regulatory or voluntary efforts
b) Inquiry and faction finding reports – why were the provisions suggested could not been implemented

c) Various structural and non-structural measures for mitigation of flood – achievements and shortcomings
d) What went wrong – critical appraisal of city flood mitigation and management in terms of planning, resources, implementation, capacity, enforcement, participation, etc.
e) Good practices and exemplary lessons

Strategies for the future

What are the strategies of city or state government to mitigate and manage the floods – what are the constraints – what should be done.

Lessons and Concerns

Flood risk depends upon the variety of sources of flooding and layout of the urban environment under concern. It is now well realized that the flood control should not be based on transferring the flood to downstream reaches and must give priority to source control measures. The urban flood mitigation management strategy covers following four components:

- Land-use planning for urban area
- Drainage network management
- Solid waste collection and disposal system
- Building designs and materials

– The *non-structural* measure includes mainly strategic measures: legislature, financing, environmental impact assessment, reconstruction, rehabilitation. Components like flood forewarning, alternative transport, media, alerting, fire service, and environmental control are the emergency issues of consideration.

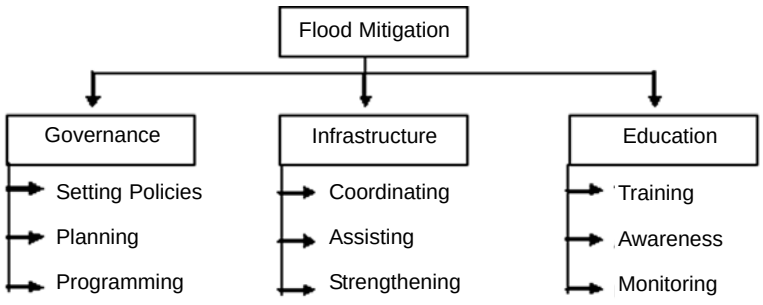

Figure 6. Non-structural strategies of urban flood mitigation

– Structural measures are the imperatives of the integrated strategy for flood mitigation. Following are the non-conventional structural aspects of integrated flood mitigation:
  (a) Improvement and maintenance of the drainage efficiency
  (b) Bulk-water resistant materials in building construction
  (c) The water infiltration process and the creativity
  (d) Restoration of urban wetlands and other natural –water storage sites
  (e) Rainwater harvesting structures promotion

Land use and zoning plans

Land use management employs two principal options: zoning control and development / building control.

Zoning control includes designating, by the responsible authority, the type of activity that can be undertaken within the flood-prone area. Most of the physical, social and economic problems associated with flooding, soil erosion and water pollution stormwater are attributable to inappropriate urbanization of the floodplain, unwise land use within the city, insufficient attention to drainage in urban planning, ineffective updating of existing stormwater control facilities and lack of enforcement of zoning ordinances.

Reducing flood damage requires strengthening resilience of low-lying alluvial lands to unexpected scale of flood hazards. People need to understand that low-lying land cannot attaint "zero flood risk", and that they are to be ready for taking an acceptable level of flood risk. It is a myth that people always demand "zero flood risk". A survey taken in a flood prone area showed that 30% of the respondents accept the risk of flooding below the level of the tatami mats (straw floor mats) in their homes in every one to thirty years (Sato, 2006). On the basis of an objective assessment of hazard, economic, social, and environmental factors, the responsible authority should impose appropriate conditions to ensure that the future development is compatible with the prevailing flood situation.

There are three basic types of floodplain development: - preventing development from constricting floodway and allowing the flood fringes to be preserved for agricultural or recreational purpose - preventing development from constricting floodway and allowing the flood fringes to obtain housing, commercial or industrial purpose as long as the encroachment results in only insignificant increase in the water surface elevation - restricting the use of the flood plain and leaving it in its original unoccupied state.

Those types of floodplain development actions are institutionally accompanied by:
- legal measures that enforce zoning, density and pace of development
- taxation measures that may guide development away from hazard areas
- government action that may alter existing land use or require compulsory purchase of the flood-prone land

Building codes generally deal with the following aspects:
- purpose for which the building is constructed
- the criteria for structural strength to withstand water action
- specifications for material
- adequate elevation of basement and first floors

Scope of master planning

The flood management master planning process is a system approach that that is expected to include following:
- documentation of the problem; investigation of the causes of the problems; determination of needs and the planning criteria
- problem inventory; appraisal of feasible solutions; setting up flooding standards based on social, economic, and environmental factors
- collection of all baseline data and identification of baseline conditions, including political, geographic, hydraulic and environmental issues based on systematic interviews and site visits
- description of the existing stormwater practice and its inadequacies
- definition of hydrologic conditions and constraints that proposed changes or development would have on baseline conditions
- definition of interdependencies with neighbouring administrative areas an related municipal infrastructure services
- analytical work that includes hydrologic, hydraulic and water quality analysis
- definition of priorities and alternative solutions (interim solutions, long-range solutions)
- description and cost estimate of proposed facilities and measures
- benefit/cost analysis and comparative evaluation of alternative solutions, including valuation of benefits, damage assessment, cost of traffic disruption, environmental and social factors; other assessment techniques that are more appropriate to urban conditions
- recognition of alternative plans; recognition of emergency plans

- practical financing program; identification of the sources of funds
- drafting legal documents needed to implement the adopted measures

Conclusion

There are varying solutions to the problem of urban flooding and the options must be screened and evaluated in order to facilitate the best practicable options in the planning approach. Besides this an assessment for the "sustainable solutions" of urban flood risk reduction shall help in the long-term basis, as if the risk reductions measures are planned only in view of short-term goals, they themselves may become the factors to aggravate risk in the times. A surface water management plan, based on the inputs from a basin flood management plan and assessment of flood risks due to local floods and coastal floods, if any, is an essential element for a comprehensive and coordinated approach to flood risk management. The planning process should not be unilateral phenomenon but shall involve the stakeholders responsible for implementing the provisions of flood risk reduction plan and allied responsibilities. The proposed case studies for the selected seven Indian cities shall be greatly helpful in identifying the root causes and their sustainable solutions in order to minimize the risk and the loss-free ways to live with the residual risks.

Acknowledgements:

A range of source of information – from published and unpublished literature including web-resources has been utilized in the articles based on appropriate interpretation. Authors acknowledge their original sources and publications.

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