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Urban flood disaster management

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Abstract

Flood impact is one of the most significant disasters in the world. More than half of global flood damages occur in Asia. Causes of floods are due to natural factors such as heavy rainfall, high floods and high tides, etc., and human factors such as blocking of channels or aggravation of drainage channels, improper land use, deforestation in headwater regions, etc. Floods result in losses of life and damage properties. Population increase results in more urbanization, more impervious area and less infiltration and greater flood peak and runoff. Problems become more critical due to more severe and frequent flooding likely caused by climate change, socio-economic damage, population affected, public outcry and limited funds. Flood loss prevention and mitigation includes structural flood control measures such as construction of dams or river dikes and non-structural measures such as flood forecasting and warning, flood hazard and risk management, public participation and institutional arrangement, etc.
This paper describes concepts, policy, plan and operation on integrated urban flood disaster and risk management. In most developing countries, flood disaster management activities are handled by government. Participation of non-governmental agencies and private sectors are very limited. Activities are exercised rather independently without proper coordination or integration. Flood disaster management in developing countries is mostly reactive responding to prevailing disaster situations (emergency response and recovery). Reactive response should be changed to proactive response to increase effectiveness of management and reduce losses of life and properties. Proactive disaster management requires more participation from various governments, non-governmental and private agencies and public participation. It involves more effort and time, more budget, equipments, facilities and human resources which leads to integration of flood disaster management for both long term and short term activities. Strategic framework on integrated flood disaster management includes four cyclic steps namely: 1) preparedness before flood impact such as flood forecasting and warning; 2) readiness upon flood arrival; 3) emergency responses during flood impact and; 4) recovery and rehabilitation after flood impact. Examples on urban flood disaster and risk management in Thailand are illustrated and discussed. Conclusions and recommendations for further improvement are provided.

Keywords: Urban floods; Flood disaster management; Flood control measures; Risk management; Thailand

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1. Introduction

Many cities and urban areas are located in flood plains because land is fertile and flat which is suitable for agriculture and urban development. Rivers provide water supply for domestic, industrial and irrigation uses; they also provide convenient means for navigation, transportation and communication. Cities have large percentage of impervious areas that prevent effective infiltration of rainfall into soil. This causes large runoff and high flood levels as shown in (Figs. 1 and 2) leading to inundation and significant flood damages [1-2] Highly populated urban areas carry high economic values and when subject to flooding results in disaster that can set back urban development for years.

Urban floods can be classified as floods due to local heavy rainfall, floods due to river overbank flow and flood due to high tides or storm surges. Floods due to local heavy rainfall are caused by insufficient or poor drainages. Floods due to river overbank flow occur when river level rises above river banks. Excessive river levels are normally caused by high runoff from upstream and backwater effect of high tides at river mouth. Construction of cities in floodplains reduces storage and block floodway in the flood plains causing flood damage even worse. Flood dikes in cities may be breached due to high flood levels and cause severe flood damages. Cities in coastal areas are normally located in low lying areas where drainage is difficult without pumping. High tides or storm surges can hamper flood drainage to the sea and cause prolonged flooding with polluted flood water and health problems in cities. Effects of climate change increase more heavy rainfall, severe and frequent flooding which are more difficult to predict [3].

To have successful flood control and flood risk management, we should consider not only hydraulic and engineering aspects but also socio-economic and environment aspects. Flood management should have involvement of various stakeholders including concerned authorities such as urban planners, civil and water resources engineers, civil disaster defence authorities, health and social services, etc. (Fig. 3)

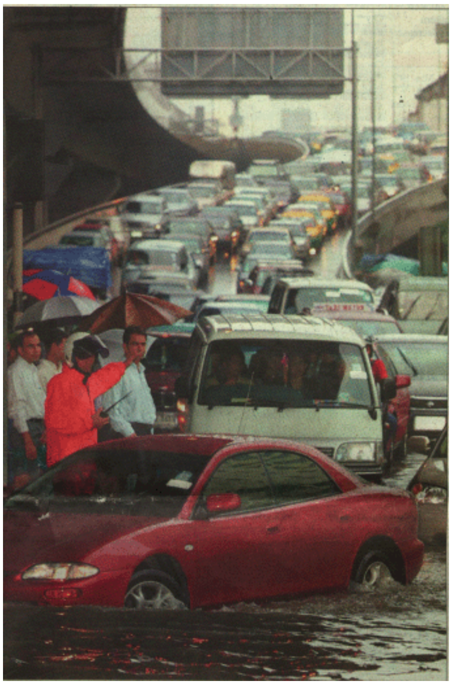
2. Urban Flood Risk

Floods are caused by natural factors or by a combination of natural and human factors. Risk is probability of loss and can be expressed as [4-5]:

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}$$

Flood hazard depends on flood magnitudes such as flood depth, velocity and duration. Vulnerability may be defined as the conditions determined by physical, social, economic, and environmental factors which increase the susceptibility of a community to the impact of hazards (Figs. 4 and 5). When flood waters physically encroach on people and infrastructure, then the vulnerability of people and infrastructure is decisive for the degree of harm and damage.

Impacts due to urban floods are significant in terms of economic losses both direct and indirect. This is due to high density of population, large impervious areas, clogging of drainage systems, high economic values of properties and infrastructures, etc. The impacts of urban floods can be: physical, economic, social and environmental. Both direct and indirect primary potential losses can be prevented through better land use planning, which also impact the potential secondary losses. Better flood emergency responses mechanisms help reduce potential secondary losses. While in rural areas the damages due to floods are mostly direct in terms of loss of agricultural production.



October 2, 2002
Bangkok traffic in Chaos as City Drain Unable to Cope With Rainfall of 60 mm/hr

CHAO PHRAYA RIVER FLOOD

Max Flood Level 2.07 m MSL

Flood Discharge 4,125 cu.m/s

Fig. 1. Flooding in Bangkok in 2002 (above) and Had Yai City in 2000 (below)

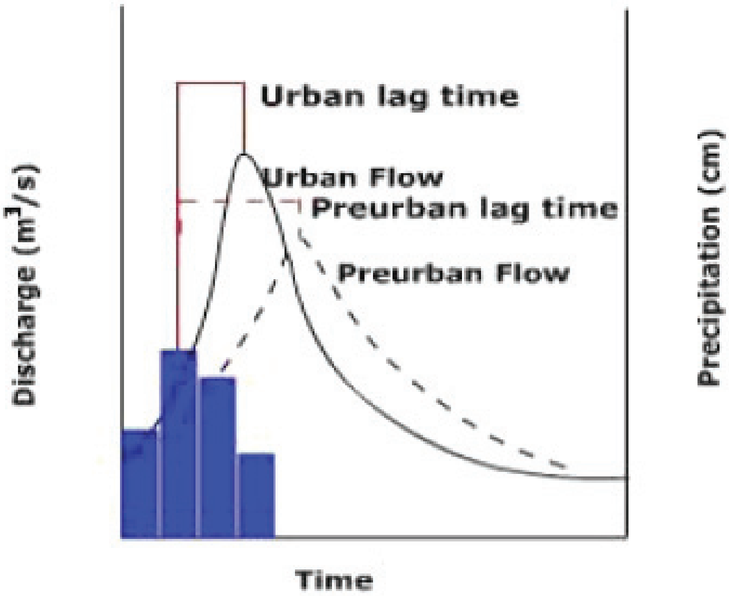


Fig. 2. Discharge accentuation due to urbanization [1]

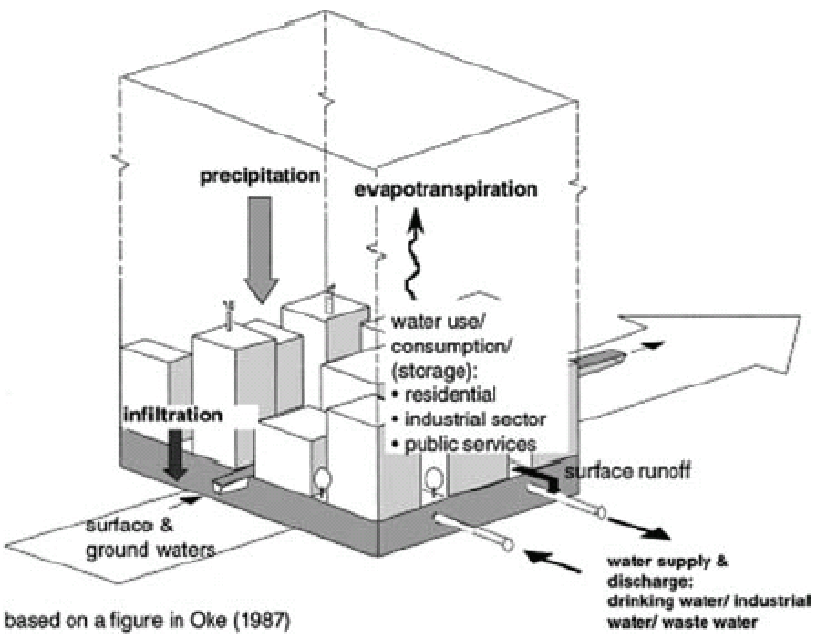


Fig. 3. Major components of urban hydrologic balance [2]

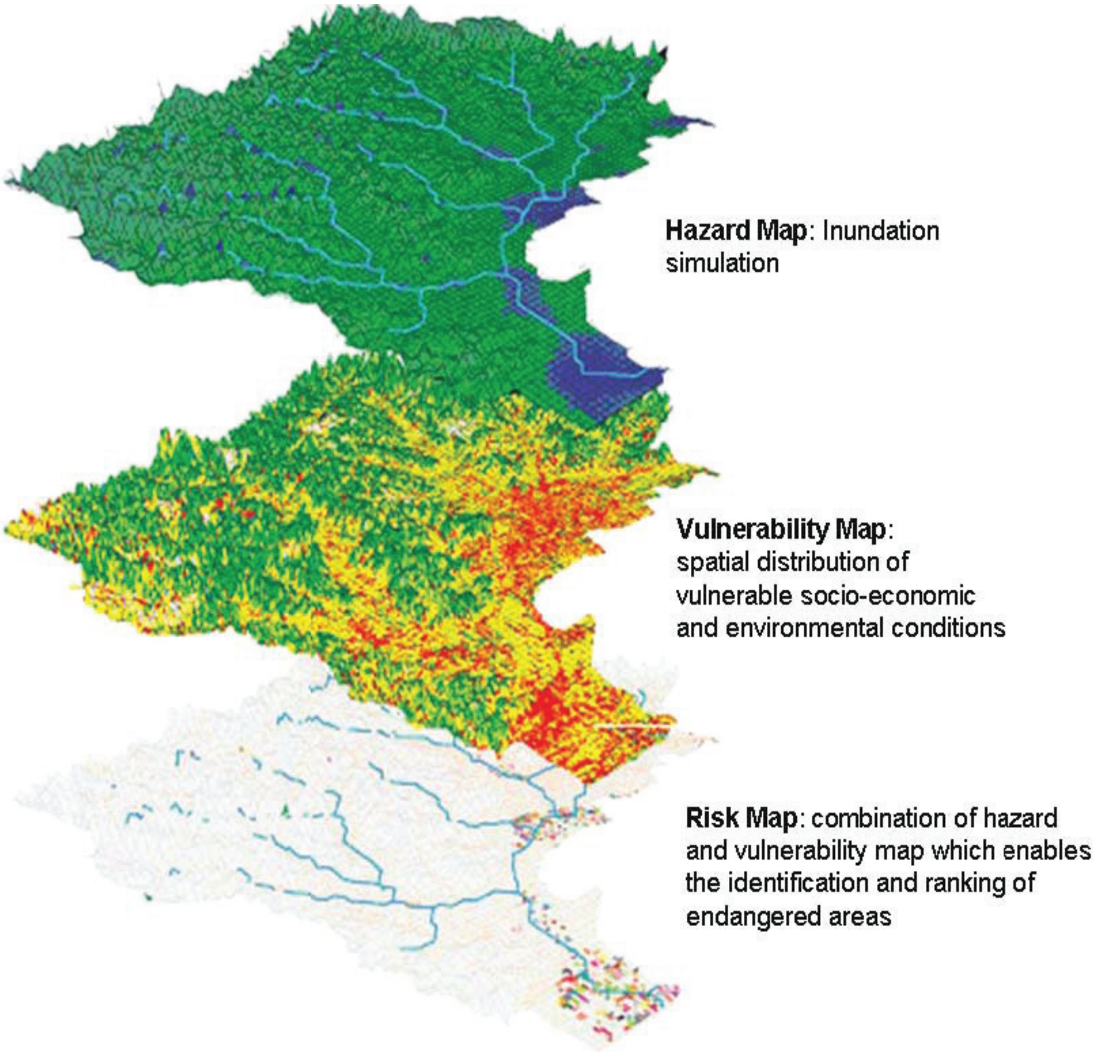


Fig. 4. Risk map with a geographical information system (GIS) [4]

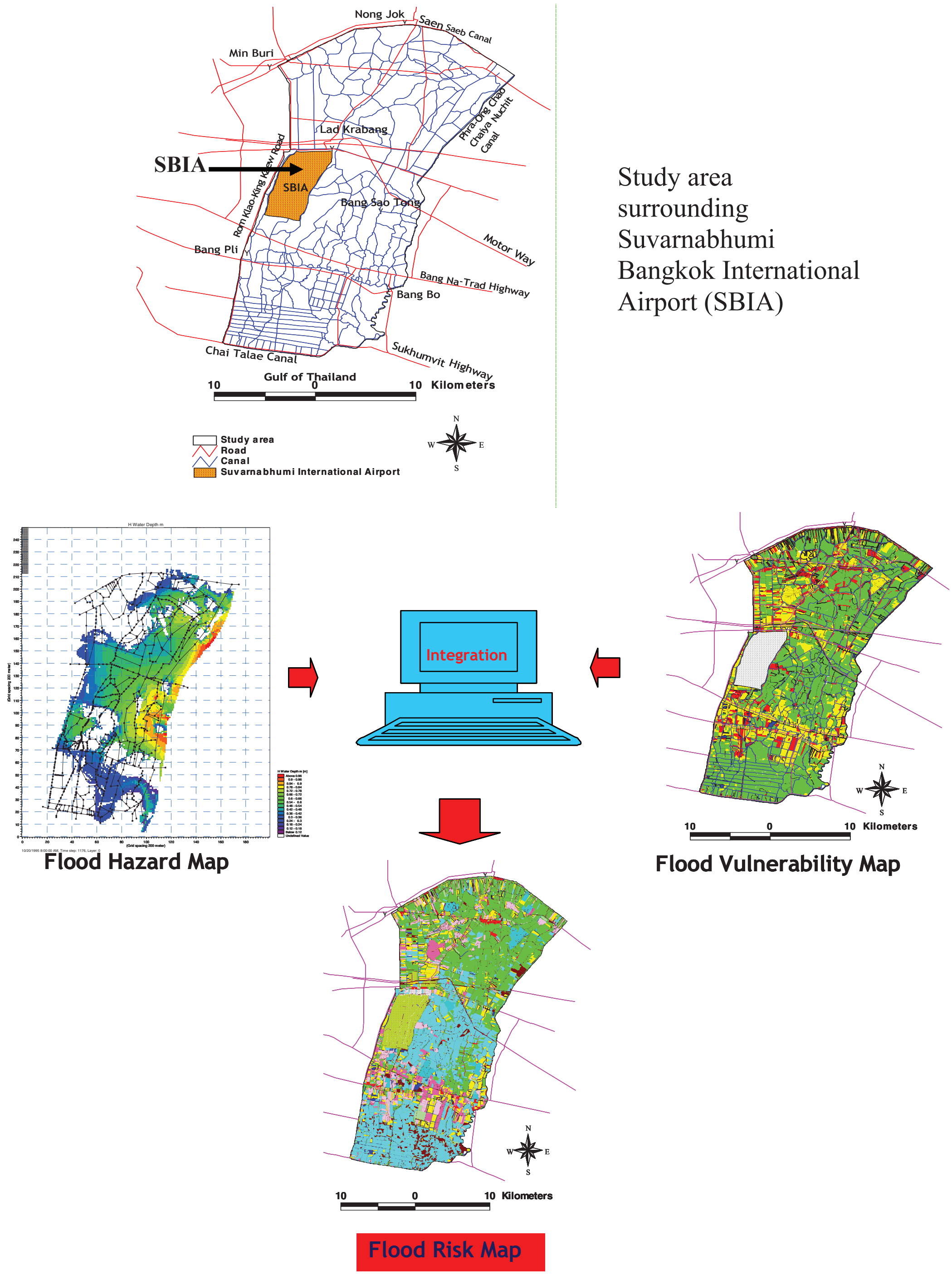


Fig. 5. Flood hazard, flood vulnerability and flood risk maps of surrounding area of Suvarnabhumi Bangkok International Airport, Thailand [5]

Damages in urban context are more complex. In addition to the vulnerability, the magnitude of the damage depends on the flood type especially in terms of depth, flow velocity and duration. One of the major factors for the rise in urban flood damages is simply the increasing number of population and assets that are physically exposed to floods in cities. Cities in many developing countries are growing rapidly. Unprecedented migration from rural areas to cities has led to uncontrolled urban sprawl with increasing human settlements, industrial growth and infrastructure development. Often, urban growth in flood plain expands over some flood ways, hence reducing its flood drainage capacity.

3. Integrated Flood Risk Management in Urban Areas

A major cause of local flooding due to heavy rainfall in many cities is the blocking of drainage facilities with garbage. Cleaning and maintenance of drainage facilities is essential to their operational reliability. Storm water retention measures are vital for mitigation of urban floods as well as for prevention of downstream floods. Storm water retention can be achieved by constructing basins or ponds that temporarily store surface runoff and release it at a controlled rate. Reduction of surface runoff can be achieved by other measures such as increase infiltration, evapo-transpiration from the catchment areas such as to preserve unsealed and greened spaces in the city.

The main aim of urban flood risk management is to minimize human loss and economic damages. Flood risks cannot be entirely avoided, thus they have to be managed. Consequently, flood management does not strive to eliminate flood hazard but to mitigate them. The basic steps of risk management (Fig. 6) are: risk assessment before and after implementing flood mitigation measures, In order to reduce flood risk, it is mandatory to evaluate the performance of implemented measures and to reassess residual risks [6]. Risk assessment has to be carried out in an integrated manner, i.e. identifying all the possible water related hazards. Hence quantification of risks has to start with the analysis of hydro-meteorological data and the hydraulic simulation of floods. A number of different scenarios should be modelled in order to factor in the consequences of likely future changes on urban floods. The results of such models provide information about the expected flood frequencies and magnitudes (extent, depth, duration and flow velocities), thereby marking those areas and subjects, which are exposed to floods.

Risk maps can be developed enable the users to clearly identify risk areas. The advantage of such comprehensive risk assessments is that it is possible to compare the components of risk in quantitative terms.

Flood disaster management has to follow the stages of a management cycle (Fig.7) [7], through preparedness; readiness, response and recovery/rehabilitation. Preparedness measures attempt to prevent potential risks turning into disasters, both at societal level as well as at individual level. This involves mitigation of flood risks to an acceptable and affordable level and at the same time develop activities to cope with the residual risks. Flood fighting by people helps to reduce flood damages during flood impact [8]. Response measures are implemented during or immediately after a flooding incidence. They need advance planning and preparedness to respond to the emergency situation.

Urban flood due to river overbank flow in cities is not an isolated phenomenon but as closely interlinked with overall basin characteristics. Comprehensive and coordinated approach to flood risk management helps develop common understanding of flood risk issues among all stakeholders at various administrative levels. Modeling flood processes is required and should not be considered as one-time task but a continuous learning process.

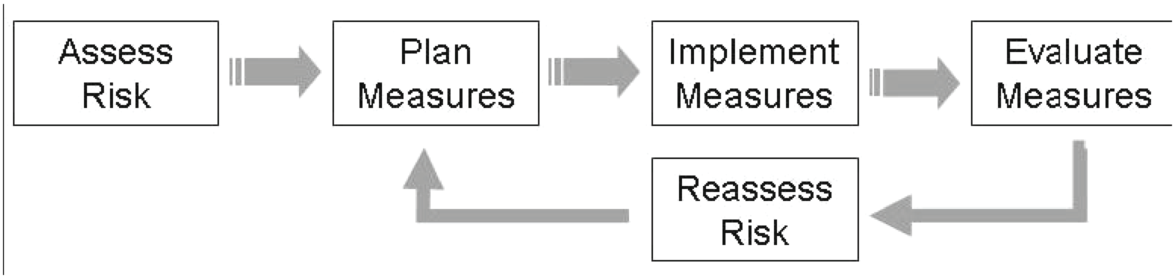


Fig. 6. Steps of risk management process [6]

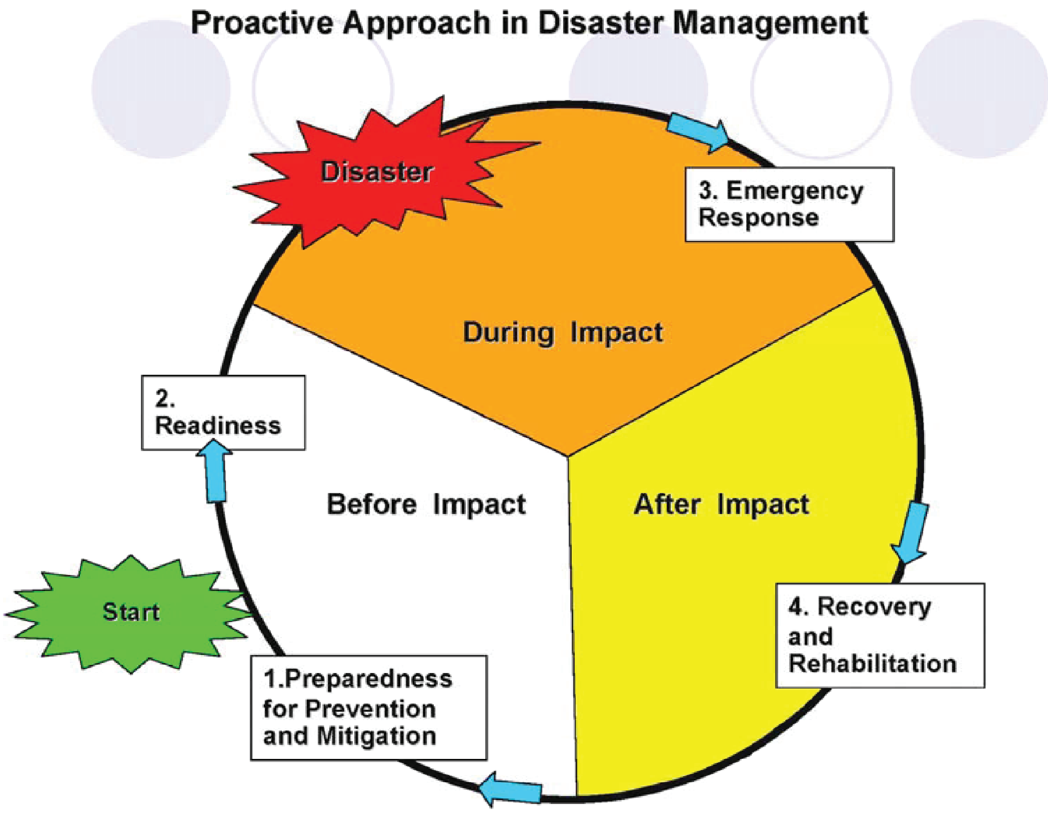


Fig. 7. Flood disaster management cycle [7]

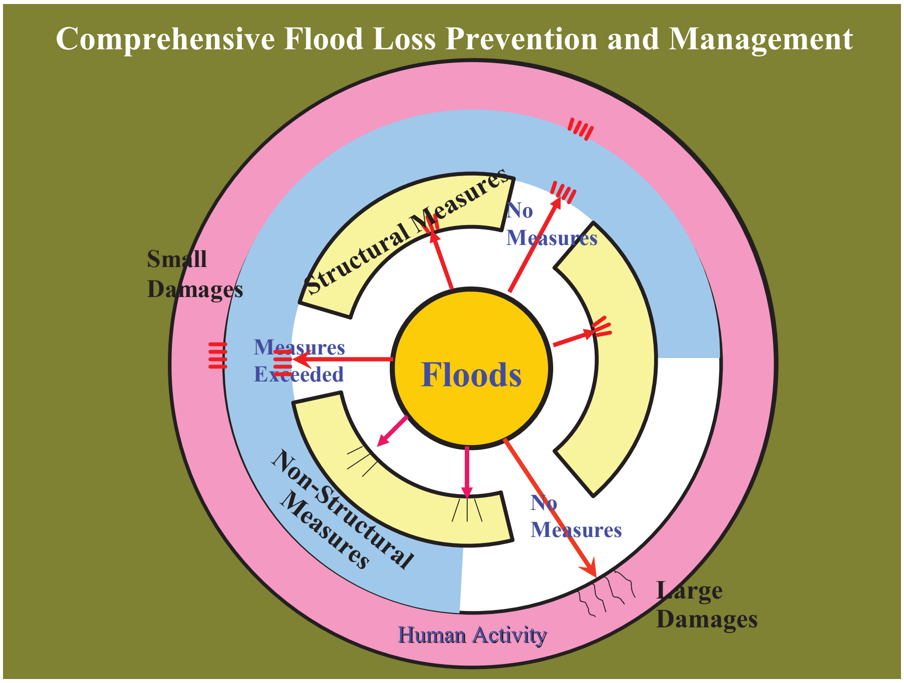


Fig. 8. Structural and non-structural flood control measures and their impacts to people [9]

The repetition of risk assessments after the implementation of structural and non-structural flood control measures [9] allows proper judgment of the effectiveness of each specific measure and the identification of those components of risk which require further mitigation (Fig. 8). Structural measures may be implemented in order to mitigate urban floods due to overbank flow by detaining or diverting run-off, for examples: polders and basins, bypass channels; dredging and widening of stream and channels, levees and embankments, etc. Flood due to high tides can be reduced by means of tidal barriers. But storm surges or tsunami purely generated by natural processes cannot be eliminated. They have to be essentially dealt with by flood disaster management.

Measures of urban planning is increasingly recognized as the central means to prevent urban flood disasters because it can lead in the long run to more effective and economically more efficient solutions than the traditional means of developing exposed areas and then protecting them by dykes[10]. By combining flood models with scenarios of urbanization in scenario modelling the delineation of zones which define the probability of flooding and the respective type of land use to minimize flood damages.

Another approach is the reduction of physical vulnerability of people by developing workable evacuation plans in close cooperation with the affected people. Provision of evacuation shelters, supply of fresh water, food, medicine etc. should be considered in evacuation plan.

Building codes play an important role in decreasing the physical vulnerability of houses and infrastructure. Based on the delineation of risk zones, building codes provide regulations with reference to the type of construction material, the structural features of the construction and in some cases also the occupancy and use of houses.

Flood warning systems need to be communicated to the communities at risk by converting forecast information into practice and by sending warning dissemination to people. Success of such a system is closely related to people's knowledge of flood risk and their familiarity with emergency response to incoming floods.

4. Conceptual Framework for Urban Flood Risk Management

Three general concepts that provide the basic conceptual framework for urban flood risk management (Fig. 9) are: Integrated Flood Management; Total Water Cycle Management; and Land-use Planning [11].

Integrated water resources management (IWRM) embraces all its principles and at the same time incorporates risk management principles. It integrates land and water resources development in a river basin and aims at combining the efficient use of flood plains and the reduction of loss of life due to flooding. The IFM concept [11] is based on the following principles: a) Employ a basin approach; b) Treat floods as part of the water cycle; c) Integrate land and water management; 4) Adopt a mix of strategies based on risk management approaches; enable cooperation between different agencies and ensure a participatory approach.

Total Water Cycle Management (TWCM) [12] is applied in order to stress the linkages between storm water management on one hand and water supply and sanitation on the other. (Fig. 10) Thus there is a need to deal more explicitly with these overlapping parts between the three basic fields of urban water management namely: drinking water supply, sewage and waste water disposal and surface run-off disposal.

Land use planning leads to calls for a closer integration or coordination between flood management plans and land use plans. The regulations and by-laws concerned with land use planning should consider the flood risks and local disaster management authorities [13].

5. Institutional Arrangements

No single organization is generally charged on comprehensive flood risk assessment. Individual organizations typically conduct their own independent work on mapping and modelling flood risk in relation to their own assets, with no one taking a strategic or holistic overview. As organizations manage different parts of the urban drainage infrastructure, they make investment decisions based on a limited cost-benefit analysis that rarely considers the wider drainage issues. The sum total of these individual and piecemeal investment strategies is unlikely to produce the most effective solution.

Performance of a municipality in flood risk management is the key factor for the success or failure of management plans. Basically, there are three main factors which are decisive for the municipal performance:

1) Organizational structure which is supposed to clearly assign tasks and responsibilities to various municipal departments and other involved institutions. Both, the overlapping of responsibilities as well as gaps of non-responsibility, within institutions or between them, hinder effective urban flood risk management.

2) Content of urban flood management policies and plans. The plans have to state clear and overall workable targets and measures. Only if these principles of clarity and workability are realized in plans they will make a valuable contribution to municipal performance.

3) Process of implementing plans in which the success depends on quality of plans and the municipality's ability to enforce plans in terms of financial and organizational capacities.

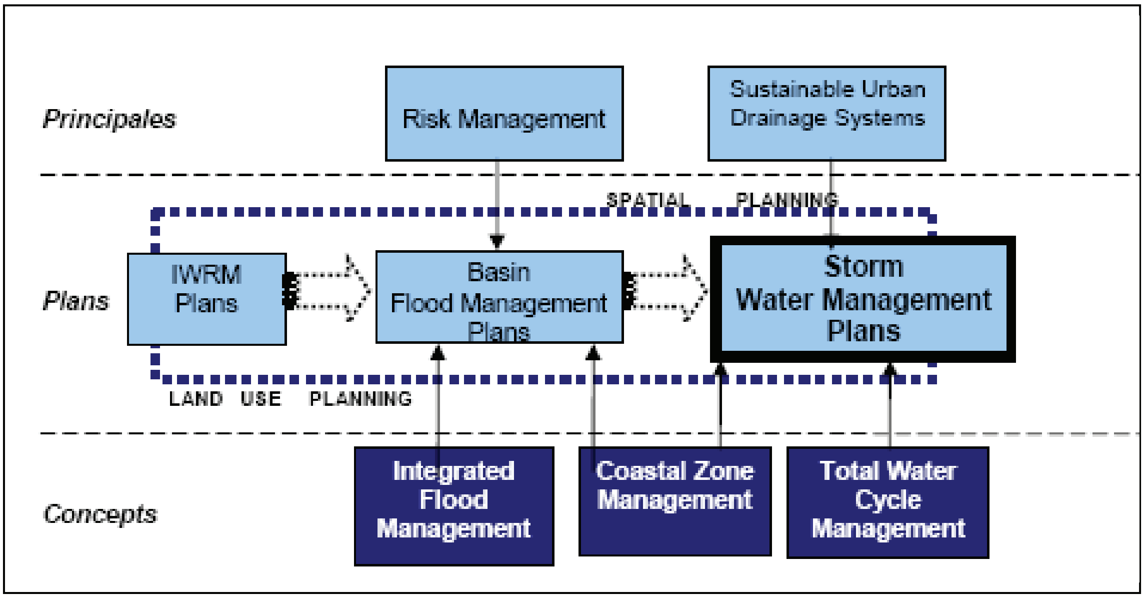


Fig. 9. Conceptual framework of urban flood risk management [6, 11]

6. Stakeholder Participation

Flood control measures planned without participation of the affected communities and other stakeholders are unsustainable as they do not meet the needs of relevant stakeholders. These situations can be overcome by establishing participatory planning process. In this context, decision making is a combination of top-down and bottom-up approaches which enables the involvement of all stakeholders on the basis of equity. The stakeholders consist of responsible municipal authorities, river basin organizations, regional development authorities; academic institutions, private sector; NGOs and concerned citizens and communities

The involvement of stakeholder knowledge from different perspectives together enables a coherent understanding of flood risks. Members of affected communities have the chance to express the community needs and to promote the integration of their demands in the decision making. Stakeholder involvement allows for identification and implementation of flood effective and sustainable management measures because the majority of stakeholders support them [14].

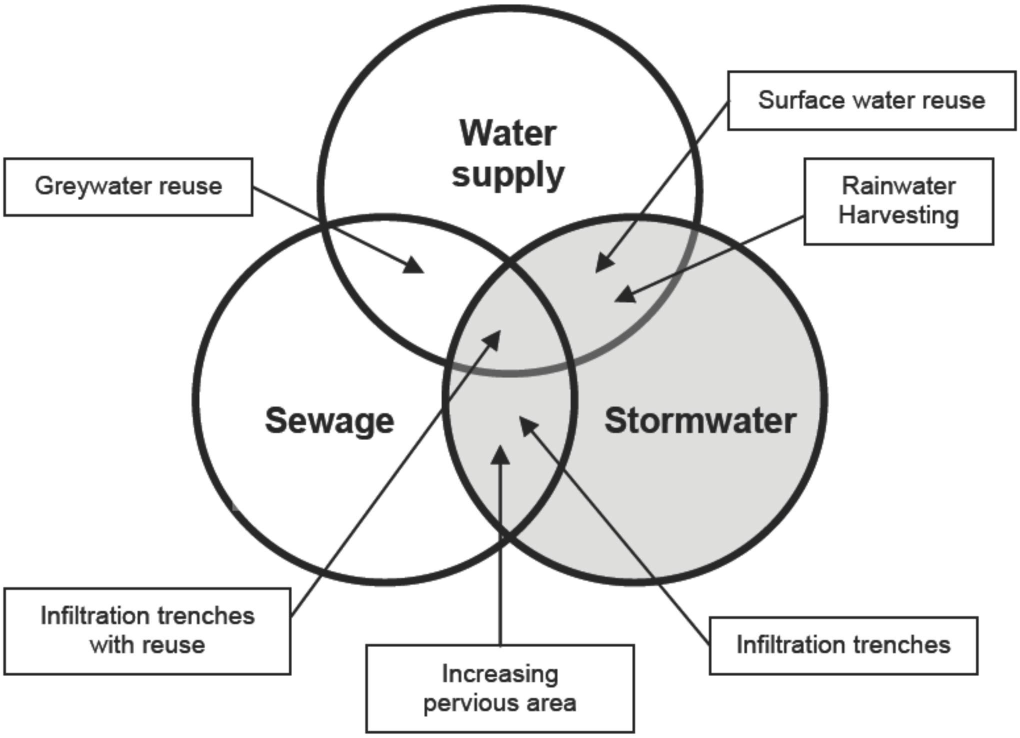


Fig. 10. Total water cycle management-concept diagram [6, 12]

7. Conclusions and Recommendations

Urban flood risk depends on a combination of components comprising hazard and vulnerability. It underlines the combination of natural and human factors that create flood risks. Flood management measures have to be planned across administrative and sector boundaries. Institutionalized links between concerned authorities facilitate cooperative planning. Successful urban flood risk management is obtained if structural and non-structural measures are implemented. The implementation of multiple purpose measures enables municipalities to achieve multiple goals such as flood mitigation, water supply, space for recreational activities, groundwater recharge and improvement of urban environment. Monitoring and evaluation of implemented measures enable the identification of best practices under the specific circumstances and help to constantly improve flood risk management plans. Community participation in flood risk assessment as well as in planning and implementation of risk management measures is a key for the success of flood risk management plans.

References

[1] Morris D, Hargreaves B, Pazzaglia F, Weisman R and Williamson C. Assessing the interactive effects of landscape, climate, and UV radiation on river ecosystems: modeling transparency to UVR and the response of biota, Workshop progress report, (Grant# R829642), Lehigh University Bethlehem, PA, USA; 2004.

[2] Pauleit S, Duhme F. Assessing the environmental performance of land cover types for urban planning. In: Landscape and urban planning. 52: 1-20, 2000.

[3] IPCC. Summary for policymakers. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ and Hanson CE, Eds.,*Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change,* Cambridge University Press, Cambridge, UK, p. 7-22; 2007.

[4] Srikantha Herath, Geographical information systems in disaster reduction, Institute of Industrial Science, The University of Tokyo, Japan; 2001.

[5] Tingsanchali T, Keokhumcheng Y. Flood damage functions for surrounding area of Second Bangkok International Airport, Proceedings, International Symposium on Urban Safety of Mega Cities in Asia, Phuket, Thailand, November, 2006; p. 291-300.

[6] WMO/GWP. Urban flood risk management, a tool for integrated flood management, Associated Programme on Flood Management, World Meteorological Organization; 2008.

[7] Tingsanchali T. Flood disaster and risk management, Invited Paper, Proceedings, 1st EIT International conference on water resources engineering, Petchaburi, Thailand, August, 2011; p. 15-24.

[8] UNESCO. Fighting floods in cities; Project training material for disaster reduction; Report, Delft, Holland; 1995.

[9] ESCAP/UNDP. Manual and guidelines for comprehensive flood loss prevention and management. UN-ESCAP, Bangkok, Thailand; 1991, 92p.

[10] Moll R. Co-operation within Europe on flood management and spatial planning. In: Szöllösi-Nagy, A. and Zevenbergen, C. [Eds.]. *Urban Flood Management*. A.A. Balkema Publishers; 2005.

[11] APFM. Integrated flood management – Concept paper. Associated Programme on Flood Management, WMO Series No. 1047, Geneva, Switzerland; 2009, 27p.

[12] Chanan A, Woods, P. Managing the Water Cycle in Sydney Metropolitan: Local Governments Do Matter! In: Khan, S.J., Schäfer, A.I. and Muston, M.H. [Eds.]. Integrated concepts in water recycling; 2005.

[13] APFM. Land use planning for IFM. In Flood management tools series. Associated Programme on Flood Management, WMO, Geneva, Switzerland; 2008.

[14] UN-HABITAT. Tools to support participatory urban decision making, United Nations Centre for Human Settlements (Habitat), Nairobi, Kenya; 2001, 150p.