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The **Associated Programme on Flood Management** (APFM) is a joint initiative of the World Meteorological Organization (WMO) and the Global Water Partnership (GWP).

It promotes the concept of Integrated Flood Management (IFM) as a new approach to flood management. The programme is financially supported by the governments of Japan, Switzerland and Germany.

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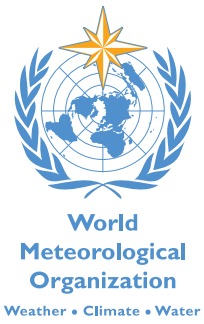

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To the reader

This publication is part of the *"Flood Management Tools Series"* being compiled by the Associated Programme on Flood Management. The *"Urban Flood Management in a Changing Climate"* Tool is based on available literature, and draws findings from relevant works wherever possible.

This Tool addresses the needs of practitioners and allows them to easily access relevant guidance materials. The Tool is considered as a resource guide/material for practitioners and not an academic paper. References used are mostly available on the Internet and hyperlinks are provided in the *References* section.

This Tool is a *"living document"* and will be updated based on sharing of experiences with its readers. The Associated Programme on Flood Management encourages disaster managers and related experts engaged in management of urban flooding around the globe to participate in the enrichment of the Tool. For this purpose, **comments and other inputs are cordially invited**. Authorship and contributions would be appropriately acknowledged. Please kindly submit your inputs to the following email address: apfm@wmo.int under Subject: *"Urban Flood Management in a Changing Climate"*.

Acknowledgements

This Tool makes use of the works of many organizations and experts, as listed in the references. Special acknowledgements are due to Dr John R. Labadie for his competent expertise and for bringing various perspectives into focus under technical guidance of the APFM Technical Support Unit; and many thanks to Mr Firas Al-Janabi, who provided a preliminary draft of this document.

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CONTENTS

FIGURES

1 INTRODUCTION

1 The problems posed by urban flooding are difficult enough to confront and manage. These problems will become even more troublesome as the climate continues to change, as the degree and extent of climate variability move in unpredictable ways, and as a high level of uncertainty remains regarding the trends and possible next equilibrium state(s) of the world climate. The main thrust of this document is to examine the major aspects of urban flood management through the lens of climate change.

2 The point of this document is not to discuss or dispute the reality of climate change, nor is it to delve into the science of climate change. The point of the document is to take as given the existence, probable course, and projected effects of climate change and to explore the question: "How does one adapt the management of urban floods to the likely effects of climate change?" That is:

- Are current policy, planning, and implementation mechanisms for urban flood management effective within the context of climate change?
- If not, what changes need to be made to address the problems posed by climate change?
- What are the major issues (political, social, economic, financial and environmental) likely to have a significant impact on urban flood management in a changing climate?
- Is it possible to identify both important synergies and significant impediments – i.e., will adapting urban flood management principles and techniques to climate change make other problems worse or better?
- Are there ancillary payoffs (environmental; economic; social) to pursuing adaptive strategies?

3 This document focuses on urban flooding, not rural flooding or flooding in general. Companion documents in the APFM *Flood Management Tools Series* address such topics as climate science and predictions, flood characteristics, risk management, emergency planning, and the like. Other APFM publications provide information and analysis regarding economic, social, and legal aspects of flood management. Information and insight from these publications and from other sources will be incorporated or referenced here throughout to provide examples or illustrations.

4 This document deals with the intersection of climate change and urban flood management. It is more about the "management" process and less about the technical, structural, and capital-intensive strategies usually pursued in coping with urban floods. It also explores the vital interaction and necessary overlap of urban flood management with land use management, urban planning, socio-economic development, and public awareness and participation. All of these issues lie at the core of planning for and carrying out strategies for climate change adaptation.

5 The intended audience for this document is as broad as the field of climate change adaptation. Although urban flood management is customarily seen as a public function, carried out by elected or appointed officials at various levels, the overlay of climate change expands the cast of characters to include a wider range of stakeholders, community groups, and citizens. The intent of this document is to provide useful guidance for urban officials, planners, emergency managers, flood management practitioners, NGOs, business leaders, civil society organizations, community organizations and other actors involved in urban flood management.

6 **Chapter 2** establishes the baseline of current flood problems and effects and then examines how climate change will likely affect these "normal" circumstances, including concurrent hazards that may be exacerbated by climate changes. **Chapter 3** examines the risks inherent in the normal operations of flood management infrastructure and demonstrates how climate change can change the risk pattern and scope for these operations. **Chapter 4** explores the strategies that may be applied in integrating flood management with climate change adaptation, especially the incorporation of other stakeholders (including the general public) into the adaptation and management process. A number of examples from around the world will illustrate the successful application and integration of these strategies. **Chapter 5** identifies a number of governance and socio-economic conditions that, if not specifically addressed in the urban flood management process, may limit the possibilities for success. **Chapter 6** provides a summary and conclusion.

2 THE CHALLENGES POSED BY CLIMATE CHANGE

7 Cities and communities around the world have enough problems with flooding as it is. Climate change will likely not make things any better or easier. It is all too possible that usual, expected precipitation and flood parameters will change, as will variations about the mean that we have become accustomed to over the past decades. Climate change will bring about alterations in meteorological circumstances lasting for long periods. These alterations will "play themselves out across space and time, owing to differences in infrastructure densities and use, difference in environmental conditions, and the long-term nature of climate change as well as the long-lived nature of the various infrastructure systems" (Kirshen et al., 2006). Climate change will likely complicate the demands imposed on communities by rapid urbanization, industrial expansion and the pressure for economic development. This section describes the "normal" flood experience and details what changes climate change may impose upon that normal.

2.1 Urban flood hazards and impacts (the "normal" situation)

8 Urban floods result from the confluence of both meteorological and hydrological factors, exacerbated by human actions. Meteorological and hydrological factors include rainfall frequency and intensity, storms, temperature, and the like. Hydrological factors include existing moisture levels in the soil, groundwater levels, extent of impervious surface, natural channelization of water courses, and tidal impacts on runoff. Human actors complicate matters through land-use changes, occupation of the flood plain, inadequate maintenance of drainage infrastructures, and obstruction of drainage channels through improper disposal of solid waste.

9 The figure below is a generalized view of water movement in an urban environment. If the amount or intensity of precipitation is greater than the capacity of the system, or if parts of the system do not function properly, floods are the result. Andjelkovic also identifies a system "minor" – consisting of sewers, curbs and gutters, open channels, and swales – and a system

"major" – consisting of natural and man-made pathways for excess water to flow overland to a receiving water body. Floods in urban areas result from the interplay between these minor and major systems. Many communities did not know that the system "major" existed until they found water coursing through their basements, industrial parks, and commercial buildings (Andjelkovic, 2001).

10 The direct impacts of urban flooding are clear and easily observed: inundation of buildings and residences, damage to structures, washing away of belongings and vehicles, destruction of public infrastructure, mud and mold everywhere – not to mention the injuries and loss of life. Less obvious are the backup of sewage into homes and buildings and the release of untreated sewage from damaged treatment plants. In addition, hazardous chemicals and fuels may be spread by flood waters from damaged production facilities or storage areas, or the flood may even float off the containers themselves to lodge in someone else's backyard. Both untreated sewage and toxic chemicals can pose significant threats to public health and the water supply.

11 Other impacts are often overlooked in planning for, responding to and recovering from urban floods. The ability to earn a livelihood may disappear for some time. The ability to travel to work may be seriously compromised. Schools and other community centers or services may be closed for days or weeks, and commercial businesses that provide food and necessary items may be damaged or inaccessible. At the same time, flood waters and related flood damages may reduce the amount of vital supplies that can be transported into the city, lengthen the travel time or even stop the movement of supplies altogether.

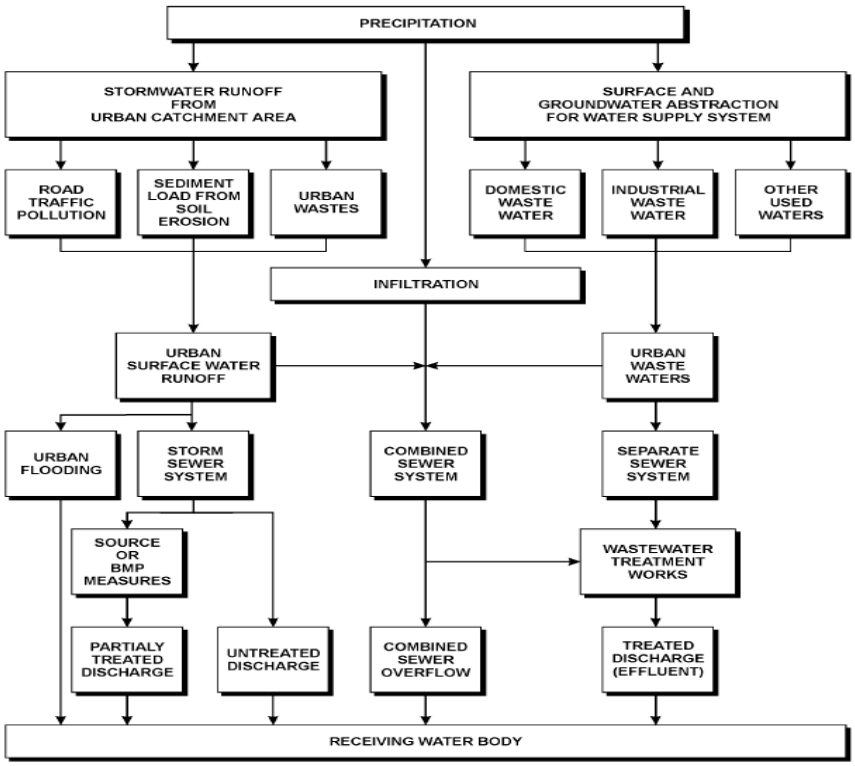

Figure 1 — Movement of Water in an Urban Environment (Andjelkovic, 2001)

2.2 How urban floods differ from rural floods

12 What are the unique characteristics of urban areas that make urban floods different from rural floods? At the most basic level, land cover and vegetation are stripped away in the process of urbanization to make way for buildings, roads, parking lots, and other impervious structures. The natural storage capacity of the soil in the area is diminished or even eliminated. Constructed (and inadvertent) drainage channels alter the existing hydrology and flow regimes, such that precipitation flows rapidly across the surface in short, intense, high-volume bursts rather than sinking into the soil. **Figure 2** illustrates this difference in the flow of urban precipitation:

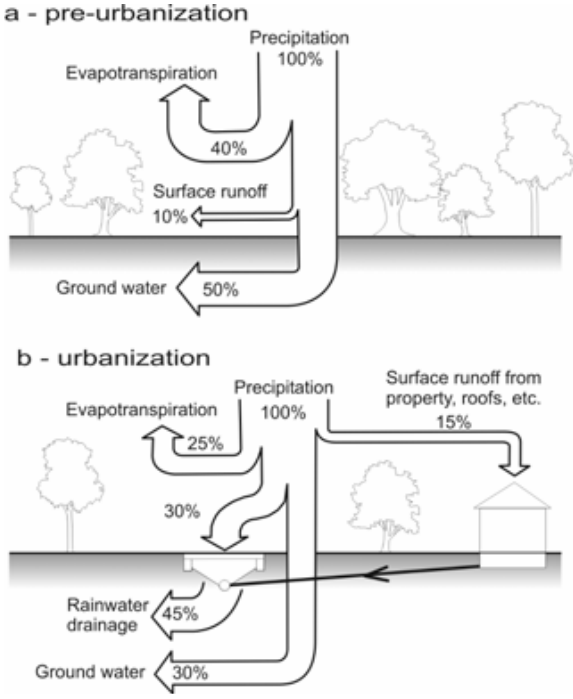

Figure 2 — Water balance characteristics in an urban watershed (Tucci, 2007)

Considerably more of the precipitation winds up as surface runoff into storm sewer systems or directly into water bodies.

13 As further described by Tucci, urban areas are characterized by population highly concentrated in a (relatively) small area, and in-migration may run well ahead of the planning and construction of infrastructure to cope with it. In developing countries, urban growth is usually concentrated in "informal" settlements, and such urban planning as there is focuses on the middle- and high-income areas of the city. Obstruction of drainage systems, ditches, culverts and streams by solid waste and refuse can be a considerable obstacle to the efficient conveyance of storm water through an urban area. Refuse (or flood debris) can block channels, causing the water to back up and spread laterally into business and residential areas.

14 Tucci notes that the following impacts generally occur as the city develops (Tucci, 2007):

- Increase in peak flows (up to 7 times) and in frequency owing to the higher runoff capacity through conduits and canals, and impermeabilization of surfaces;

– Increased sediment production from unprotected surfaces and production of solid waste (refuse);

– Deterioration in quality of surface and ground water, owing to street cleaning, transport of solid material and clandestine sewage and storm water connections;

– Disorganized implementation of urban infrastructure, such as: *(a)* bridges and street embankments obstructing runoff; *(b)* reduced channel section due to backfilling in bridges and building in general; *(c)* deposition in and obstruction of rivers, canals and conduits by refuse and sediments; *(d)* inappropriate drainage projects and works, with reduced downstream diameters, drainage without runoff.

15 Andjelkovic provides a visual summary of the interlocking problems brought on by urbanization:

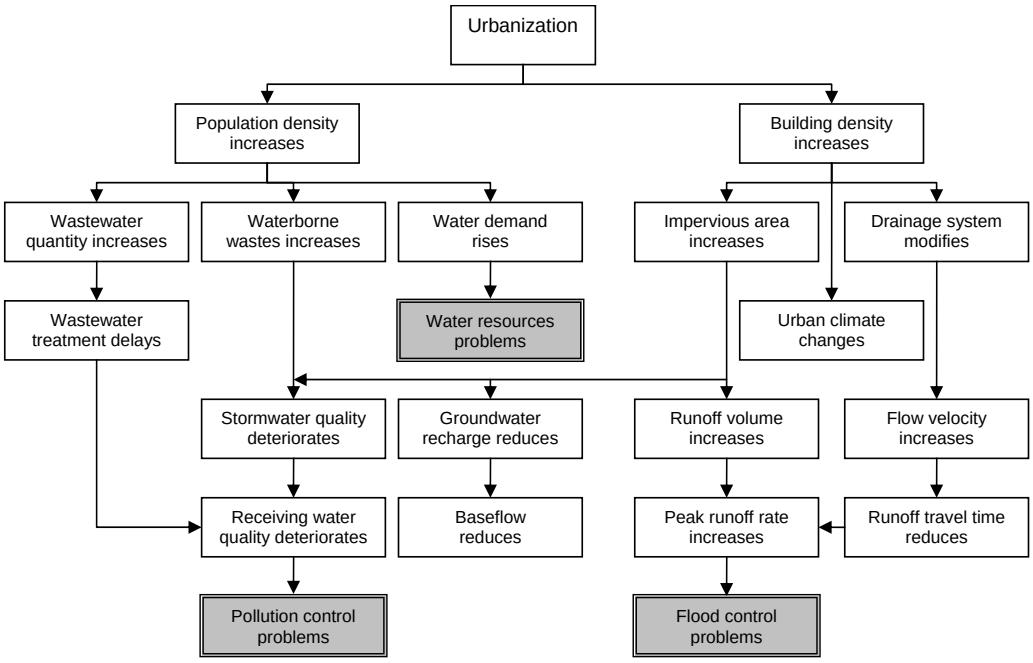

Figure 3 — Hydrologic impacts of urbanization (Andjelkovic, 2001)

2.3 Climate variability and uncertainty (how this could affect the "normal" situation)

16 Climate scientists are comfortable with the issue of uncertainty in research results, and they address it specifically in all of their models and analyses. The wide range in estimates of possible climate change effects, timing and intensity—not to mention the lengthy time scale over which these might happen – are of great interest in scientific debates. Managers, however, must deal with budget and planning processes that require hard numbers and clear (sometimes spuriously so) predictions. Urban flood planners and managers will find it difficult to make planning and investment decisions regarding adaptation to climate change when faced with questions for which there are, as yet, few clear and definitive answers. For example:

– Will there be floods or droughts?

– Will it be too hot or too cold?

- Will there be higher intensity rain storms over a shorter period of time?
- Will extreme weather events happen more often with less time (for recovery) in between?

17 An increase in average atmosphere temperature will increase the moisture capacity of the atmosphere. This will likely lead to altered precipitation patterns, changed atmospheric circulation and storm tracks, a more unstable hydrological cycle with more frequent and intense precipitation events and increased flood risk. The instability will increase both the uncertainty and scope of the risks, including residual risks.

18 Uncertainty will also play into adaptation decisions in the private sector, as people weigh the costs and benefits of investment in climate-proofing the built environment. Stern points out that *"there will be little financial incentive for developers to increase resilience of new buildings unless property buyers discriminate between properties on the basis of vulnerability to future climate"* (Stern, 2007, p. 467). On the other hand (Labadie, 2011), how will prospective purchasers or developers factor in a 100-year flood (or other extreme weather event) if they plan to occupy the property for only 5–10 years?

19 Actions sensitive to climate change include those sensitive to current climate variability (hydrologic systems), actions regarding systems that have a long operational life, actions with a long construction lead-time, or actions addressing a single hazard. Uncertainty carries with real risks of mal-adaptation, for which planners and elected officials will have to answer (Ranger and Lopez, 2011):

- Over-adaptation: where adjustments are proven to be unnecessary given the climate realised, e.g. a sea defence built to withstand 4m of sea level rise that never emerges;
- Inaction/under-adaptation: a failure to act or where adjustments do not achieve the maximum potential reduction in losses for the realised climate, or in some cases, actually increase impacts above what they could have been given improved ex-ante adaptation;
- Incorrect adaptation: where adjustments are made, but are later found to be either not adaptive or counter-adaptive.

20 Designers and planners will have to become more comfortable with uncertainty and learn to deal with a more mobile target when planning flood responses and designing systems. Past history – upon which much of planning and design rest – may no longer be such a reliable guide to future performance.

> *Traditional approaches to designing and operating urban storm drainage assets have relied on past performance of natural systems and the ability to extrapolate this performance, together with that of the assets across the usable lifetime. Whether or not climate change is going to significantly alter future weather patterns in Europe, it is clear that it is now incumbent on designers and operators of storm drainage systems to prepare for greater uncertainty in the effectiveness of storm drainage systems.*
> (Ashley et al., 2005)

21 A recent study of flood policy in the United States notes the inability of the National Flood Insurance Program to encompass the vulnerability of urban areas to flooding. The program generally looks at precipitation peaks from longer rainfalls and does not reflect the shorter-duration events that significantly affect urban streams. The flood behavior of urban streams

is not well understood due to the shortage of flow data on urban streams and the rapidly changing urban construction and infrastructure (Ntelekos et al., 2010).

22 Given this high level of uncertainty, budgeting for flood planning & response may be even more difficult and fraught than it already is. Urban managers and elected officials will have to address vulnerable infrastructure, built with a considerable investment of money and resources, but which is aging and deteriorating with less money being invested to maintain, replace or retrofit it. Is it useful to maintain or retrofit systems to past design standards based on past climate history? Vulnerability of urban systems increases as population density increases, and the effects are multiplied when flooding damages electrical, electronic, communications and other support systems. Citizen concerns over public safety, public health and damage/destruction to private property won't make this task any easier.

23 How best, then, to meet the challenges imposed by climate variability and uncertainty?

> *These uncertainties all together pose a serious challenge in planning and implementing adaptive actions and have two implications. First, adaptation procedures need to be developed which do not rely on precise projections of changes in river discharge, groundwater, extremes etc. Another way of coping with the uncertainty associated with estimates of future climate change is to adopt management measures that are robust. Approaches like Integrated Flood Management (IFM), for example, is based around the concepts of flexibility and adaptability, using measures which can be easily altered or are robust to changing conditions.*
> (WMO, 2009b)

2.4 Urban development as a consequence of climate variability

24 It is a common assumption that urban populations will increase as people move to the cities as a response to worsening conditions brought about by climate change. This assumption is especially strong regarding the least-developed countries. However, the situation is not as straightforward as it might seem.

25 A recent study by the British Government Office for Science acknowledges that climate-induced migration to cities is already happening and likely to continue in the future. Cities are particularly vulnerable *"and are faced with a 'double jeopardy' future. Cities are likely to grow in size, partly because of rural–urban migration trends, while also being increasingly threatened by global environmental change. These future threats will add to existing fragilities; new urban migrants are, and will continue to be, particularly vulnerable"* (Foresight: Migration and Global Environmental Change, 2011). The report points out, though, that migration is a complex phenomenon, driven by political, environmental, demographic, economic, and social factors, and that it is impossible to distinguish "environmental migrants" from other migrants. Indeed, environmental change is just as likely to prevent migration.

26 The IPCC notes that migration from rural to urban areas is a common (and often temporary) response to extreme environmental events. Determining why people migrate is problematic and must be considered in the context of changing economic opportunities.

> *Estimates of the number of people who may become environmental migrants are, at best, guesswork since (a) migrations in areas impacted by climate change are not one-way and permanent, but multi-*

> *directional and often temporary or episodic; (b) the reasons for migration are often multiple and complex, and do not relate straightforwardly to climate variability and change; (c) in many cases migration is a longstanding response to seasonal variability in environmental conditions.*
> (IPCC, 2007, Box 7.2)

27 Regardless of how one parses the motivations and circumstances of migration from rural areas to cities, urban populations will continue to grow, adding to the stresses and difficulties posed by climate change. An increasing urban population will place ever-higher burdens on support services, housing stock (very likely built in poorer, marginal areas and/or the flood plain), infrastructure, employment, and social organization. At the same time, reduction in the agricultural workforce in the surrounding areas may affect the quantity and quality of foodstuffs available to support the urban population.

2.5 Climate change as a driver of concurrent hazards in an urban environment

28 The imposition of projected climate change affects can only serve to make the circumstances, experience and outcomes of "normal" urban flooding even worse. It is certainly possible that climate change coupled with urban growth could create urban flooding problems where none had existed previously.

29 Urban floods do not happen as discrete, bounded events. They occur as part of the overall urban context, and they affect – and are affected by – other concurrent hazards. Increases in average atmospheric temperatures are one of the projected impacts of climate change. An increase in air temperature increases the amount of water that the air can hold, increasing the water available for precipitation. Large urban agglomerations can function as "heat islands" further raising the air temperature in a localized area. The resulting micro-climate may further increase the amount and intensity of precipitation in the urban area. Even a small increase in the total precipitation can have a major effect on drainage infrastructures **(Section 3.1)**.

30 Overloading of sewer and drainage systems due to increased precipitation, coupled with actual damage to or failure of system elements, can release untreated sewage into the community. This problem is even more serious in urban areas in developing countries where untreated sewage is disposed of into open drainage systems. The resulting contamination of urban flood water with fecal material presents a substantial threat of enteric disease.

31 Where diseases are normally endemic, flood waters can facilitate the spread of disease vectors, potentially leading to increased incidence of water-borne diseases such as leptospirosis and cholera. The flooding of toxic materials production/storage areas, hazardous waste dumps and treatment plants can release microbial pathogens, suspended solids, toxics, nutrients, trash and other pollutants, not only posing a direct health risk to the public but also contaminating drinking water sources.

32 The effects of urban flooding can extend even further. Flooded areas are inaccessible, and any activity (truck gardens, home-based production and industrial production) becomes impossible. Overland flow of flood waters increases non-point source pollution loads, and the extended

floodplain can create more erosion and debris which may exacerbate already extensive flood damage. All of these factors will create losses in property, productivity, livelihood, and quality of life. Those on the lower end of the socio-economic scale will have less capacity to respond and recover, placing even greater demands on social service mechanisms (Kirshen et al., 2006).

3 THE RISKS IMPACTING URBAN FLOOD MANAGEMENT

3.1 Managing infrastructure for flood control and prevention

33 A study of climate change effects on urban drainage systems in Norway demonstrated that increased rainfall amounts and intensities put a greater than expected load on existing sewer systems. The authors note the challenges imposed by climate change, rapid urbanization, and under-designed systems. Flooding is the most serious consequence of intense precipitation, and even small increases in precipitation can have inordinately large effects on the drainage system. Basing their findings on both actual events and simulations, they show that a 20 percent increase in precipitation (in a single event) leads to a 365 percent increase in flood volume; the number of at-risk buildings increases by 120 percent (Nie et al., 2009).

34 How do city managers design, operate, and maintain a drainage and/or flood control infrastructure in the face of a changing climate and likely higher precipitation? Systems are normally designed based on 25-, 50- or 100-year flood frequencies and other previous experience factors. However, as we have seen, past history may no longer be a reliable guide to future events in the climate change context. Drainage systems and other flood control measures can take a long time to develop and build, and decisions made during the scoping and early design stages can have significant impacts on the total construction cost. Changes made at a later stage of design or construction – in order to accommodate changing climate circumstances – become more costly, yet both under-sizing and over-sizing of the infrastructure are equally problematic: larger damage and casualties in the one case; unnecessarily high cost in the other.

35 Operations and maintenance of drainage systems and flood control measures is important, especially when these systems intersect or overlap with other infrastructure elements and operations. Poor maintenance of roads and culverts can negatively affect the effectiveness of flood control measures; lack of an effective solid waste disposal system can increase the amount of trash and debris clogging drainage channels, reducing the carrying capacity. At the

same time, the operation of sewage treatment systems, along with combined sewer overflow elements, must be emphasized in order to protect public health.

36 Efforts to manage urban flood water tend to focus on confining the water in restricted channels, preventing it from flowing into certain "high-value" areas, and speeding its transit through the urban areas to somewhere else. These tactics, of course, don't really solve the problem; they merely shift the problem, and the deleterious effects, to a different part of the city or to the next urban area downstream.

37 There is a tendency to focus on technical and engineering issues in addressing urban flood problems or issues and to discount the influence of social characteristics and circumstances on susceptibility to flood risk. This bias toward technological and physical solutions (e.g., flood walls, levees or drainage systems) can encourage development in hazard areas when, in fact, hazards can surpass the margin of safety provided by technological solutions.

3.2 Operation of utilities in extreme weather events

38 Drainage and wastewater utilities will be adversely affected by climate change, especially extreme weather events.[1] Higher volumes and intensity of storm water may exceed infrastructure capacity, with higher volumes of storm water entering the sewers. Surcharge events will increase, and larger volumes of waste water will be conveyed to sewage treatment plants. Treated effluent may not flow easily from treatment plants, causing backups and overflows. All of this can lead to increased flooding incidence, increased damage to infrastructure and an increase in soil erosion (Sinisi and Aertgeerts, 2010, Table 10).

39 Storms, heavy rainfall events and a higher frequency of flood events require protection of drainage systems, sewer systems and treatment plants against high peaks of hydraulic load; additional storm water storage in retention structures; treatment of the "first flush" storm water containing high concentrations of pollutants. Accelerated maintenance of the drainage infrastructure will be necessary to remove blockages, repair leaks and breaks, and ensure that vital pumping stations have sufficient power to keep operating. Up-to-date mapping and modeling of the system will help to identify potential problem areas and choke points and to predict how the system will operate under conditions of higher flow volume and intensity.

40 Floods can affect the hydraulic capacity of an entire drainage system. Natural gravitational discharge from the drainage system is gradually disabled, and it is necessary to start operating reserve pumping stations. That is why full operability of ordinary as well as emergency electromechanical equipment (flood pumps) should be secured. Long-lasting rainfall events can lead to waterlogging of the soil, leading to increased surface flow, destabilization of slopes, and landslides – all of which can damage infrastructure elements, whether installed above ground or below the surface.

41 Expedient measures, such as moveable flood walls, sandbag emplacements, back-flow prevention devices and portable pumps can provide short-term relief from flood intrusion,

1 Much of this subsection is drawn from Sinisi, L. and R. Aertgeerts, Editors, 2010: *Guidance on Water Supply and Sanitation in Extreme Weather Events,* United Nations Economic Commission for Europe and the World Health Organization, Regional Office for Europe.

but they may be less effective in intense precipitation events. These are technical solutions to immediate problems, and they should be combined with the non-technical planning and management approaches discussed in **Chapter 4** of this document.

3.3 Uncontrolled development of informal settlements

42 The world trend toward urbanization is growing and accelerating and with it the number of people who are even more exposed to the effects of urban flooding.

> *Climate change will impact future city spatial patterns, growth, and development. The world's population is moving to cities; one-half of the global population is already urban. By 2030 at least 61 percent of the world's population will be living in cities. Cities of the developing world will absorb 95 percent of all urban growth and will be home to almost 4 billion people, or 80 percent of the world's urban population. What was once dispersed rural poverty is now concentrated in urban informal and squatter settlements. Asia holds more than one-half of the world's slum populations of 581 million. By 2015, 12 out of the largest 15 cities in the world will be in developing countries, and 4 of those will be in Asia.*
> (Prasad et al., 2009)

43 Deleterious effects of degraded environmental conditions are felt most keenly (though not exclusively) by the poor, residents of shantytowns, "favelas," and other marginal or hazardous areas. They are often clustered on steep slopes subject to flash floods and erosion, in dwellings built of substandard materials, with poor water and waste disposal systems. Natural disaster effects can be greatly magnified by the poor environment in which these people live.

44 Informal settlements, as the term implies, are not planned nor are they usually subject to land-use restrictions or to enforcement of building codes or drainage codes. Migrants to urban areas build shelters on marginal or unimproved land because they cannot afford to live elsewhere. Their shelters are built of bamboo, tin, cardboard, scrap metal or other light materials that will not withstand flood waters. In many cases residents of informal settlements fill in natural drainage channels with dwellings or waste materials, preventing normal rainwater flow and causing the water to spread out into the residential area. Pathways and (unpaved) streets that reflect the travel patterns of the residents are beaten flat and impervious, affording no means for soil absorption of precipitation, but providing a free passage of precipitation and flood water into homes and businesses (Satterthwaite, et al., 2007a).

45 Where water supply and drainage/wastewater infrastructure exists, it is easily overwhelmed by the movement of people into the area and the construction of marginal shelters. Mostly, however, there is minimal or no infrastructure in these areas, in part because they have grown in an unplanned and uncontrolled manner, and in part because municipal governments avoid making the kind of infrastructure investments in these settlements necessary to support the increasing population. Many informal settlements, especially in low-income nations in Africa and Asia have no sewers, no piped-in water, and no solid waste collection and disposal service (Satterthwaite, 2007).

46 Residents of informal settlements have little incentive to improve their properties or to invest in infrastructure improvement or maintenance because they have no legal tenure rights to the

property and may be forced out of the area by government or private development efforts (Braun and Aßheuer, 2011). In fact, municipal governments in these cities usually are more solicitous of the demands and needs of middle- and upper-income residents. Informal settlements generally reflect and demonstrate the way risks are distributed in a society: benefits accrue to the top of the socioeconomic scale while risks accumulate at the bottom.

3.4 Sea-level rise and storm surges in coastal urban areas

47 Increases in precipitation volumes and intensities will pose serious challenges to urban flood management, but they are not the only threat to cities. Projected sea level rise (SLR) will likely create problems in flood management from (if you will) the other end of the pipeline.

48 Large populations around the world live in the low-level coastal zone:

> *"... the continuous area along the coast that is less than 10 metres above sea level, represents 2 percent of the world's land area but contains 10 percent of its total population (i.e., over 600 million people) and 13 percent of its urban population (around 360 million people). Almost two thirds of the world's large cities with more than 5 million inhabitants fall in this zone, at least partly."*
> (Satterthwaite et al., 2007a)

49 Mumbai, Dhaka and Shanghai are quite vulnerable to sea-level rise, as well as major settlements in Brazil and Venezuela. One-half of Africa's "million cities" are wholly or partially in the low-level coastal zone, Lagos and Alexandria for example. Highly urbanized coastal areas at risk include Vietnam, Gujarat and Orissa in India, and the Caribbean (Satterthwaite, et al., 2007b).

50 The immediate and obvious effects of sea-level rise include increased seawater infiltration volumes, more saline waste water and hence treated effluent, and loss of land area. Increased flooding of coastal areas may require the need for additional flood defenses, requiring considerable investment in new construction. In addition, flood insurance premiums may increase (Sinisi and Aertgeerts, 2010). Sea-level rise, coupled with the increase in strong storms (and hurricanes), can cause direct flooding of urban areas along coasts, deltas, or major rivers through storm surge and high water. At the same time, an increase in sea level may submerge or reduce the freeboard of both natural defenses (such as mangrove swamps) and man-made structures (for example, the Thames Barrier in London, the Delta works in the Netherlands or the MOSE Project in Venice), reducing their protective capacity (IPCC, 2007, Chapter 6).

51 Even a small amount of sea-level rise (with or without storm surges and increased tides) will create significant back pressure on both natural and constructed urban drainage channels. With a higher water level in a receiving water body (a river or bay), urban flood water will not be able to drain as effectively. Both gravity and pumped drainage systems must have someplace for the water to drain to, and if that place is not available, the water will simply spread laterally farther into urban areas. Communities may be forced to choose between extremely expensive upgrades to existing drainage infrastructure (and/or construction of new infrastructure) or accepting greater levels of flood damage and dislocation.

4 INTEGRATED FLOOD MANAGEMENT ELEMENTS FOR ADAPTATION

52 Urban flood management plans and approaches share a common feature: a focus and concentration solely on the technical (hydraulic and engineering) aspects of flood management. This ignores the very real environmental, ecological, political and socioeconomic aspects of flood management. It is not really possible to control or totally eliminate floods, and planners and practitioners should concentrate instead on enhancing the resilience of the population to flood risks. Tucci puts it most succinctly:

> *Flooding is controlled by a combination of structural and non-structural measures enabling the riverside population to minimize its losses and continue to live in harmony with the river. These include engineering and social, economic and administrative measures. Planning of protection against flooding and its effects involves research into the ideal combination of these measures.*
> (Tucci, 2007)

53 Technical approaches to urban flood management are fairly straightforward and well-understood. This section will focus on the non-technical, non-structural elements of flood management that will embed flood management firmly in the climate change adaptation paradigm.

4.1 Urban Flood Management and adaptive strategies

54 Urban flood management must deal directly and explicitly with drinking water supply, sewage and wastewater disposal, and surface runoff disposal, while managing both stormwater quantity and the effects of stormwater on water quality.[2] In so doing, urban flood managers must also work within the framework of Integrated Flood Management so as to meet the larger issues of effectiveness, socioeconomic equity, and long-term positive outcomes. The urban flood zone

2 This discussion is largely drawn from WMO, 2009c.

lies within a larger watershed and floodplain area, and its flood hazard and experience cannot be divorced from the management of the hydrology of the entire system.

4.1.1 Integration of UFM, IFM and IWRM

55 Integrated Flood Management (IFM), as discussed at length in a variety of WMO documents, addresses key elements for managing floods in an integrated manner (WMO, 2009c):

- Manage the water cycle as a whole;
- Integrate land and water management;
- Manage risk and uncertainty;
- Adopt a best mix of strategies;
- Ensure a participatory approach;
- Adopt integrated hazard management approaches.

56 Integrated Flood Management makes use of policy, regulatory, financial and physical measures to move from traditional "flood control" towards "flood management" recognizing and appreciating the full range of interactions between floods and the places of human habitation (WMO, 2008a). Integrated Flood Management must address issues concerning human security and sustainable development from the perspective of flood management, within the framework of Integrated Water Resources Management **(IWRM)**. It must also accommodate Integrated Coastal Zone Management **(ICZM)**, since the lower reaches of a river estuary and coastal zone form an integral part of the river basin. Floods, urban and otherwise, are a natural phenomenon, related to the natural regime of a river. Structural and non-structural interventions anywhere along that river or anywhere within the watershed will have impacts on the natural environment, possibly causing environmental degradation and impairing natural ecosystem services (including natural flood water attenuation and dispersal) (WMO, 2007a). Urban flood management must be integrated with both IFM and IWRM to ensure that economies of scale are captured, to create synergies wherever possible, and to avoid maladaptive behaviors.

57 Decisions made regarding the provision of irrigation water to the agricultural hinterland can affect the amount, flow rate and quality of water reaching the urban areas. Management of runoff from upper reaches of the watershed can affect the ability of urban flood management systems to handle increased flows. On the other hand, building of urban flood control structures (dikes, levees, diversions) can merely shift the flood problem downstream, affecting distal rural and urban areas. Efforts to keep flood water out of the urban core may negatively impact suburban populations or nearby agricultural/industrial areas; the reverse is also true[3]. Land-use planning, as well as zoning and development schemes, should be analyzed and implemented in such a way as to maximize the benefit for the entire floodplain and watershed. Finally, all of these strategies and approaches must protect and enhance environmental quality and the flow of ecosystem services (WMO, 2007a; 2009b).

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3 Recent floods in Thailand provide an excellent illustration of this point.
An extensive summary is available at en.wikipedia.org/wiki/2011_Thailand_floods

58 Implementing urban flood management as an adaptive strategy goes well beyond the traditional, structural approaches, and it includes a great number of issues and practices that are not usually considered in flood management. To illustrate:

> *Adaptation is a process by which individuals, communities and countries seek to cope with the consequences of climate change, including climate variability. It should lead to harmonization with the country's or community's pressing development priorities such as poverty alleviation, food security, disaster management of economic development. It can be undertaken in a pro-active mode: through strategic planning in incremental stages; or autonomous mode where ad-hoc tactical adjustments are made as the events and situations unfold. [There are] four basic approaches towards adaptation: hazard-based approach; vulnerability-based approach; policy-based approach; and adaptive-capacity approach.*
> (WMO, 2009b)

59 The **hazard-based** approach concentrates on the physical characteristics and capacities of structural, technical flood controls. Climate change adaptation under this approach consists of matching the design features and capacities to the projected precipitation and water levels. Structures may be strengthened or improved to meet these new requirements, or if physical improvements are not possible or cost-effective, non-structural adaptive elements may be explored as a means of reducing residual risk.

60 The **vulnerability-based** approach focuses on reducing the vulnerabilities of the affected population and considers economic activities and degree of development of the area, frequency and intensity of floods, land and land use, anticipated impacts of development activities and demand for resources throughout the community. Circumstances of vulnerability can be improved through economic development and public development policies that are generally beyond the scope of flood management policies and plans.

61 The **policy-based** approach is structured around four major principles (WMO, 2009b):

- Adaptation to short-term climate variability and extreme events serves as a starting point for reducing vulnerability to longer-term climate change;
- Adaptation policies and measures are best assessed in a developmental context;
- Adaptation occurs at different levels in society, including the local level;
- The adaptation strategy and the process by which it is implemented are equally important.

62 This approach focuses on the development of long-term national/regional plans of action (addressing planning and finance, education, health, agriculture, food security, environment and emergency response) that then form the basis for action at the local (urban) level through involvement of community groups, civil society organizations and the private sector.

63 The **adaptive-capacity** approach seeks to raise the general capacity of the community to adapt to climate-induced shocks and to remain resilient in the face of both extreme events and longer-lasting adverse trends. It depends heavily on enhancing and sharing knowledge about climate change effects and adaptation, creating better early warning capabilities, and generally improving the socioeconomic level of the populace. **Chapter 5** of this document further explores the concept of adaptive capacity as both a supporting and limiting factor for flood management.

64 The four approaches, in the context of urban flood management as an adaptive strategy, are not mutually exclusive. They may be applied at different stages in the adaptation process or in different combinations that match the capability of the government and the community to use these approaches.

65 An excellent example of integrated planning and implementation occurred in the neighborhood of Augustenborg (Malmö, Sweden). Augustenborg has experienced periods of socioeconomic decline in recent decades and has frequently suffered from floods caused by overflowing drainage systems. In 1999-2001, the City of Malmö initiated a Sustainable Urban Drainage Systems (SUDS) as part of an effort to combat flooding, improve waste management and enhance biodiversity.

> *Due to recurring flooding problems it was proposed that stormwater from Augustenborg should be disconnected from the existing combined sewer, and drained by means of an open system. The main intention was to reduce flooding by 70%, eliminating combined sewer overflow completely, by both lowering the total volume of stormwater reaching pipes and reducing the peak flow rates. This has been achieved by reducing the impervious areas and the associated runoff, preserving and enhancing green spaces, and managing stormwater to reduce total runoff.*
> (Kazmierczak and Carter, 2010)

66 As a result of this project, the stormwater system is now able to handle runoff volumes locally. The implementation of this system has improved both stormwater management in the area, and the performance of the combined sewer system. The volume of stormwater draining into the combined system is now negligible, and this system now drains almost only wastewater. This type of integrated planning takes into account not only the outcome of flood risk mitigation, but also of the resulting economic and environmental impacts.

67 A somewhat different example occurred in the United Kingdom, based on a Foresight review of potential future floods and the traditional approach to flood risk management. A new concept was proposed for managing flood risk in urban areas, that of "integrated urban drainage management" within the perspective of "Making Space for Water".

> *A major driver for this has been the complex and dispersed institutional responsibilities for managing flood risk in England and Wales, comprising different responsibilities residing in the various stakeholder communities. As a consequence, the management of flood risk arising from more than one source is problematic and responses to floods or the threat of flooding may not necessarily be delivered in the most cost-effective or sustainable way ... Nonetheless in England and Wales there are no plans to change the complex institutional and governance structure; rather to promote better partnering between the various major stakeholders.*
> (Ashley et al., 2007)

4.1.2 Risk Assessment

68 Risk assessment (and the decision-making process based on that risk assessment) must change from a backward-looking model to one based upon understanding current and future levels of risk. The basis for any urban flood management plan is a comprehensive assessment of current and potential flood risks that identifies all the possible flood- related hazards, including how they are likely to develop in the future as a consequence of further urbanization, urban development,

land-use changes or climate change. In a sense, risk assessment is basically a quantification of hazards: areas and structures at risk, estimation of risk parameters, hazard costs, availability of resources for mitigation, and so on. Assessments provide information about the probability of a hazard's occurrence and the respective potential of loss, based upon an in-depth analysis of hydro-meteorological data and the hydraulic simulation of floods. However, numbers are only part of the risk story. Risk assessment numbers can:

> *...provide an overview of the financial burden to which a flood event may lead, but they fail to project non-economic aspects of vulnerability. This shortcoming has two respects. First, many objects in poor communities overall in informal settlements are of very low financial value but nonetheless they might be crucial for livelihoods, and thus their destruction can have very severe consequences. Secondly, a risk assessment that takes only economic aspects into account does not provide information about the community's vulnerability in social and environmental terms nor does it adequately express the community's capacity to cope with emergency situations.*
> (WMO, 2008a)

69 The most accessible output of a flood risk assessment is the identification of levels of protection vs the requirements imposed by specific hazards. It is also necessary for integrated flood management planning to consider the levels of acceptable risk as experienced by sectors of the affected community. An acceptable risk assessment entails (ACCCRN, 2009):

- An understanding of projected climate scenarios and potential impacts and the limitations of the projections
- Identification of who/what are the most vulnerable groups, areas, sectors, and urban systems and how they may be affected
- Identification of the range of factors that systematically combine to make them vulnerable, including both direct (e.g. exposure to hazards) and indirect (e.g. regional or international food security) factors
- Assessment of existing capacities to adapt

70 Thus, both qualitative and quantitative assessments must be included as a basis for comprehensive urban flood management. Assessing levels of acceptable risk – what is essential, acceptable, affordable or realistically possible – is essentially a political process conducted by political and community leaders. Defining levels of acceptable risk must be based on both the quantitative analysis, such as evaluation of flood damage costs, and on qualitative, human-centered analysis.

71 The proper outcome of a flood risk assessment is a set of flood risk maps reflecting hazards imposed by various flood and climate scenarios on specific areas and neighborhoods. Flood hazard maps provide basic information on the magnitude of flood hazards. They not only identify the extent and magnitude of flooding under various scenarios, but they also convey the sensitivity of such scenarios to various land uses and drainage operations.

72 GIS-based flood mapping rests on two main methods for estimating the direct damages due to flooding. The first method collects historical flood damage information, including building type, water depth in cellar and ground floor, damage to the building material, as well as flood height markings on buildings and personal accounts from flood victims. The second method uses predefined relationships between water depth and monetary damages to generate stage-

damage relationships for both residential and commercial property. In addition, surveys by experts appraising the potential damages on building structure and inventory for different water levels are also valuable (Kron, 2007). A recent study posits the development of a "digital city" concept that combines GIS-based maps with digital data collection, archiving and analysis to provide powerful tools for risk mapping, simulation and modeling, integrated flood management and flood emergency response (Price and Vojinovic, 2008). Flood mapping models and processes are subject to uncertainties and to the quality of information gathered in preparing them, but they are a valuable tool not only for estimating potential flood risks but also for informing both decision-makers and the affected communities.

73 Flood risk maps are certainly excellent tools for risk assessment and planning, but they can also be valuable tools for public education and awareness. Properly presented, flood maps allow urban residents to see exactly where and how they may be impacted by flood waters. They can also see who in the community is vulnerable to flooding and who is not. Since concise visual information is often more compelling than reams of text, residents may be thereby induced to take a more active, personal part in community flood planning and management and to hold their elected officials more accountable for effective flood planning and management.

> *Describing the hazards of flooding without giving advice on what to do is insufficient, as it confuses individuals on what appropriate actions to take in case of disastrous floods. Flood mapping exercises need to be combined with on-the-ground training, which demonstrates that the possibility of an event is recognized and improves actions, maintaining continuous planning and updating of action plans as a part of flood emergency planning.*
> (WMO, 2011b)

74 A flood risk map can have other direct effects. It may lower property value in projected flood areas and hinder development. On the other hand, the map can drive the development of flood loss prevention measures, alert prospective land and property owners to both hazards and opportunities, and provide new development ideas to the local planning authorities (Andjelkovic, 2001). The risk assessment and flood mapping process can also inform and guide the development, revision and enforcement of the regulatory regime that impacts both economic development and flood management.

4.1.3 Land-use Management; Codes and regulations

75 It should come as no surprise that most of the physical, social and economic problems associated with urban flooding, stem from inappropriate occupation of the floodplain, poorly-planned land use within the city, insufficient attention to drainage and stormwater control facilities and haphazard (defined as *"dependent upon or characterized by mere chance"*) enforcement of existing regulations. Land-use regulations establish the basis for the kinds of uses permitted in the floodplain, and zoning is essentially the enforcement mechanism. Regulation and zoning may take the form of: restrictions (prohibitions, penalties, resettlement); incentives (preferential or punitive taxation); information and education; public investment through purchase of property.

There are three basic types of floodplain development (WMO, 2008a):

- 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 (Andjelkovic, 2001):

- 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.

76 Land-use management policies and processes are a natural companion for urban flood management, and both contribute significantly to Integrated Flood Management and Integrated Water Resources Management. A collaborative approach involving planning at all levels, specialized technical agencies and local governments would maximize the efficient use of flood management resources. The Associated Programme on Flood Management has published a document that provides considerable detail on the most effective interaction between land-use management and all aspects of urban flood management (WMO, 2007b).

77 Building codes provide specifications for the design, operation and maintenance of buildings and infrastructure facilities. Application of building code requirements may add considerable costs, so there is usually a measure of flexibility in the codes, and builders have considerable leeway in how they meet those requirements. Building codes generally deal with: purpose for the building; structural strength criteria (to withstand water action); material specifications; adequate elevation of basement and first floors. These may extend to the requirements for flood-proofing of buildings (WMO, 2012).

78 Municipal drainage and stormwater codes regulate the operation of stormwater systems, covering what can legally go into the system, how the system must be managed and operated, and what is allowed to exit the system – whether into a treatment plant or into a water body. These codes usually require the application of a number of Best Management Practices (BMPs), non-structural and structural measures to be applied in mitigating the flooding and pollution effects in urban settings. These can include BMPs for stormwater treatment and flow control, source controls, storage of hazardous chemicals, erosion and sedimentation control, impacts of impervious surfaces, and low-impact development.

79 Regulations and codes can, and should, be harnessed to the effort to develop and implement adaptive strategies in urban flood management and Integrated Flood Management. The Government of Japan has established a subcommittee on climate change adaptation for flood control under the Ministry of Land, Infrastructure, Transport and Tourism. Their adopted strategy has a prominent place for adaptation through control and guidance of community development:

> *Land-use regulation can enhance the effectiveness of prevention measures. Designation of disaster risk zones based on a legal code can prohibit further development or promote flood proofing in the area. A new concept for urban development, aiming towards more compact built-up of urban areas makes flood protection measures more effective, on the one hand, and more effective in*

> *energy consumption, on the other. Regulations, such as city codes and subsidies, should promote implementation of facilities for rainwater storage, infiltration and runoff control in an integrated manner at the (urban) basin scale.*
> (WMO, 2011a)

80 The limiting factor in the application of codes and regulation is, of course, the willingness and capacity of the local/municipal government to enact and enforce them.

- To enforce existing land-use regulations, the administrator of a floodplain or local authority requires a series of legal powers. Land-use regulations or zoning ordinances usually provide such powers to administrators using various means of enforcement. Depending on the applicable laws and regulations an administrator may obtain legal powers, for instance:
- To take remedial action as necessary to prevent damage to property or danger to life
- To negotiate a schedule for the completion of the construction, repairs or other activity necessary to abate the violation;
- To initiate a civil or criminal complaint against the violator;
- To use work forces or contract to perform the required remedial actions, and submit an invoice to the person for payment;
- To initiate a procedure resulting in denial of flood insurance due to the violation of existing laws and regulations.

(WMO, 2007b)

81 If local legislation and regulation favors the upper end of the socio-economic scale, if business development and expansion receives preferential treatment at the expense of flood management, if local ordinances and permitting processes are ignored or not enforced, then both adaptation and urban flood management will suffer. This is an issue of governance, which is discussed in more detail in **Chapter 5** of this document.

4.2 Emergency management

82 Emergency management (also known as emergency preparedness, disaster management, disaster preparedness – the terms are often used interchangeably) is a recognized strategy for adaptation to climate change. Both flood emergency management and integrated flood management lie well within the realm of all-hazards emergency planning and management. All of these management processes will work best when folded into the on-going process of adaptation to climate change.[4]

83 Emergency managers will have to deal with the impending, uncertain, and possibly extreme effects of climate change. Yet, many emergency managers are not aware of the full range of possible effects, and they are unsure of their place in the effort to plan for, adapt to, and cope with those effects. This may partly reflect emergency mangers' reluctance to get caught up in the rancorous—and politically-charged—debate about climate change, but it mostly is due to the worldview shared by most emergency managers. Emergency managers focus on: extreme

4 Much of this section is drawn from *Flood Emergency Planning* (WMO, 2011b)

events; acute vs. chronic hazards (floods vs. droughts); a shorter event horizon (5 years vs. 75–100 years); and a shorter planning and operational cycle (Labadie, 2011).

84 The four phases of emergency management (in the US, at least) consist of: mitigation (reducing vulnerability), preparedness (planning, preparation and training), response (limiting damage and protecting people and property) and recovery (restoring and improving what was damaged). Put another way, *"What you can't prevent, you have to respond to; what you can't respond to, you have to recover from."* **Figure 4** is a European version of the same model. The terms are slightly different and in a slightly different configuration, but the principle is the same: an iterative process of identifying hazards and vulnerabilities, acting to prevent or lessen expected damage, preparing ahead for dealing with possible disaster effects, acting to prevent loss of life and damage to property, and rebuilding (perhaps to a higher standard) what is damaged.

85 Emergency management plans and programs are based on a Hazard Identification and Vulnerability Analysis (or equivalent) that is prepared for a specific community or geographical area. Thus, historical experience of hazards and disasters drives emergency managers to focus on certain hazards, with a certain frequency, and certain expectations regarding what is likely to happen. This in turn drives decisions on funding, staffing, and resources. Can one rely on past experiences as a guide to the future where climate change is concerned (Labadie, 2011)?

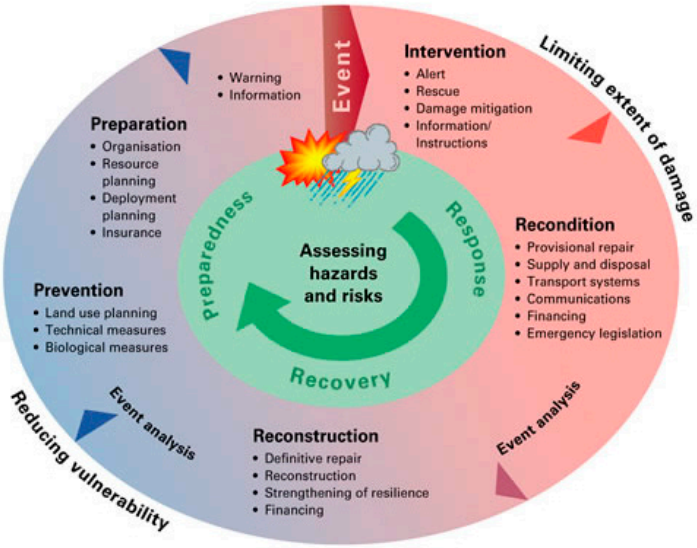

Figure 4 — Risk management stages (FOEN, 2009)

86 Flood management practitioners and policymakers should consider uncertainties from climate variability and change as well as the cost of related flood risk reduction measures across populations at risk. This issue can be addressed through emergency preparedness and response measures that ease the financial burden from flooding, and ensure operational continuity in response to flooding (WMO, 2011b). There are economies of scale to be gained by conducting flood emergency planning and response within the community's overall emergency management process. Those economies will enhance, and be enhanced by, the larger planning and implementation effort directed at climate change adaptation.

87 Since those most affected by flood waters are also the first respond to those effects, preparedness must start at the local community level. Improving the ability of residents in a vulnerable area to respond to floods is the prerequisite for flood risk reduction. The local inhabitants should be aided and empowered to plan and implement their own flood preparedness measures that reflect local conditions and actual experience (WMO, 2006b). Preparedness plans (including flood management plans) should form the basis for training of government officials, responders and the general populace in the policies, expectations, procedures and protocols involved in coping with floods and other disasters. Finally, all plans and coordination mechanisms at the local, regional, state/prefecture and national levels should be tested to identify and correct gaps in plans and procedures. Information on conducting drills and exercises may be found in Flood Emergency Planning (WMO, 2011a).

88 Emergency management plans must also be reflected in the operating plans and procedures for all agencies, utilities, factories and even community/neighborhood groups. All entities with a stake in the capacity to respond effectively to an emergency should (Sinisi and Aertgeerts, 2010, Table 24):

- develop and regularly update maintenance, crisis and emergency plans based on cooperation of all actors (facilities owners, operators, municipal authorities, road management, river basin authorities, flood authorities, flood forecasting authorities, stakeholders, etc.);
- train the staff for the emergency (drought, flood, storm, wind etc.);
- involve and inform public;
- test the emergency system regularly.

89 Warning is a vital function in emergency management. The short response time of urban flooding between peak rainfall and runoff makes the introduction of warning systems in urban areas more difficult. In order to make such warnings credible, it may be necessary to forecast rainfall hours or even days ahead. Whatever the lead-time, warnings must be clear and unambiguous, expressed in terms that the residents can understand and apply to their situation, and delivered by a recognized, competent authority. The current channels and procedures for dissemination of flood warnings may be too slow and imprecise to be useful to those who need it the most. The growth and popularity of social media and cell phones may provide an accessible channel for targeted, timely flood warnings.

90 Emergency response to floods can include a number of activities involving local, regional, state and national government resources as well as the private sector. Installation and maintenance of flood barriers, channeling flood waters away from certain high-value areas, search and rescue, evacuation of people stranded by flood waters, removal of people and their property from areas potentially threatened by floods are all possible response actions. In addition, accelerated maintenance, strengthening, and expedient repair of drainage infrastructure elements can also be considered as emergency response. Emergency response elements also include such activities as sheltering and mass care, emergency delivery of food and water, organization of relief supplies and operations – although these efforts often extend well beyond the emergency response period and into the recovery period.

91 While residents in poorer countries or in temporary settlements have shown considerable ingenuity in coping with flood waters (for example, Heinrichs, 2009; Satterthwaite et al., 2007b; Braun and Aßheuer, 2011), it will likely be necessary to provide shelter and care for some portion of

the population affected by the flood. Even in developed countries, some urban residents may not be able to remain in their homes during the flood and for a time afterward. Residents may take shelter in churches, schools, community centers or other structures that have been pre-designated as safe and, perhaps, stocked with shelter supplies. Wherever possible, such shelter facilities should not be located so far from areas of employment and shopping that the shelterees cannot easily get to work or procure necessary supplies. It is not enough for a local government simply to open a shelter and let the shelterees fend for themselves. Shelters must be staffed with trained personnel and managers to ensure that those sheltered are safe and supported, especially those portions of the population that are vulnerable.

> *Safe shelters should be identified in advance, and evacuation routes leading to designated shelters clearly marked. Organization of shelters and distribution of aid among the affected population should be mainly in the hands of local community organizations. Priorities should be established to prepare exclusive response programmes to meet the specific needs of infants, the elderly, pregnant women and the disabled. One area that requires attention, particularly in flood-prone locations, is the lack of an exit strategy in relief operations. Lack of a strategy that results in poor planning may force a community to become dependent on relief handouts for their survival rather than addressing their vulnerabilities pro-actively.*
> (WMO, 2011b)

92 After any flood event (or emergency in general), it is vital to conduct a post-event review to capture lessons learned from the experience and to identify ways in which the planning and response could be done better in the future. Such reviews should involve representatives of all participants – response agencies, NGOs, community groups, victims – and may take the form of a surveys, structured interviews and questionnaires, workshops, review of event logs and operations orders, and so on. The goal is to cast as wide a net as possible – to include anecdotal evidence – so that everyone can learn from the experience. It is also important to collect, maintain, and analyze all of the documentation of activities during the flood. Documentation includes: event logs and operational orders, policy determinations and decision records, dispatch logs, records of donations, personnel time records, photographs, situation reports and message traffic, and any other types of records that afford a clear picture of what happened during the flood and what was done in response. All of this information, as well as the report summarizing the flood response actions, can then be fed back into the planning process for the next disaster.

93 Integration of both preparedness and flood management considerations into the climate change adaptation process can exploit the considerable overlap among flood management, environmental management and disaster management. Planners and practitioners these fields must recognize that they have a common objective to promote a sustainable community – whether directly or indirectly. Sustainability should be considered both prospectively (in sustainable development planning and adaptation) and retrospectively (in response and recovery). Areas of fruitful interaction among these disciplines include (Labadie, 2011):

- Identifying enhancements to infrastructure and environmental assets/resources that support adaptation (e.g., preservation of ecosystem services, sustainable drainage systems);
- Identifying development options for environmentally sensitive areas that may serve to mitigate future disaster damage (e.g., creation, enhancement, or preservation of wetlands, mangrove swamps, and coral reefs for flood mitigation);

- Identifying and reconciling the trade-offs between environmental enhancement opportunities and disaster-resistant construction and development practices (e.g., siting of dikes/levees; identification and pre-approval of waste disposal methods/sites; preservation of open spaces for water spread);
- Identifying development techniques and practices that contribute to both environmental quality and long-term survivability (e.g., siting of industrial sites; stricter environmental management requirements for environmentally-risky facilities)

94 Integration of all of these efforts can make significant contributions toward maximizing the effectiveness of climate change adaptation efforts. These multiple disciplines can cooperatively seek solutions that will enhance environmental quality as well as meet the needs of disaster preparedness and recovery by identifying and implementing strategies that combine disaster risk and vulnerability reduction, post-disaster recovery, environmental sustainability, and community survivability.

4.3 Dissemination of flood risk information

95 One would think that, with all of the current publicity, political commentary, media coverage of international conferences and agreements (or lack thereof), and acrimonious debates regarding climate change, there would be a significant level of awareness among the general public of climate change impacts, mitigation and adaptation. This does not seem to be the case. While people are generally aware of the possibility of climate change, they do not necessarily connect that awareness to their own lives and living conditions, they do not understand or appreciate the difference between mitigation and adaptation, and they are not aware of adaptation efforts in their communities or how those activities might affect their lives (Heinrichs, 2009).

96 The City of Capetown, for example, published and widely disseminated a report detailing the consequences of sea-level rise on the city. The report was attacked by some land-holders as too alarmist, dismissed by others as too muted, and regarded by most of the population as *"someone else's problem"* (Heinrichs, 2009). How, then, to provide sufficient information and awareness of flood management activities, especially in the context of adapting to climate change?

> *Awareness can be raised through education and regular training – particularly in areas exposed to infrequent hazards or within new settlements. Flood hazard maps, depicting flood-prone areas, evacuation routes and safe shelters, can play a critical role in awareness building. Women and children should be included in education strategies, as they are disproportionately affected by natural disasters. Outreach efforts should be made to minorities and ethnic groups, as their mobility may be limited or affected owing to cultural, social or economic constraints.*
> (WMO, 2011b)

97 *Guiding Principle Number 4* of the Nairobi Statement on Land and Water Management for Adaptation to Climate Change states that *"information and knowledge for local adaptation must be improved, and must be considered a public good to be shared at all levels"* (Nairobi, 2009). The important parts of this principle are that the information provided must be appropriate to the audience and adequate in detail, and that it must clearly communicate the linkages between climate change effects and other local risks (such as water scarcity or flooding) related to people's daily lives.

98 The Netherlands' *Live with Water* campaign, started in 2003, used a combination radio and television commercials, newsletters, advertising and information booklets, informative events and a comprehensive website in an effort (Kazmierczak and Carter, 2010):

- To increase the awareness of the water problem, stimulating a sense of urgency without frightening the people;
- To communicate that a new approach and policy for water management is needed and also the reasons why;
- To increase knowledge of what this new policy ('giving more room to water') means and what the consequences will be;
- To get acceptance of the idea that far-reaching measures are needed now to keep Holland safe in the future, even if these measures have unpleasant personal consequences.

99 The campaign also enlisted a popular weather forecaster as a spokesman who conveyed the problems and solutions to peoples' attention through cartoons and personal appearances. The campaign highlighted the efforts implemented by the national government, provincial authorities and water boards to keep the country safe and dry; information emphasized the concrete measures and examples of adaptation that are recognizable to the public. Follow-up studies and surveys indicate that the campaign has been quite successful in raising public awareness of flooding and sea-level rise issues.

100 Is the information on flood impacts and flood management in a form suitable for use by decision-makers and the public? And, for that matter, are decision-makers and the public able to make use of the information? Highly-technical hydrologic data and mapping may be suitable for academics and experienced planners, but it may not be accessible to elected officials and the general public. To be effective, public information of flooding must be both context- and location-specific, and it must integrate both scientific information and local knowledge. The links between meteorological services and end-users must be clear, and information available from global climate impact models and national-level forecasts must be refined and adapted to support local flood management and adaptation actions.

101 Public education and training (consider these a form of very early warning) can provide urban residents with the information and tools both for understanding precipitation forecasts and flood warning information and for taking positive, effective actions to protect themselves from flood effects. An effective public education campaign can also empower individuals and families to identify and carry out long-term strategies as adaptation to climate change. **Figure 5** conveys the elements of an effective education and warning model.

RISK KNOWLEDGE **Systematically collect data and undertake risk assessment** Are the hazards and the vulnerabilities known? What are the patterns and trends in these factors? Are risk maps and data widely available?	**MONITORING AND WARNING SERVICE** **Develop hazard monitoring and early warning services** Are the right parameters being monitored? Is there a sound scientific basis for making forecasts? Can accurate and timely warnings be generated?
DISSEMINATION & COMMUNICATION **Communicate risk information and early warnings** Do warnings reach all of those at risk? Are the risks and warnings understood? Is the warning information clear and usable?	**RESPONSE CAPABILITY** **Build national and community response capabilities** Are response plans up to date and tested? Are local capacities and knowledge made use of? Are people prepared and ready to react to warnings?

Figure 5 — Elements of people-centered early warning systems (UNISDR/DKKV, 2010)

102 Communication throughout the education and warning process must be two-way and interactive. Continuing contact and feedback among planners, elected officials, educators and the general public (the end-users of the information) is vital to making the system responsive to people's needs, priorities and decisions. The system must adjust to its users; not the other way around.

103 As previously discussed (**Section 4.1.2**), flood risk maps are an excellent tool for public education and awareness. Concise and vivid visual information, paired with clear textual information on risks and adaptive strategies, can drive home the real risks of urban flooding and induce residents to take personal action to protect themselves. This information – demonstrating a clear connection between urban flooding (and climate change) and one's personal life and livelihood – can also induce residents to participate more directly and actively in the planning and implementation of urban flood management.

4.4 Recovery and rebuilding

104 Vital lifeline facilities such as water supply, electricity supply, roads and telecommunications, hospitals and sewage systems have to be repaired (perhaps provisionally or expediently) as soon as possible. Restoring education and health systems, rebuilding damaged houses, restoring contaminated water sources and restoring access to livelihoods are high priorities during the flood recovery phase (WMO, 2006b).

105 The complex and multi-faceted processes of post-disaster recovery and reconstruction extend well beyond the immediate period of restoring basic services and life support infrastructure. While immediate restoration of services can be a matter of weeks, full recovery can stretch out 10-15 years. What will happen during that period? Will the emphasis be on re-creating what was there before? Or on improving the built environment, the larger physical environment, and the quality of life?

106 Will recovery efforts focus on enhancing the ability of the community to mitigate and survive future disasters? Will the community leaders evaluate recovery success through traditional

measures (restoration of economic activity; construction of old vs. new buildings and residences; repopulation of devastated areas), or will they try to create a "new normal"? Will the recovery and reconstruction process address such equity issues as (Labadie, 2007): industrial plant and landfill siting; development in industrial or depressed areas; residential settlement on slopes or in other marginal areas; higher population density; immigrants and language differences; differential access to social services and information sources?

107 Assets and infrastructure should be rebuilt according to the latest standards ("no regret reconstruction"). Rebuilding of structures may be delayed in certain areas, since these areas might fall within the new risk zones prohibiting reconstruction; building permits should be granted only after reassessment of the hazards. If temporary solutions are required, they should be seen as just that, and not as a permanent installation. Provision of direct disaster and rebuilding assistance to victims (such as cash and grants, loans and credits, distribution of construction materials) should be linked to the observance of risk reduction practices. Ideally, the entire recovery and rebuilding process should be oriented toward reducing vulnerability and enhancing the resilience and overall adaptive capacity of the community (WMO, 2006b).

4.5 Broader strategies for urban flood management

108 Many urban flood management and adaptive actions have multiple drivers, and both are embedded in broader development planning, economic strategies, and regional/local planning initiatives, such as water resources planning, coastal flood defense, and disaster risk reduction. These initiatives often reflect the concrete experience of communities and individuals in facing economic hardships or natural disasters. This experience can reinforce awareness of climate change effects and drive the need for adaptation programs. Tying flood management and adaptation to these broader community initiatives can help make the best use of limited funds and can enhance both resilience and adaptive capacity of the community as a whole. Two major strategies in this context are "mainstreaming" and "no-regrets strategies."

109 **Mainstreaming** – *"In the climate change context, the term 'mainstreaming' has been used to refer to integration of climate change vulnerabilities or adaptation into some aspect of related government policy such as water management, disaster preparedness and emergency planning or land-use planning"* (IPCC, 2007). The integration of urban flood management (and related climate change adaptive activities) into community/development planning is often more a matter of funding than philosophy—funds are limited, and multiple-use (or multiple-benefit) projects would receive the most support from decision-makers. In addition, multiple-use projects can expand the pool of stakeholders and/or politicians whose standing in the community may be enhanced by promoting them.

110 One example of mainstreaming is the London Borough of Sutton. Council members made considerable efforts to include policies on climate change adaptation and flood risk in spatial planning documents guiding future development within the Borough. This was an effort to avoid, reduce and manage flood risks while promoting the multi-functional benefits of overall development. This effort was part of the Borough's implementation of a Sustainable Communities Strategy. In another example, the City of Toronto, Canada, implemented a city-wide program to address climate change problems of urban flooding, lake-level rise and elevated temperatures by integrating spatial plans, green space strategies, emergency response plans, drainage infrastructure upgrades, and economic development strategies (Kazmierczak and Carter, 2010).

111 Urban water supply and sanitation, housing settlements, pollution control, transport systems, industrial activities, health and social welfare are many of the development activities undertaken by municipal governments and private-sector institutions. It is quite likely that these activities will be impacted by flood hazards and by the flood management actions taken to cope with those hazards. It is also possible that development activities will have some impact on flood management policies, plans and actions. In addition, certain other regional development activities beyond the municipal limits such as agricultural production, watershed management, energy production, and environmental protection, among others, also effect flood management in urban areas. For these reasons, it is vital that urban flood management activities be mainstreamed in all these related activities (WMO, 2008a).

112 No-regrets strategies – activities and policies that support development goals even if climate change effects never happen – can reduce vulnerability to climate change but also generate immediate benefits by reducing vulnerability to current climate variability. These strategies can improve the general quality of life in a community, enhance the provision of services, and contribute to the overall resilience of a community, while at the same time contributing to the success of urban flood management practices. A sustainable urban drainage system is a benefit to the community whether climate change increases the flood risk or not. Other actions and planning initiatives can bring benefits for community development while advancing flood management goals:

- Updated flood plain maps
- Better disaster management planning
- Improved weather and flood forecasting/warning programs
- Maintenance (or expansion) of hydrological, meteorological monitoring networks
- "Greening of urban landscapes" in land use planning
- Monitoring & enforcement of policies/regulations of land use in floodplains, unstable areas

113 In many cases, a range of no-regrets options will have immediate benefits and can enhance long-term flexibility to cope with climate change and other risk drivers (Ranger and Lopez, 2011):

- Measures to better cope with current climate variability (such as well-maintained drainage systems and early warning systems)
- Measures to manage non-climate drivers of risk (such as limiting building in exposed areas, managing erosion and increasing permeability of urban areas)
- Measures to reduce systemic vulnerability or resilience to shocks (insurance systems, emergency response planning)
- Some measures with strong co-benefits (such as natural ecosystem flood storage systems, regenerating mangrove areas, green urban spaces)

Mainstreaming of flood management and climate change adaptation strategies into development efforts and pursuing "no-regrets" adaptive strategies may be the best and most cost-effective path to success. Doing so could lead to immediate benefits and could thereby lend credibility to longer-term flood management and adaptation efforts.

4.6 Multi-stakeholder approach

114 Community activities play an important role throughout the process of urban flood management. Flood management addresses the practical aspects of managing floods, and community participation becomes fundamental and essential for each stage. In the planning process for flood management, for mitigation, for land use planning and for flood emergency planning, community participation in flood management contributes to building consensus among stakeholders and creating linkage with other activities. It is vital to identify and understand relevant stakeholders' needs, aspirations and concerns from the beginning. Each stakeholder has different perceptions of risk, and various community members and groups have different vulnerabilities and capacities (determined by age, gender, class, source of livelihoods, ethnicity, language, religion and physical location). Community participation can provide common vision to overcome such differences by focusing on reducing loss and maximizing benefits from floods (WMO, 2008b).

115 Even before flood management planning and implementation commence, stakeholder participation in the data-gathering process can produce significant dividends in the character and credibility of the information produced:

> *There is an inherent, democratic value in including in a research project those segments of society who are ultimately affected by the decisions that are based, at least in part, on that research. The responsibility of researchers to include stakeholder involvement is greater the more a project attempts to address issues that are of direct relevance to the lives of stakeholders, and the more the project relies on funds made available by the tax payers [...] Stakeholders can posses valuable knowledge that may be difficult to access by researchers. Stakeholder involvement can thus not only broaden the information base on which science operates, but can provide a powerful means for 'ground-truthing' of data, models and model scenarios.*
> (Kirshen et al., 2006)

116 It is difficult to cast the stakeholder and community participant net too widely. Everyone in the community will be affected (directly or indirectly) by floods and by the measures put in place to manage those floods. Other levels of government, NGOs, professional organizations, citizens' advocacy groups, trade associations/guilds and private companies will all have some interest in how floods are managed in the urban environment. **Annex II** of *Social Aspects and Stakeholders Involvement in Integrated Flood Management* (WMO, 2006b) identifies stakeholders who may be involved in flood management. It would not be difficult to add to this already extensive list.

117 Apart from involvement in decisions on planning particular activities or programs that may potentially have an impact on flood management, the participation of local communities that are closer to the event and are the first to be affected by flood waters is vital. Local volunteers may be asked to contribute materials and equipment, and to take part in manual labor either individually or with other emergency response services in the area during flood crises. It may also be necessary to involve representative associations at the local level, for instance Community Flood Management Committees **(CFMCs)**. Local groups will likely have a far greater understanding and awareness of local watercourses than those in central administrations. Additionally, CFMCs improve the self-help capacity of individuals affected (WMO, 2011b). This reflects the growing view of citizens (including the poor) as a resource rather than a problem.

118 Experience from flood prone regions in South Asia indicates that the establishment of Community Flood Management Committees with clearly defined institutional structures, roles and responsibilities before, during and after a flood, can be an effective platform for the participation of those most affected by floods. CFMCs perform such activities as (WMO, 2008b):

- assessing the needs and capability of the community;
- making provisions for emergency situations;
- raising awareness;
- managing information for future references;
- training and capacity-building;
- networking, monitoring and reporting;
- planning and interface with government institutions, and
- resource mobilization

119 Broad-based inclusion in the flood management process can facilitate the self-organization of neighborhoods by supporting existing social networks or by encouraging the establishment of new community-based organizations **(CBOs)**. In this context, it is important to bear in mind that not only those CBOs that deal explicitly with disaster management (e.g. voluntary fire brigades) are capable of effective contribution to response and recovery efforts but also many other formal or informal CBOs and other social networks which may form ad-hoc aid groups in the case of emergency. Every flood management plan should recognize and support the vital contributions of CBOs and social networks (WMO, 2008a) . Engagement of multiple parties in the flood management process can also foster social development and integration across different levels of government:

> *Developing and implementing integrated approaches to flood risk management will require a new set of skills and capacities in practitioners. Participatory processes to develop solutions to urban flooding should consider the changing urban ecosystem as a whole [...] Developing capacity in a range of practitioners to facilitate such integrated processes would therefore enhance vertical integration between national, regional and local scales, and strengthen the potential of resilience to influence differing spatial levels of scale. It would also improve horizontal linkages between actions in one part of an urbanised catchment and impacts elsewhere.*
> (Tippett and Griffiths, 2007)

120 Asian Cities Climate Change Resilience Network **(ACCCRN)** has been organized to help cities and their citizens build flexible and dynamic systems for responding to climate change in urban areas. ACCCRN engages in a Shared Learning Dialogue **(SLD)** process that builds partners' capacities to (ACCCRN, 2009):

- Deal with the uncertainty of climate projections;
- Understand and work with complex, adaptive urban systems;
- Generate new information and utilize multiple sources of existing information and expertise in new ways;
- Engage vulnerable groups and involve them in resilience planning;
- Cross disciplinary and organizational boundaries and scales of governance;

- Test and adapt tools to local conditions and capacities;
- Develop new planning and learning processes suited to different city contexts and actors;
- Share lessons between cities and beyond

121 It is not a simple task to organize and manage a multi-stakeholder process for urban flood management. Even if all parties are in basic agreement on the need for and general concepts of urban flood management (no doubt a rare occurrence), keeping them focused on the common goal and ensuring that competing agendas are given a fair hearing and that conflicts are equitably resolved requires considerable energy and close attention over an extended period of time. The stakeholder involvement process may be initiated in a burst of enthusiasm and activity, but over time members will lose interest (especially if no floods happen for a while), organizations will drop out of the effort, and individuals will decide to find other uses for their time. Those at the lower end of the socio-economic scale may not have the time or energy to participate in planning activities when they are focused on feeding their families. It may be necessary to offer financial incentives for participation in flood management planning and preparation activities. The publication, Social Aspects and Stakeholders Involvement in Integrated Flood Management (WMO, 2006b) provides extensive guidance in establishing community-based disaster risk management **(CBDRM)** organizations and the process of enhancing stakeholder involvement.

122 The International Council on Local Environmental Initiatives **(ICLEI)**, also known as ICLEI – Local Governments for Sustainability, has sponsored and facilitated the development of a number of guidebooks to assist communities in planning for adaptation to climate change. These guidebooks are intended to lead a community through the process of organizing and managing a team, identifying issues, setting priorities and developing an adaptation plan. Though not specifically directed at flood management, these guidebooks can provide considerable assistance to urban flood managers as they pursue Integrated Flood Management in the face of climate change. Two examples of guidebooks are *Preparing for Climate Change: A Guidebook for Local, Regional and State Governments* (Snover et al., 2007) and *Local Government Climate Change Adaptation Toolkit* (ICLEI, 2008).

5 LIMITING FACTORS

123 Response to, and management of, urban floods does not occur as a singular event, unconnected to anything else happening in the community. As has been discussed in the sections above, urban flood management – especially in the context of climate change and associated extreme weather events – works best when it is integrated into efforts by the entire community at adapting to the likely effects of climate change. There are a number of factors – inherent characteristics of the community and the government – that can place bounds on the possibilities for success in urban flood management and adaptation. These include lack of access to resources and information, and the lack of power to demand an active and meaningful role in the planning and implementation of adaptation policies, strategies and activities. These shortfalls have varying effects on different communities and on different groups within those communities (WMO, 2009c).

5.1 Financial

124 The most obvious limiting factor is the competition for scarce public resources. There is seldom enough money to go around, and difficult decisions have to be made regarding spending priorities. Immediate, short-term needs may crowd out longer-term requirements, perhaps on the assumption that other levels of government, NGOs, or international aid donors will eventually provide funds.

125 The lack of an identified budget line for environmental protection, or emergency planning and management, or climate change adaptation might easily result in these activities being ignored, overlooked or pushed out of the budget by other priorities. At the same time, if environmental protection and adaptation activities are funded at the national/regional level, rather than at the local level, resources may be directed toward national plans of action, and relatively little will filter down to be applied at the community level. Global market forces may conflict with local adaptation programs, and national governments may be so caught up in economic competition among regions or special economic zones that financing and support for local initiatives is less available (Heinrichs, 2009).

126 Government budgets and finances are based (at least theoretically) on hard facts, firm numbers and clear projections, usually reflecting recent documented experience. Climate change, as previously noted, carries with it a great deal of uncertainty. It may be difficult to make a credible budget case for investment of resources in adaptation and flood management projects when there is less reliable experience upon which to ground the numbers. Will bond investors or banks be willing to support projects to build or improve over-sized (or potentially unnecessary) infrastructure, based on vague predictions?

127 Also, there is the problem of short-term budget cycles vs. long-term adaptation activities. Adaptation and flood management projects, especially involving extensive construction, may take longer to finish than the attention span of most elected officials. Officials and politicians are less likely to respond to the possibility of a distant event than to the threat of a more immediate disaster. Clear, persistent and sustaining support for climate change adaptation from local leaders and the heads of government will go a long way in mitigating these financial roadblocks.

128 A financial process that is both an advantage and a limitation is that of risk sharing through insurance, in this case specifically flood insurance. Risk Sharing in Flood Management describes a number of flood insurance approaches (including no flood insurance at all) in various countries around the world (WMO, 2009a, Table 2). A prime example of a flood insurance scheme is the US National Flood Insurance Program **(NFIP)** which has been in force in one form or another since the 1950s. The NFIP process designates the 100-year flood plain and identifies communities and properties vulnerable to flooding through the mechanism of the Flood Insurance Rating Map. A major drawback of the NFIP is its inability to address the inherent vulnerability of the urban environment to floods, and it does not distinguish how measures for floodplain protection are applied between rural areas and highly urbanized areas (Ntelekos et al., 2010). As urban areas in the US are increasingly impacted by climate change, the NFIP will have to be updated and modernized to reflect these changing conditions.

129 While traditional flood insurance programs are popular in developed countries, they are much less so in developing nations. Non-traditional finance and insurance mechanisms will be required in these areas if risk-sharing is to be implemented as a viable strategy for adapting to climate change effects. These non-traditional mechanisms include index-based insurance contracts, catastrophe bonds, micro-insurance policies, as well as government catastrophe taxes and reserve funds, and direct government loans to victims (WMO, 2009a).

130 The application of risk-sharing as an adaptation strategy may be limited by the lack of an "insurance culture" in the community. If citizens are not accustomed to monetizing their risks and seeking to insure against those risks in advance of a disaster, then insurance schemes will likely not be economically viable, and potential insurers will find their markets elsewhere. On the other hand, those in developing countries who would benefit most from some form of risk-sharing through flood insurance may not be in a financial position to pay the necessary premiums, however small.

5.2 Socio-economic

131 It is no secret that middle and upper income groups (in most every country, developed or developing) tend to benefit most from government investment in infrastructure and services. Where government does not provide these, higher income groups have the resources to deal with the problem themselves. It is also clear that, in most cities, the urban poor live in the riskiest urban environments: flood plains, unstable slopes, river basins and coastal areas. These are also usually the sites most at risk from climate change, as we have seen (Satterthwaite, 2007).

132 The disparity between the highest incomes and the lowest, as well as the proportion of people at the lowest rungs of the economic ladder, will have a considerable effect on the ability of the community to plan for, manage and recover from urban floods. Those at the higher income levels, generally enjoy more access to municipal services (including properly-functioning infrastructure), while those at the lower income levels are usually left out of decisions that may affect their material well-being. In addition, they may not have the inclination, or the leisure, to devote their time to participating in community efforts at adaptation.

133 Cost-benefit analysis – a mainstay for identifying, categorizing and analyzing risks – is an excellent tool for choosing from among competing strategies. It emphasizes maximizing efficiency, but it is less effective at addressing issues of equity and socio-economic disparities.

> *Different societal mechanisms for spreading the financial burden can be discussed in terms of efficiency and fairness. A complicating feature of this type of comparison is that while normally there is consensus on what efficiency means, there is seldom consensus on interpretations of equity or fairness. Who should pay for the risks being taken by a few living in the flood prone areas is always debatable and would depend on the societal context.*
> (WMO, 2007a)

134 The processes of adaptation and urban flood management may be driven by value-laden arguments about equity and fairness. Who sets the priorities for recovery? How are the needs of low-income residents valued in relation to the needs of those who are better off? Who decides what will be rebuilt where? Whose home or business gets flooded when levees are breached to relieve flood water buildup? Who gets displaced when new facilities are constructed during recovery? All of these issues must be addressed in some equitable fashion if adaptation is to achieve the best result.

5.3 Governance

135 Governance is one of those ideas that everybody talks about, but nobody really knows what it is…until it fails. At bottom, governance is about who decides what gets done, to whom, in what ways, and about how the ones who do the deciding are chosen. The World Bank offers a comparative description:

> *Good governance is epitomized by predictable, open and enlightened policy-making, a bureaucracy imbued with a professional ethos acting in furtherance of the public good, the rule of law, transparent processes, and a strong civil society participating in public affairs. Poor governance (on the other*

> *hand) is characterized by arbitrary policy making, unaccountable bureaucracies, unenforced or unjust legal systems, the abuse of executive power, a civil society unengaged in public life, and widespread corruption.*
> (World Bank, 1994)

136 Governance revolves around such themes as:

- Decentralization and autonomy – decisions made at the lowest operational level; relationships with other levels of government and private interest groups; managerial capability;
- Accountability and transparency – adherence to administrative/legal norms, policies; openness of information regarding finances;
- Responsiveness and flexibility – adaptive decision-making; able to respond to changing circumstances and needs;
- Participation and inclusiveness – ability of all citizens and social groups to participate in decision-making and evaluation of effectiveness;
- Experience and support – ability to build on local capabilities and experience; ability to learn and adjust.

137 There are strong linkages among good governance, climate adaptation and resilience, and sustainable development. Given that adaptation and sustainable development will likely require new methods and priorities – and inevitable social disruption – governance will be a vital factor in enhancing popular credibility and support. **Table 3** in the WMO document, *Social Aspects and Stakeholder Involvement in Integrated Flood Management*, lists vulnerability factors linked to governance issues (WMO, 2006b).

138 A number of questions must be addressed at national, regional and local levels of government in order to effectively merge urban flood management with overall planning for climate change adaptation. Will existing structures and forms of governance be sufficient and effective in addressing climate change effects or will new forms, methods of organization, and practices be necessary? If changes are necessary, who will be empowered to identify those changes, by what process, and who will be empowered to make those changes?

> *Shifts in European policy have taken place within a context of changing ideas of government. Instead of governments acting directly to impose the provisions of plans and policies, their role is seen as shifting to one of facilitators. Government thus shifts towards governance, a process of facilitating partnerships and enabling actors to implement policies.*
> (Tippett and Griffiths, 2007)

139 Planning for, and implementation of, urban flood management involves such complex matters as quality control, accountability, financial probity, and honesty in bidding and procurement. If local authorities are not equipped to manage these processes in a fully-transparent manner, it is likely that not only will construction projects be of poor quality but the government will lose credibility. The local populace will be reluctant to cooperate with local government efforts to improve flood response and survivability, on the assumption that the government is not really looking out for their interests.

140 For government agencies at all levels, it is vital that legal liabilities and obligations for pre-flood planning and preparation, during flood response, and for post-flood recovery and reconstruction be as clear as possible. Institutions and individuals must not only have the necessary rights to be able to implement necessary policies and actions, but they must also know their appropriate responsibilities and the extent to which they will be held accountable for their actions or inaction (WMO, 2011b).

141 Good governance by itself cannot ensure the success of adaptive or development efforts, but lack of it will most likely lead to maladaptation or even failure. At the most basic level, government should provide a measure of governance and transparency that keeps everybody honest and keeps the benefits of adaptation from being captured by predatory forces in society.

5.4 Adaptive Capacity

142 The literature is replete with examples and instances of people coping with urban flooding on a regular basis. (For example, Heinrichs, 2009; Satterthwaite et al., 2007a; Braun and Aßheuer, 2011) Moving to a higher platform within the dwelling, placing belongings on tables and higher shelves, using light building materials that can be easily removed to avoid water damage are examples of coping techniques. However, these activities are embedded firmly within the traditional and expected model for dealing with floods. They do not constitute adaptation, which is the development and use of new models and strategies to meet the requirements of a wholly new situation. Paving courtyards, raising plinths of houses, using flood-resistant building materials are examples of adaptive behavior in flood-prone areas (Satterthwaite et al., 2007a).

143 Although the terms "coping" and "adaptation" are often used interchangeably, they are conceptually quite different. Coping implies getting by with what you have and continuing to operate within common patterns of life to the extent that one can. Adaptation requires shifting to a new paradigm, a new way of doing things, a new way of organizing one's life. Part of that shift is depends on the community's capacity to carry out adaptive activities.

144 *"Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies"* (IPCC, 2007). Adaptive capacity refers to a society's ability to adapt to changing climatic conditions, whether by reducing harm, exploiting beneficial new opportunities, or both. This ability to adapt, whether to changing climate or other new circumstances, is in part a function of a society's level of wealth, education, institutional strength, and access to technology. Some of the elements of adaptive capacity in a community or society are:

- Excess capacity
- Economic surplus
- Experience with natural disasters
- Strong governmental or social institutions
- Robust communications
- Sustainable income levels
- Good governance and transparency
- Natural resources
- Robust infrastructures
- Social protection & social transfer mechanisms

145 All of these elements are beneficial and desirable in themselves. They make it easier for a community or a society to adapt more easily to any kind of changing condition. Experience in coping with natural disasters is especially important in that the community can (and should) learn from that experience and be in a better position to deal with future disasters. The nature and the extent of a society's development heavily influence both its degree of vulnerability to climate risks and its capacity to adapt. Important aspects of the adaptation discussion are the inherent characteristics and institutions of a society or community that provide stability, encourage innovation, and allow it to meet new challenges and changing circumstances.

146 One often sees the terms resilience and adaptive capacity conflated or used interchangeably. Resilience refers to the ability of a community to remain strong or unharmed, and/or to be able to quickly and effectively recover from a disaster's impact upon its infrastructure, economy, social and natural environment. Both adaptive capacity and resilience are related to and depend upon the amount and diversity of social, economic, physical, and natural capital available. They depend on the social networks, institutions, and entitlements that govern how this capital is distributed and used. Resilience includes an element of learning from past experiences and applying those lessons to future plans and activities. Put another way, resilience includes the elements of adaptation to climate change, hazard mitigation and sustainable human development.

147 Institutional capability and social capacity for adaptation is relatively weak in low-income nations and perhaps in many middle-income nations as well. Where the network of government agencies, civil society groups, robust and well-maintained infrastructure, social support mechanisms, and economic surplus are weak or missing, it will be quite difficult to mobilize the necessary resources, social capital, and political will to meet the needs of adapting to climate change. When government agencies are less-effectual or controlled by the upper strata of the community, and when many residents of the community are too poor to concentrate on anything but subsistence, urban flood planning – one of many adaptive activities possible – will be much less effective, if possible at all.

6 CONCLUSION

148 Urban flood management is not a singular event or process. It is imbedded within integrated flood management, which is an integral part of integrated water resources management on a basin-wide basis. All of these processes take place within the context of climate change, and they must be responsive to the likely – but as yet uncertain – effects of climate change. At the same time, population growth and related social dynamics, livelihood requirements, economic development, land use development, environmental degradation and so on interact to influence the hydrological circumstances of a river basin and floodplain. Each of these forces is dynamic and continues to evolve, as do the direct and indirect pressures they exert on flood management practices. One cannot create a comprehensive picture of the future by examining each of these factors independently. They interact in various expected and unexpected ways and must be addressed holistically.

149 The uncertainty inherent in climate change projections may mean that risk-centered approaches and risk-based analysis (including cost-benefit analysis) are no longer as useful or robust as they have been. The past may no longer be a reliable guide to the future, especially when it comes to urban flood management planning and implementation. The combination of climate change, increasing urbanization, demands for housing and industrial land (often in the floodplain), economic development and rising expectations cannot be discounted in urban flood management. Rather than focusing on any one of these issues, it will be necessary to combine them – and their many stakeholders – into a comprehensive planning process for increasing adaptation and enhancing community resilience.

150 One example of this kind of integrated effort is the *International Flood Initiative*, a joint WMO, UNESCO-IHP, UNISDR, IAHS and IAHR initiative that sets out to establish a more inclusive approach within the recommendations arising from the World Conference on Disaster Reduction in Kobe in 2005. The objective is to contribute to flood damage mitigation by developing and integrating scientific, operational, and educational aspects of flood management, including the social response and communication dimensions of flooding and related disaster preparedness. Key elements include (Ashley et al., 2007):

- Living with floods – proactive multi-hazard risk based approaches to develop culturally sensitive and sustainable ways of living with and managing floods;
- Equity – the equitable distribution of the burdens and benefits of flood risk management policy and management processes across generations;
- Empowered participation – of all stakeholders through appropriate institutional frameworks and governance mechanisms, with cleverly designed communication technologies as part of social development;
- Interdisciplinarity – integrate and exploit better across disciplines;
- Trans-sectorality – to include all levels of stakeholder as well as national and international bodies;
- International and regional cooperation – clearly important across physical boundaries but also across socio-political boundaries as well.

151 Failure or hesitation to incorporate both urban flood management and climate change into current decision processes could lead to future unnecessary costs, wasted investments and risks to life and property. Long-term investments in building or improving infrastructure are likely to be sensitive to assumptions about future climate conditions. Therefore it is important to focus on identifying 'no-regrets' options that provide benefits under any climate scenario. The goal is to reduce risk today while building long-term flexibility into flood risk management plans and investment decisions. To achieve this flexibility, planners should: consider ensembles of scenarios and not just focus on a single set of possibilities; promote robust, rather than optimal, strategies that perform "well enough" across a broad range of plausible futures; explore and employ adaptive strategies.

152 While technical matters will remain both important and thorny, successful adaptation to climate change will revolve around the major themes of technical feasibility, funding sources and mechanisms, governance at all levels, private/public sector conflict, equity and ethics, poverty, and sustainable development, to name but a few. Adaptation is essentially a local activity. The best thing that "government" can do to make adaptation happen is to provide: *(a)* the best and most timely information (climate models, weather predictions, planning guidance, etc.); *(b)* adequate and sustained funding; and *(c)* a level of governance and transparency that keeps everybody honest and protects the benefits of adaptation from predatory forces in society.

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