Ana Lopez

Understanding flood hazard

Book section (Published version)

Original citation:
Originally published in Jha, Abhas K., Bloch, Robin and Lamond , Jessica, (eds.) and Global Facility for Disaster Reduction and Recovery (GFDRR) (corp. ed.),*Cities and flooding: a guide to integrated urban flood risk management for the 21st century* (Washington, USA: The World Bank, 2012), pp. 51-129. ISBN 9780821388662

Cities and Flooding

A Guide to Integrated Urban Flood Risk Management for the 21st Century

Abhas K Jha | Robin Bloch
Jessica Lamond

THE WORLD BANK

GFDRR
Global Facility for Disaster Reduction and Recovery

Cities and Flooding

Cities and Flooding

A Guide to Integrated Urban Flood Risk Management for the 21st Century

Abhas K Jha | Robin Bloch
Jessica Lamond

THE WORLD BANK
Washington, D.C.

GFDRR
Global Facility for Disaster Reduction and Recovery

Cover photo: Wilaiporn Hongjantuek walks through chest-high water in Amornchai on the outskirts of Bangkok, Thailand (2011). Source: Gideon Mendel

Back cover photos source: Gideon Mendel

The World Bank
1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org

1 2 3 4 15 14 13 12

ISBN (paper): 978-0-8213-8866-2
ISBN (electronic): 978-0-8213-9477-9
DOI: 10.1596/978-0-8213-8866-2

Library of Congress Cataloging-in-Publication data have been requested.

Contents

Acknowledgements

Cities and Flooding: A Guide to Integrated Flood Risk Management for the 21st Century and *A Summary for Policy Makers* were researched and written by a team led by Abhas K. Jha (Task Team Leader, The World Bank). Robin Bloch (GHK Consulting) was the Project Manager and Jessica Lamond (University of the West of England) the Technical Editor. Zuzana Svetlosakova (The World Bank) and Nikolaos Papachristodoulou (GHK Consulting) provided invaluable service and input as coordinators of the project.

We acknowledge the financial support of the Global Facility for Disaster Reduction and Recovery (GFDRR).

This document was prepared under the overall guidance of Zoubida Allaoua, John Roome and Saroj Kumar Jha.

Special acknowledgement is due to those organizations who were partners with the World Bank in this project: World Meteorological Organization (WMO) and Japan International Cooperation Agency (JICA).

The consultancy group was headed by GHK Consulting; Baca Architects, London; and the University of Wolverhampton's School of Technology. Contributors comprised Robert Barker, Alison Barrett, Namrata Bhattacharya, Alan Bird, John Davies, Emma Lewis, Peter Lingwood, Ana Lopez and David Proverbs.

The Guide's design concept was developed by Baca Architects. Chris Jones and Jamie Hearn from Artupdate, London, created the print version.

The large-format photographs, including the cover, are from 'Drowning World', a project by Gideon Mendel who since 2007 has photographed flood events in the UK, India, Haiti, Pakistan, Australia and Thailand. The work has featured in the Guardian, and in other publications.

We would also like to acknowledge contributions from the following institutions and organizations: Asian Disaster Preparedness Center (ADPC); UN-HABITAT; Central Public Health & Environmental Engineering Organisation (CPHEEO), Ministry of Urban Development, Government of India; Deltares; German Research Centre for Geosciences GFZ; Metropolitan Manila Development Authority (MMDA), Stadtentwässerungsbetriebe Köln, AöR (StEB-TB); and Queensland Reconstruction Authority.

We benefited greatly from our core peer reviewers and advisors: Franz Drees-Gross, Michael Jacobsen, Manuel Marino, Joe Manous, Carlos Costa, Frans van de Ven, Victor Vergara, Baba Hitoshi, Avinash Tyagi, Burrell E. Montz, Curtis B. Barrett, Jose Simas, Heinz Brandenburg, and Emily White.

For their sharing experiences, making suggestions, participation in regional stakeholder and expert workshops, contributing to case studies, and commenting on drafts, and providing support we are grateful for the inputs of the following individuals: Mathias Spalivero, Silva Magaia, R.D. Dinye, Madame Ayeva Koko, Ndaye Gora, Zounoubate N'Zombie, Pramita Harjati, Muh Aris Marfai, N.M.S.I. Arambepola, Ho Long Phi, Menake Wijesinghe, Fawad Saeed, Janjaap Brinkman, Fook Chuan, Trevor Dhu, Achmad Haryadi, Marco Hartman, Josefina Faulan, Dinesh Kumar Mishra, Stéphane Hallegatte, Aphisayadeth Insisiengmay, L.V. Kumar, Rajesh Chandra Shukla, Divine Odame Appiah, Robert Belk, Juzer Dhoondia, Heidi Kreibich, Philip Bubeck, Bill Kingdom, Fritz Policelli, Loic Chiquier, Marcus Wijnen, Marianne Fay, Nicola Ranger, Paul Huang, Rolf Olsen, Shahid Habib, Vijay Jagannathan, Winston Yu, Zachary Usher, John Frimpong Manso, Tony Asare, Segbefia Alexander Yao, Stephen Yao, Anthony Mompi, Richard Dugah, Martin Oteng-Ababio, Grace Abena Akese, Clifford Amoako, Solomon N-N Benni, Mohammed Alhassan, Kwasi Baffour Awuah, James K. Boama, Daniel Ayivie, Felix Agyei Amakye, Wise Ametefe, David Asamoah, Ranjini Mukherjee, Rajeev Malhotra, Rajesh Chandra Shukla, Anirban Kundu, Ranu Sinha, Amit Saha, Deepak Singh, Ahmed Kamal, Naseer Gillani, Hazrat Mir, Alamgir Khan, John Taylor, Oktariadi Adi, Nanang W.P. Safari, Febi Dwi Rahmadi, Teguh Wibowo, Jose Miguel Ruiz Verona, Desti Mega Putri, Matt Hayne, Jonathan Griffin, Aris Munardar, Gita Chandrika, Iwan Gunawan, Peter de Vries, Koen Elshol, Jurjen Wagemaker, Tanaka Kataya, Yulita Sari Soepardjo, M. Abdul, Anton Sunarwibowo, Olivia Stinson, M. Rudy, G. Dedi, M. Feuyadi, A. Andi, Elfina Rosita, Omar Saracho, Yusak Oppusunggu, Faisyar, Suryani Amin, Paul van Hofwegen, Rinsan Tobing, Achmad Haryadi, Shinghu Tamotsu, Ampayadi N, Bambang Sigit, M. Feryadiwinarso, Hetty Tambunan, Michael van de Watering, Dan Heldon, Christopher Yu, Ramon Santiago, Liliana Marulanda, Wilson A. Tabston, Gloria R., Arnold Fernandez, Aristioy Teddy Correa, Shelby A. Ruiz, Alvidon F. Asis, Noel Lansang, Reynaldo Versomilla, Joel Las, Yolando R. de Guzman, Morito Francesco, Gabrielle Iglesias, Khondoker Golam Tawhid, Prasad Modak, Young Kim, Arlan Rahman, Stefan G. Koeberle, Ousmane Diagana, Zie Ibrahima Coulibaly, Fasliddin Rakhimov, Makhtar Diop, Boris Enrique Utria, Yolande Yorke, Klaus Rohland, Kate Isles, Lasse Melgaard, Julia M. Fraser, Sombath Southivong, Khamlar Phonsavat, Alaa Hamood, Emmy Yokoyama, Faris Hadad-Zervos, Francis Ato Brown, Pilar Maisterra, Abdulhamid Azad, Suzy Kantor, Poonam Pillai, Anil Pokhrel, Penelope J. Brook, Ellen A. Goldstein, Swarna Kazi, Patricia Lopez, Tatiana Proskuryakova, Giovanna Prennushi, Raja Rehan Arshad, Haris Khan, Yan Zhang, Catherine G. Vidar, Mark C. Woodward, Asta Olesen, Nicholas J. Krafft, David Sislen, Jonathan Rothschild, Dzung Huy Nguyen, Dean A. Cira, Benita Sommerville, Josephine Masanque, A. David Craig, Piers E. Merrick, Chris Pratt, Marie E. Brown, Ana Campos Garcia, Geoffrey H. Bergen, Daniel M. Sellen, Eric Dickson, Francoise Clottes, Michael Corlett, Herve Assah, Syed Waqar Haider, Emmanuel Nkrumah, Camille Lampart Nuamah, Nelson Antonio Medina Rocha, Francisco Carranza, Charles Tellier, Helene Djoufelkit, Michael John Webster, Carlos Felipe Jaramillo, Giuseppe Zampaglione, Armando Guzman, Asif Faiz, and Rachid Benmessaoud.

We would also like to thank Liz Campbell, Ryan Hakim, Lawrence Dakurah, D.K. Ahadzie and Ruby Mangunsong for organizational and logistical support on regional workshops that took place in Accra, Ghana, Delhi, India, Jakarta, Indonesia, and Manila, the Philippines. Support was also provided by Mathis Primdal and Roy Brockman of GHK Consulting.

Carly Rose copy edited a late draft of the book. Jeffrey N. Lecksell at the World Bank's Map Design Unit developed a number of maps. The Office of the Publisher, The World Bank, provided printing services under the supervision of Patricia Katayama and with the support of Andrés Meneses and Denise Marie Bergeron. A portal and the project website: http://www.gfdrr.org/gfdrr/urbanfloods, on which the Guide and supporting materials can be accessed, was developed by Indy Gill, and constructed by the World Bank's Jaime Yepez and Ritesh Sanan, with assistance from Hemang Karelia.

WMO OMM

JICA ジャイカ

About the authors

Mr. Abhas K. Jha is Lead Urban Specialist and Program Leader, Disaster Risk Management for the World Bank's East Asia and the Pacific Region. In this capacity he is responsible for managing the Bank's disaster risk management practice in the region. He has been with the World Bank since 2001, leading the Bank's urban, housing and disaster risk management work in Turkey, Mexico, Jamaica and Peru as well as serving as the Regional Coordinator, Disaster Risk Management for Europe and Central Asia. Abhas has also served as Advisor to the World Bank Executive Director for India, Bangladesh, Sri Lanka and Bhutan on issues related to urban development, infrastructure and climate finance. He earlier served for 12 years in the Indian Administrative Service (the national senior civil service of India) in the Government of India (in the Federal Ministry of Finance and earlier in the state of Bihar) and is also the lead author of the World Bank publication "Safer Homes, Stronger Communities: A Handbook for Reconstructing after Disasters". Abhas' core interests are urban resilience and cities as complex adaptive systems.

Dr. Robin Bloch is Principal Consultant and Head of the Planning, Land and Economic Development practice at GHK Consulting, London. He is an urban planner, educated first in South Africa and then in the United States. His main areas of expertise and research interest include urban, regional and metropolitan spatial and land use planning; urban environmental management, sustainability and resilience; and urban industry. Robin has over 20 years of international experience, principally in Sub-Saharan Africa and South Asia and East Asia, of policy, strategy and plan making, and project and programme formulation, implementation and evaluation. He is a Visiting Adjunct Professor at the School of Architecture and Planning, University of the Witwatersrand, Johannesburg, and an Associate Research Fellow at the Centre for Social Science Research at the University of Cape Town.

Dr. Jessica Lamond is an experienced researcher in Flood Risk Management with particular focus on the implications of flooding in the built environment. Her specialism includes flood recovery, financial and economic impacts on property stakeholders, the valuation of property at risk, the implications for insurance and the barriers to and drivers for adaptation to flooding. She is currently a senior research fellow at the University of the West of England, where she is currently involved in research supported by leading research funders and industry and consults for government bodies and the FRM profession. Jessica publishes widely in academic/research journals and is the principal editor of the book "Flood hazards: impacts and responses for the built environment" for Taylor publishing which brings together views from experts on structural and non-structural approaches to urban flood risk management.

Contributors

Robert Barker, Baca Architects

Alison Barrett, Independent Consultant

Namrata Bhattacharya, School of Technology, University of Wolverhampton

Alan Bird, Independent Consultant

Prof John Davies, Professor of Civil Engineering, Architecture and Building, Faculty of Engineering and Computing, Coventry University

Emma Lewis, GHK Consulting

Dr Peter Lingwood, CeConsult

Dr Ana Lopez, Grantham Research Institute and Centre for the Analysis of Time Series, London School of Economics and Political Science

Nikolaos Papachristodoulou, GHK Consulting

Prof David Proverbs, Professor and Head of the Department of Construction and Property, University of the West of England

How to use the Guide

Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century provides comprehensive, forward-looking operational guidance on how to manage the risk of floods in a rapidly transforming urban environment and changeable climate. The Guide serves as a primer for decision and policy makers, technical specialists, central, regional and local government officials, and concerned stakeholders in the community sector, civil society and non-governmental organizations, and the private sector.

The Guide starts with *A Summary for Policy Makers* which outlines and describes the key areas which policy makers need to be knowledgeable about to create policy directions and an integrated strategic approach for urban flood risk management. The *Summary* concludes with 12 guiding policy principles for integrated flood risk management.

The core of the Guide consists of seven chapters, organized as follows:

Chapter 1. Understanding Flood Hazard

Chapter 2. Understanding Flood Impacts

Chapter 3. Integrated Flood Risk Management: Structural Measures

Chapter 4. Integrated Flood Risk Management: Non-Structural Measures

Chapter 5. Evaluating Alternative Flood Risk Management Options: Tools for Decision Makers

Chapter 6. Implementing Integrated Flood Risk Management

Chapter 7. Conclusion: Promoting Integrated Urban Flood Risk Management

Each chapter starts with a full contents list and a summary of the chapter for quick reference. It is then made up of sections which combine general narrative on key aspects of urban flood risk management, case study evidence in the form of lessons from the field on the methods and techniques of flood risk management, both positive and where relevant problematic, and "How To" sections on necessary and immediate operational tasks. Each chapter contains a full reference list. This is augmented by lists of further readings for operational tasks.

The last chapter captures briefly the essential considerations for ensuring that flood risk management is provided in an integrated way. It sets out benchmarks for assessing progress towards better urban flood risk management, which are presented in alignment with the 12 guiding policy principles and a five-step process, with reference to relevant case study examples.

The Guide is supported by a website: http://www.gfdrr.org/gfdrr/urbanfloods. The website aims to form a platform for practitioners for dialog around the Guide's themes and content as well as a vehicle for dissemination of the Guide. The website contains additional resources related to the content of the Guide.

A Summary for Policy Makers

A Summary for Policy Makers

Background

Urban flooding is a serious and growing development challenge. Against the backdrop of demographic growth, urbanization trends and climate changes, the causes of floods are shifting and their impacts are accelerating. This large and evolving challenge means that far more needs to be done by policy makers to better understand and more effectively manage existing and future risks.

This summary accompanies *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century* which provides forward-looking operational guidance on how to manage the risk of floods in a transforming urban environment and changeable climate. The Guide argues for a strategic approach to managing flood risk, in which appropriate measures are identified, assessed, selected and integrated in a process that both involves and informs the full range of stakeholders.

The Guide embodies the state-of-the art on integrated urban flood risk management. It is designed in a comprehensive and user-friendly way to serve as a primer for decision and policy makers, technical specialists, central, regional and local government officials, and concerned stakeholders in the community sector, civil society and non-governmental organizations, and the private sector.

It contains chapters which:

- Describe the causes, probabilities and impacts of floods
- Propose a strategic, innovative, integrated approach to managing flood risk accomplished by selecting and combining structural, hard-engineered measures and non-structural management measures
- Discuss the means by which these measures can be financed and implemented while engaging with and drawing on the capacities and resources of all involved stakeholders
- Specify the procedures by which progress with implementation can be monitored and evaluated.

Over fifty case studies on management measures and procedures from across the world illustrate the key policy messages. They demonstrate what has been implemented in a wide variety of urban contexts in order to meet the challenges of dealing with flood risk.

A series of "How To" sections covers the operational details of implementing a number of key flood risk management measures, and provides the reader with core technical information.

In conclusion, 12 guiding policy principles for integrated flood risk management are presented.

This overview summarizes the key areas that policy makers need to be knowledgeable about and to take action on as they create policy directions for urban flood risk management and develop the strategic frameworks to manage successfully the growing risk of urban flooding.

Urban flooding poses a serious challenge to development and the lives of people, particularly the residents of the rapidly expanding towns and cities in developing countries.

Ghulam Rasool Burriro walks through the flooded centre of the town of Khairpur Nathan Shah, 2010, Pakistan. Source: Gideon Mendel

The growing challenge of urban flooding

Flooding is a global phenomenon which causes widespread devastation, economic damages and loss of human lives.

Over the past eighteen months, destructive floods occurred along the Indus River basin in Pakistan in August 2010; in Queensland, Australia, South Africa, Sri Lanka and the Philippines in late 2010 and early 2011; along with mudslides, in the Serrana region of Brazil in January 2011; following the earthquake-induced tsunami on the north-east coast of Japan in March 2011; along the Mississippi River in mid-2011; as a consequence of Hurricane Irene on the US East Coast in August 2011; in Pakistan's southern Sindh province in September 2011; and in large areas of Thailand, including Bangkok, in October and November 2011.

The occurrence of floods is the most frequent among all natural disasters. In the past twenty years in particular, the number of reported flood events has been increasing significantly. Figures 1 and 2 illustrate this trend. The numbers of people affected by floods and financial, economic and insured damages have all increased too. In 2010 alone, 178 million people were affected by floods. The total losses in exceptional years such as 1998 and 2010 exceeded $40 billion.

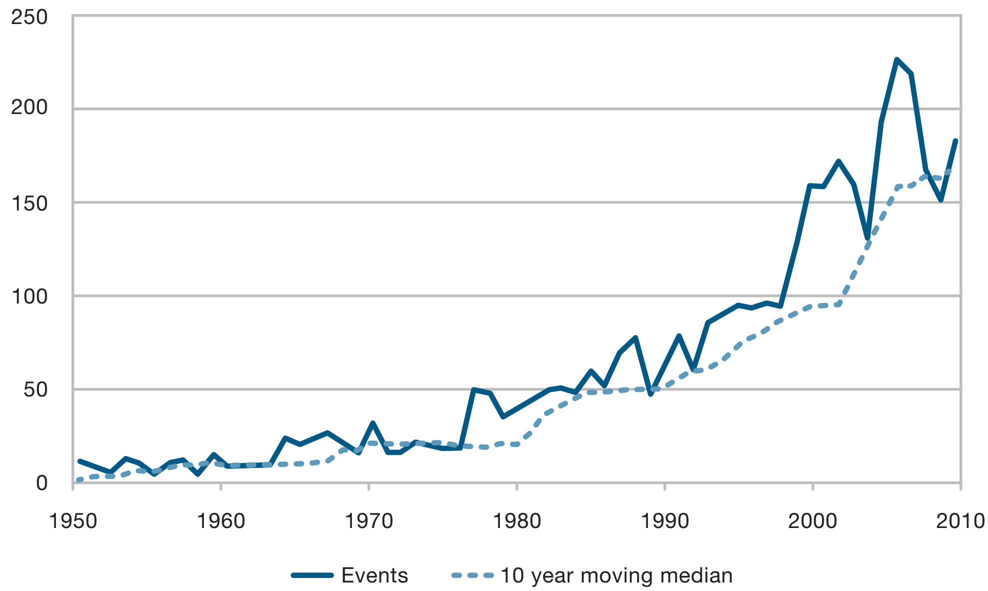

Figure 1: Number of reported flood events. Source: based on EM-DAT/CRED

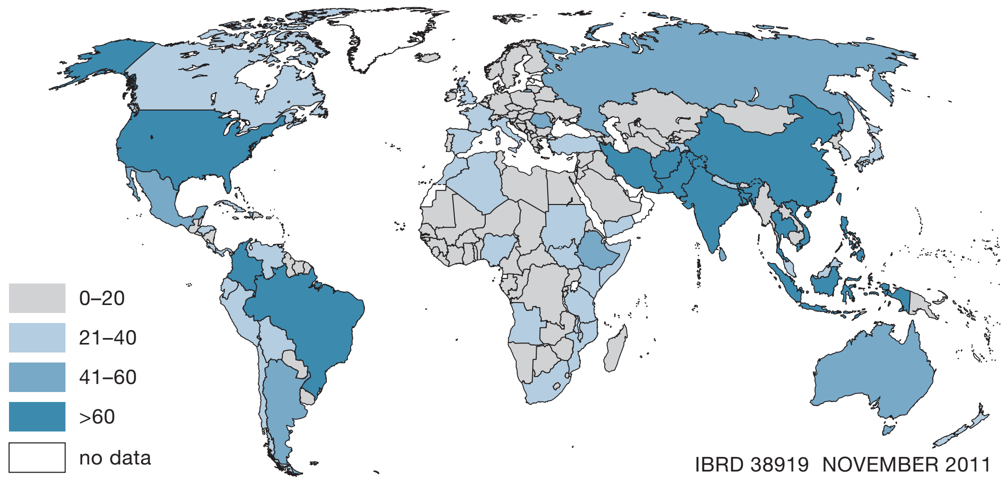

Figure 2: Flood Events, 1970-2011. Source: EM-DAT: The OFDA/CRED International Disaster Database www.emdat.be - Université Catholique de Louvain - Brussels - Belgium"

Immediate loss of life from flooding is increasing more slowly or even decreasing over time, reflecting the successful implementation of flood risk management measures. While this is encouraging, fatalities still remain high in developing countries where flood events have a disproportionate impact on the poor and socially disadvantaged, particularly women and children.

Urban areas at risk from flooding have been hit particularly hard by the observed increase of flooding impact across the world. The current and projected levels of flood impacts give urgency to the need to make flood risk management in urban settlements a high priority on the political and policy agenda. Understanding the causes and effects of flood impacts and designing, investing in and implementing measures which minimize them must become part of mainstream development thinking and be embedded into wider development goals.

Floods affect urban settlements of all types, from small villages and mid-sized market towns and service centers, for example along the Indus River, to the major cities, megacities and metropolitan areas like Sendai, Brisbane, New York, Karachi and Bangkok, all of which were struck by recent floods.

Countries define "urban" settlements in very different ways, which makes urban flooding hard to define in a consistent manner. Damage statistics are not usually classified by urban or rural location, making it difficult to apportion losses between urban and rural populations.

However, there are real functional differences between urban and rural flooding. While rural flooding may affect much larger areas of land and hit poorer sections of the population, urban floods are more costly and difficult to manage.

The impacts of urban floods are also distinctive given the traditionally higher concentration of population and assets in the urban environment. This makes damage more intense and more costly. Urban settlements also contain the major economic and social attributes and asset bases of any national population, so that urban flooding, by causing damage and disruption beyond the scope of the actual floodwaters, often carries more serious consequences for societies.

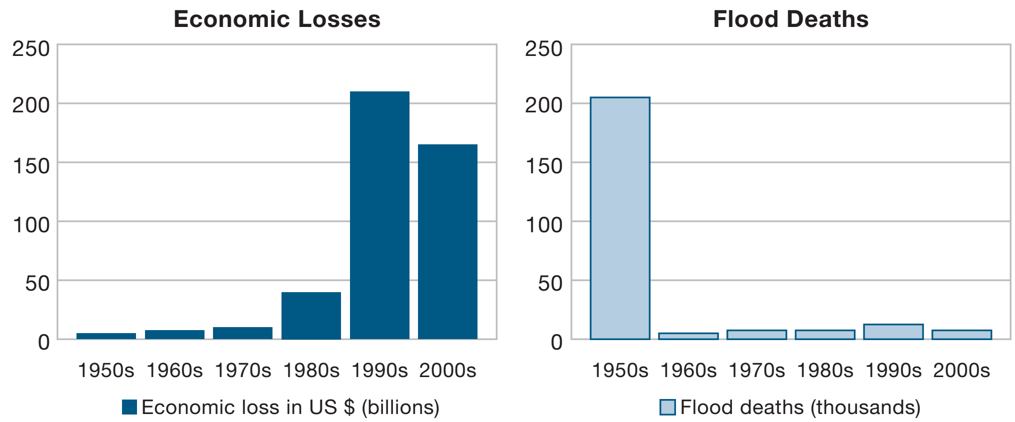

Figure 3: Reported economic losses and deaths. Source: based on EM-DAT/CRED

Direct impacts from major events represent the biggest risk to life and property. Figure 3 shows the growth in direct monetary impacts resulting from flood events. Indirect and often long-term effects, such as disease, reduced nutrition and education opportunities, and loss of livelihoods, can also erode community resilience and other development goals, as does the need to constantly cope with regular, more minor, flooding. Such indirect impacts can be hard to identify immediately and harder still to quantify and value. However, the poor and disadvantaged usually suffer the most from flood risk.

Urbanization, as the defining feature of the world's demographic growth, is implicated in and compounds flood risk. In 2008, for the first time in human history, half of the world's population lived in urban areas, with two-thirds of this in low-income and middle-income nations. This is estimated to rise to 60 percent in 2030, and 70 percent in 2050 to a total of 6.2 billion, or double the projected rural population for that time. As the urban population comes to represent the larger proportion of world population, urban floods will account for an increasing part of total flood impact.

Urban flooding is thus becoming more dangerous and more costly to manage because of the sheer size of the population exposed within urban settlements. This affects all settlement sizes: while in 2030 the forecast is for 75 agglomerations of over five million inhabitants, urban populations in all size classes are also expected to continue to grow, as Figures 4 and 5 demonstrate. By 2030 the majority of urban dwellers, in fact, will live in towns and cities with populations of less than one million where urban infrastructure and institutions are least able to cope. Management of urban flood risk is not an issue that is confined to the largest cities alone.

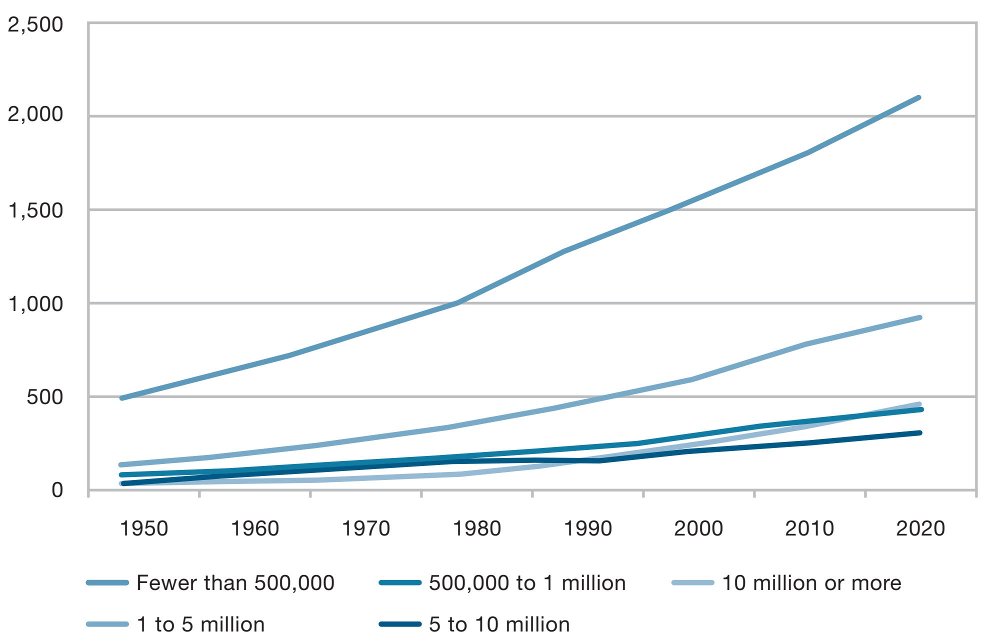

Figure 4: Growth in population by city scales. Source: based on Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision and World Urbanization Prospects: The 2009 Revision.

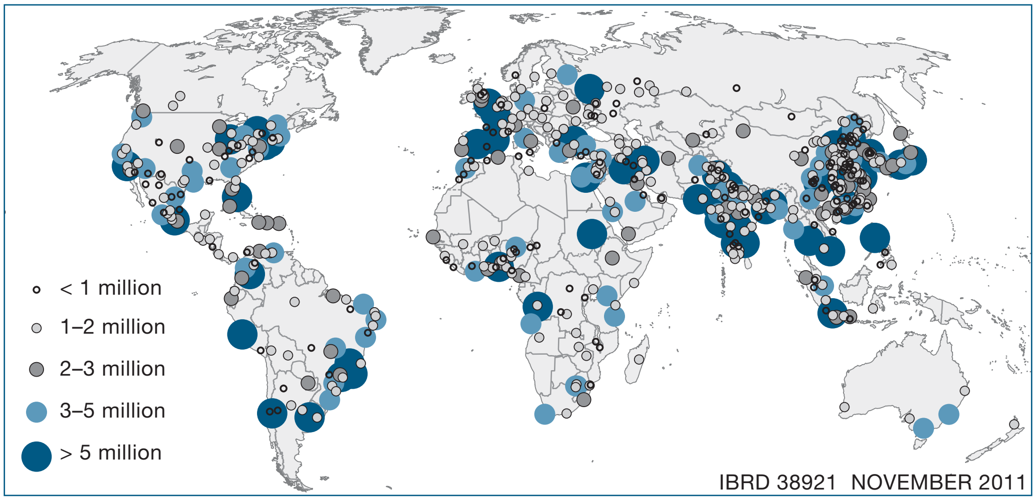

Figure 5: Urban agglomerations with more than 750,000 inhabitants, 2010. Source: United Nations, Department of Economic and Social Affairs, Population Division; World Urbanization Prospects: The 2009 Revision; File 12: Population of Urban Agglomerations with 750,000 Inhabitants or More in 2009, by Country, 1950-2025 (thousands)

Poorly planned and managed urbanization also contributes to the growing flood hazard due to unsuitable land use change. As cities and towns swell and grow outwards to accommodate population increase, large-scale urban expansion often occurs in the form of unplanned development in floodplains, in coastal and inland areas alike, as well as in other flood-prone areas.

In the developing world, a very high proportion of urban population growth and spatial expansion takes place in the dense, lower-quality informal settlements that are often termed "slums." These are located in both city-center and peripheral, suburban or peri-urban locations and are frequently at highest risk. The concentration of the poor within these areas, which typically lack adequate housing, infrastructure and service provision, increases the risk of flooding and ensures that flood impacts are worst for the disadvantaged.

The increased impacts of urban flooding which policy makers must address are further affected by development outside the protection of existing flood defenses; an increase in paving and other impermeable surfaces; overcrowding, increased densities and congestion; limited, ageing or poorly maintained drainage, sanitation and solid waste infrastructures; over-extraction of groundwater leading to subsidence; and a lack of flood risk management activities.

Climate change is the other large-scale global trend perceived to have a significant impact on flood risk. The alterations in meteorological patterns which are associated with a warmer climate are potentially drivers of increased flooding, with its associated direct and indirect impacts. Observed and projected patterns of climate change can have an amplifying effect on existing flood risk, for example by:

- Augmenting the rate of sea level rise which is one of the factors causing increased flood damage in coastal areas
- Changing local rainfall patterns that could lead to more frequent and higher level of floods from rivers and more intense flash flooding
- Changing the frequency and duration of drought events that lead to groundwater extraction and land subsidence which compounds the impact of sea level rise
- Increasing frequency of storms leading to more frequent sea surges.

In the opinion of climate scientists, as reflected by the Intergovernmental Panel on Climate Change (IPCC), the observed increase in extreme weather is consistent with a warming climate. Although individual extreme weather events cannot be attributed to climate change, climate change can increase the chance of some of those events happening. Sea level rise is also an acknowledged and observed phenomenon. While climate change has the potential to greatly increase flood hazard and the risk from flooding, it does not appear to be the main driver of the increased impacts seen at present.

Over shorter time scales the natural variability of the climate system and other non-climatic risks are in fact expected to have a higher impact on flood risk than longer term climate trends. Accelerating urbanization and urban development could also increase significantly the risk of flooding independent of climate change. As an illustration, in Jakarta, Indonesia, land subsidence due to groundwater extraction and compaction currently has effects on the relative ground and seawater levels ten times greater than the anticipated impact of sea level rise.

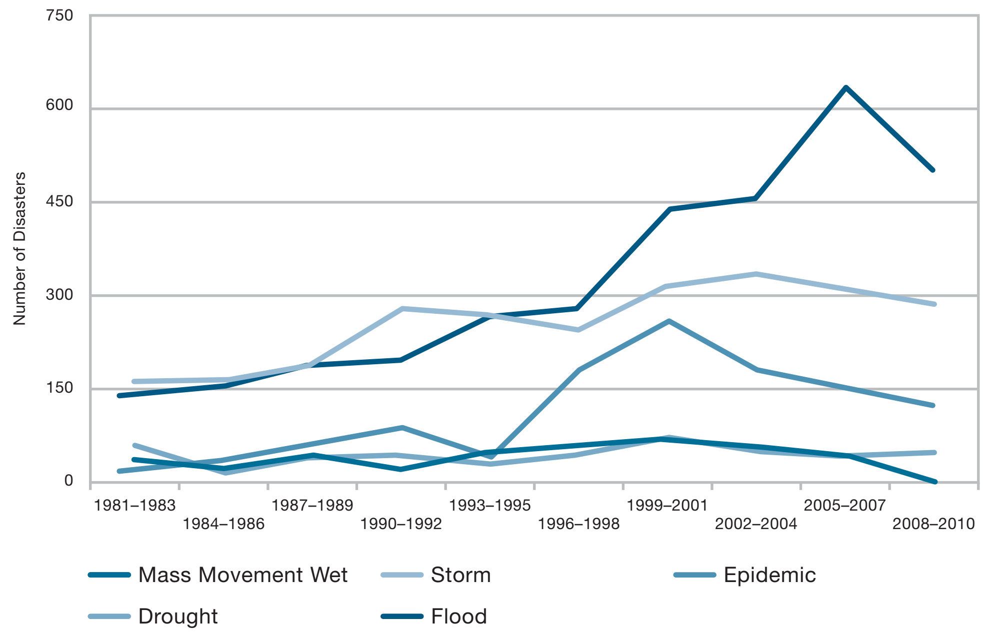

Figure 6: Trends in water-related disasters. Source: based on EM-DAT/CRED

On longer time scales, climate change might play a more significant role. Both short-term and long-term prospects need to be considered in managing flood risk: "The basic issue is finding ways to build into near-term investments and choices an appropriate consideration of long-term trends and worst-case scenarios."[1] Figure 6 illustrates trends in water-related disasters over a 30 year period.

In managing flood risk today, and in planning for the future, a balance must be struck between common sense approaches that minimize impacts through better urban management and the maintenance of existing flood mitigation infrastructure, and far-sighted approaches which anticipate and defend against future flood hazard by building new flood mitigation infrastructure or by radically reshaping the urban environment. The balance will be different for each city or town at risk. In reaching decisions on the appropriate prioritization of flood management effort, an understanding of both current and future flood risk is needed.

[1] Revkin A. "On Dams, Gutters, Floods and Climate Resilience." Dot Earth blog in The New York Times, August 30, 2011

A resident tries to remove mud after flooding in Gonaïves, Haiti, 2008. Source: Gideon Mendel

Understanding the causes and risk of urban flooding

As a first step in urban flood risk management, policy makers need to understand the flood hazard that can affect the urban environment. Understanding hazard requires a better comprehension of the types and causes of flooding, their probabilities of occurrence, and their expression in terms of extent, duration, depth and velocity.

This understanding is essential in designing measures and solutions which can prevent or limit damage from specific types of flood. Equally important is to know where and how often flood events are likely to occur, what population and assets occupy the potentially affected areas, how vulnerable these people and their settlements are, and how these are planned and developed, and what they already do towards flood risk reduction. This is critical in grasping the necessity, urgency and priority for implementing flood risk management measures.

As flood risk evolves over time, policy makers also need to explore how decisions change in the light of changing climates. Information about the existing models used to account for climate change at different scales and an understanding of the uncertainties regarding those results need to be at the core of any decision-making process.

Urban areas can be flooded by rivers, coastal floods, pluvial and ground water floods, and artificial system failures. Urban floods typically stem from a complex combination of causes, resulting from a combination of meteorological and hydrological extremes, such as extreme precipitation and flows. However they also frequently occur as a result of human activities, including unplanned growth and development in floodplains, or from the breach of a dam or an embankment that has failed to protect planned developments.

It is important here to distinguish between the probability of occurrence of a weather event and the probability of occurrence of a flood event. Flooding is primarily driven by weather events which can be hard to predict. For this reason, flood hazard predictions are commonly available in terms of probabilities computed using historical data for the area of interest. The value of inference based on historic observations is naturally dependent on the availability and quality of data.

Understanding these probabilities is therefore critical to understanding risk. The language of probability can be confusing as people do not intuitively understand an annual one percent (or one in 100) chance of flooding. The use of the alternative concept of the estimated return period, such as “a 100-year flood” is also misunderstood as a flood that is certain to occur over the next 100 years – or is sometimes even assumed to be a flood that can only occur once in 100 years. Similarly, two events reported with the same return period can have different magnitudes, and consequently affect the same people in different ways. When the uncertainties are far-reaching or poorly understood, for instance due to inadequate data, the communication of flood risk in terms of flood probabilities and their use in flood management decisions can be misleading.

The use of maps for communicating hazard and associated risk is therefore a valuable aid to decision-making. Flood hazard maps are visual tools for communicating the hazard situation in an area. Hazard maps are important for planning development activities, for emergency planning, and for policy development. Flood risk maps incorporate flood hazard information within the context of data on exposed assets and population, and their vulnerability to the hazard. They can often be articulated in terms of expected damage, and can be used as supplementary decision-making tools.

Flood forecasting is another essential tool which provides people still exposed to risk with advance notice of flooding in an effort to save lives and property. However, without an analysis of the physical causes of recorded floods, and of the geophysical, biophysical and anthropogenic, or human-made, context that determines the potential for flood formation, predictions have the potential to contribute to the damages caused by floods by either under-estimating or over-estimating the hazard. Modelling today’s hazard has many challenges.

For the projection of future flood risk, there are even greater sources of uncertainty. The assumption usually made is that future flood patterns will be a continuation of the past because they are generated from the same cyclical processes of climate, terrain, geology, and other factors. Where this assumption holds true, a system is said to be stationary, which makes the future predictable from the past. If this assumption is not true, the future becomes much more uncertain. Figure 7 illustrates the use of hazard maps to depict current and future hazard situations. For urban flooding, two potential major sources of what is consequently termed non-stationarity (i.e. past patterns and trends are poor predictors of the future), are the rapid development of flood-prone areas as urbanization proceeds, and the changes in weather patterns associated with climate change.

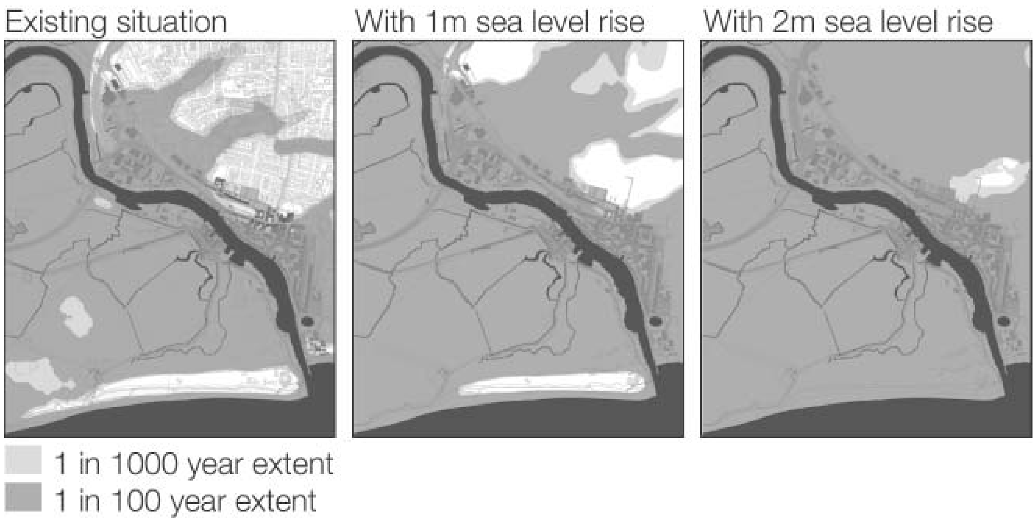

Figure 7: Flood hazard map. Source: Baca Architects

Urbanization is arguably an inevitable, unstoppable and positive trend which nevertheless has the potential to greatly increase flood risk. However, the projection of future urban population growth has associated uncertainties in the scale and spatial distribution of populations. Equally, the impact of future urban growth on flood risk is influenced by the policies and choices of urban dwellers as they may or may not occupy areas at risk of flooding, or adopt suitable urban planning and design.

There are also considerable uncertainties in climate projections. This owes to the difficulty of accurately predicting the future trajectory of socio-economic development, and as a consequence of incomplete knowledge of the climate system and the limitations of the computer models used to generate projections. The relative and absolute importance of different sources of uncertainty depends on the spatial scale, the lead time of the projection, and the variable under consideration.

The inevitable conclusion is that the accuracy or precision of long-term flood risk forecasts will be low, and that over-reliance on future probabilities is not appropriate. It is equally apparent that better planned and managed urban development can mitigate the expected growth in future flood risk.

The development of appropriate adaptations that will protect against an uncertain future risk is further complicated by a combination of the characteristics of the urban infrastructure to be protected and the long lead-in and lock-in periods of urban flood protection infrastructures and projects. This can result in large flood protection schemes facing new challenges even before they are completed as for example in Ho Chi Minh City, Vietnam, where the 2001 Master Plan to mitigate flooding via improved drainage had to contend with higher than expected increases in peak rainfall.

Defending against future floods will therefore require more robust approaches to flood management that can cope with larger uncertainty or be adaptive to a wider range of futures. This could lead to a greater reliance on more flexible, incremental approaches to flood risk management, the incorporation of greater flexibility into the design of engineered measures, or acceptance of potential over-specification for inflexible measures.

With a solid understanding of the causes and impacts of urban flooding, an appreciation of the likely future flood probability and of the uncertainties surrounding it, and knowledge of both the potentials and the limitations of various flood risk management approaches, policy makers can adopt an integrated approach to flood risk management.

People queue for food relief in the flooded city of Gonaives in Haiti two weeks after the entire city had been engulfed during Hurricanes Ike and Hanna, 2008, Haiti. Source: Gideon Mendel

An integrated approach to urban flood risk management

An integrated flood risk management approach is a combination of flood risk management measures which, taken as a whole, can successfully reduce urban flood risk. The Guide helps policy makers in developing such an integrated, strategic approach to reducing flood risk which fits their specific conditions and needs.

Flood management measures are typically described as either structural or non-structural. Structural measures aim to reduce flood risk by controlling the flow of water both outside and within urban settlements. They are complementary to non-structural measures that intend to keep people safe from flooding through better planning and management of urban development. A comprehensive integrated strategy should be linked to existing urban planning and management policy and practices.

Structural and non-structural measures do not preclude each other, and most successful strategies will combine both types. It is also important to recognize the level and characteristics of existing risk and likely future changes in risk to achieve the balance between the required long and short term investments in flood risk management. But as both urbanization and climate change accelerate, there may well be the need to move away from what is often today an over-reliance on hard-engineered defenses towards more adaptable and incremental non-structural solutions.

Structural measures range from hard-engineered structures such as flood defenses and drainage channels to more natural and sustainable complementary or alternative measures such as wetlands and natural buffers. They can be highly effective when used appropriately, as the well-documented successes of the Thames Barrier, the Dutch sea defenses and the Japanese river systems attest. Structural measures can, however, be overtopped by events outside their design capacity. Many structural measures also transfer flood risk by reducing flood risk in one location only to increase it in another. The redirection of water flows also frequently has environmental impact. In some circumstances this is acceptable and appropriate, while in others it may not be. In all cases a residual flood risk remains. Structural solutions can also have a high upfront cost, can sometimes induce complacency by their presence, and can result in increased impacts if they fail or are overtopped, as was tragically illustrated in the tsunami in Japan in 2011.

These considerations, and the fact that there will always remain a residual flood risk, leads to the need to incorporate non-structural measures into any strategy. There is always a role for non-structural measures which manage risk by building the capacity of people to cope with flooding in their environments. Non-structural measures such as early warning systems can be seen as a first step in protecting people in the absence of more expensive structural measures – but they will also be needed to manage the residual risk remaining after implementation of structural measures. Non-structural measures do not usually require huge investments upfront, but they often rely on a good understanding of flood hazard and on adequate forecasting systems – as an example, an emergency evacuation plan cannot function without some advance warning.

Non-structural measures can be categorized under four main purposes:

- Emergency planning and management including warning and evacuation as, for example, in local flood warning systems in the Philippines and in the Lai Nullah Basin, Pakistan.
- Increased preparedness via awareness campaigns as demonstrated in Mozambique and Afghanistan. Preparedness includes flood risk reducing urban management procedures such as keeping drains clear through better waste management.
- Flood avoidance via land use planning as seen in the German Flood Act and planning regulations in England and Wales. Land use planning contributes both to mitigation of and adaptation to urban floods.
- Speeding up recovery and using recovery to increase resilience by improving building design and construction – so-called "building back better." Planning the resilient reconstruction of a damaged village has been seen, for example, in the tsunami-damaged village of Xaafuun, Somalia. Appropriate risk financing such as flood insurance, where it is available, or using donor and government sources of funding assists in quick recovery.

The challenge with many non-structural measures lies in the need to engage the involvement and agreement of stakeholders and their institutions. This includes sometimes maintaining resources, awareness and preparedness over decades without a flood event, bearing in mind that the memory of disaster tends to weaken over time. This challenge is also made greater by the fact that most non-structural measures are designed to minimize but not prevent damage, and therefore most people would instinctively prefer a structural measure.

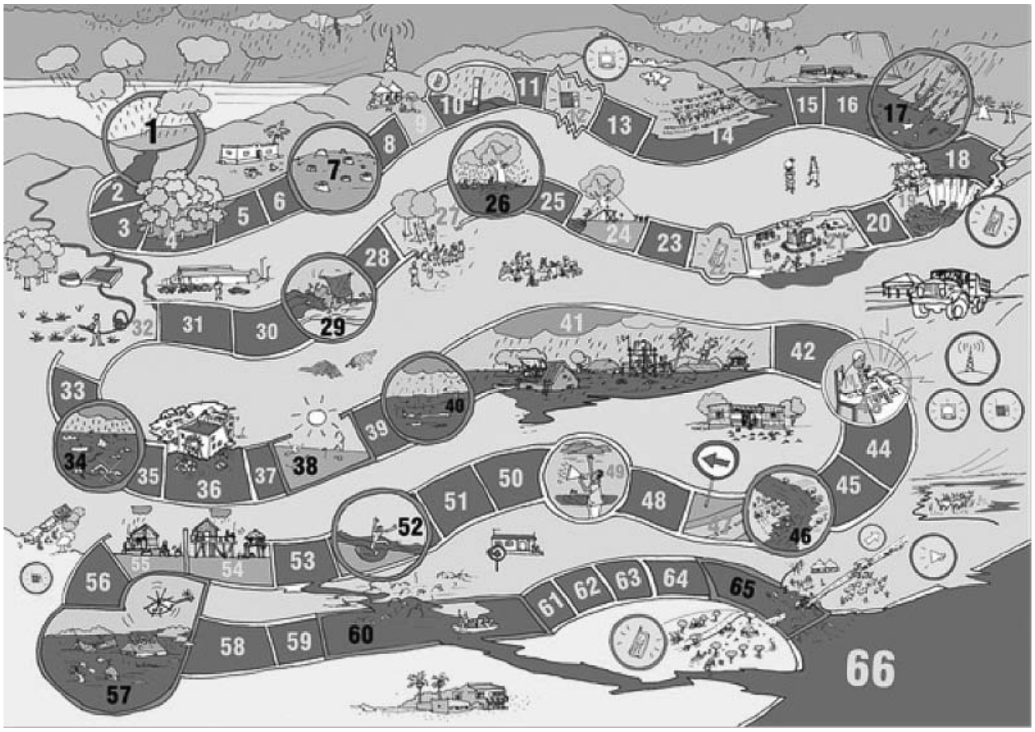

Figure 8: The River Game. Source: UN-HABITAT

Generating the necessary attitudinal and behavioral change may take time and investment in wide communication and consultation. A good practice example of community engagement via didactic tools is seen in Mozambique where the River Game developed under a Cities Alliance project by UN-HABITAT and local partners (Figure 8) is used to educate, communicate with and engage multiple stakeholders.

Flood management may hugely benefit by the involvement of stakeholders. Indeed, if the communication and consultation challenge is successfully overcome, the gains in flood resilience are significant.

It is also important to take account of temporal and spatial issues when determining strategy. Integrated urban flood risk management takes place at a range of scales, including at the river basin and water catchment as a whole. This is due to the fact that the source of flooding may be at some distance from the city or town. Often the best option may be to tackle flooding before it reaches the urban setting.

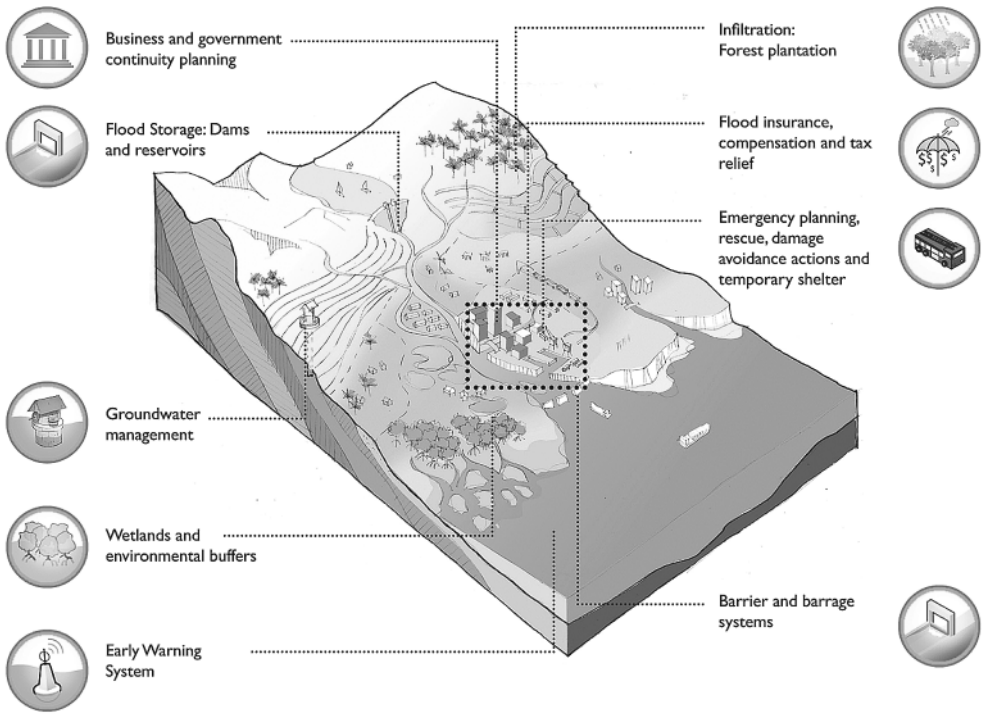

Figure 9: Overview of flood risk management options. Source: Baca Architects

There are multiple management techniques that can be identified in their appropriate catchment locations surrounding an urban environment, as illustrated in Figure 9. Structural measures such as flood defenses and conveyance systems can form a long-term response to flood risk. However, these require large investments which will not always be available. Non-structural measures such as flood warning systems and evacuation planning are necessary for the safeguarding of the population of cities and towns already at risk from flooding, whether protected by defenses or not. There are also urban design and management measures which can be implemented more quickly, such as better operations and maintenance of infrastructure; greening of urban areas; improved drainage and solid waste management; and better building design and retrofitted protection. These will enable occupation of flood risk areas while reducing the expected impacts from flooding.

Land use planning and the regulation of new development is a key aspect of integrated urban flood risk management. In developing countries in particular, the opportunity to better plan the formation of new urban areas is central to prevent the predicted increase in future flood impacts from being realized.

The need to integrate flood risk management into land use planning and management is therefore important in order to minimize risk and manage the impacts of flooding. In growing urban settlements in particular, flood risk may be seen to be of lesser importance than other social and economic concerns. It is hence likely that floodplain development will continue, due to pressure on land resources and other political and economic considerations. However, where new urban environments are better planned within areas at risk from flooding, flood-receptive design can be employed at a potentially lower cost and disruption during the build or reconstruction phase than to attempt to later retrofit. This allows the building in of resilient design – with potential payoff well into the future.

The potential for reduced costs and extended benefits from flood risk management measures also needs to be explored. For example, a highly effective utilization of the limited land available in densely populated cities and urban areas is the construction of multi-purpose retarding basins which store flood water for outflow control when necessary. At other times these basins are used for other purposes such as sport and leisure facilities or car parking. Rainwater harvesting can also be seen as an innovative measure to prevent urban flooding. It forms part of a sustainable drainage system and can simultaneously be used for non-drinking purposes, resulting in water conservation. Investment in better urban management, such as for solid waste, also reduces flood risk, can have health and environmental benefits, and can be used to create employment and relieve poverty.

Groundwater management can prevent land subsidence which mitigates flood risk in low-lying areas but also protects buildings and infrastructure from subsidence-induced failure, as for example has been attempted in Bangkok. Wetlands, bio-shields, environmental buffer zones and other “urban greening” measures that produce environmental and health benefits in urban areas can also reduce flood impacts. These greening measures will have many other benefits in addition to reducing flood risk in surrounding areas, including reducing the urban heat island effect and the level of CO_2 emissions, and thus creating a healthier urban environment. For example, buffer areas around the Primero River in the city of Cordoba, Argentina, improved the urban environment and removed residents at risk to safer locations.

Given the many urgent development goals and resource constraints faced by urban policy makers, it is not possible to be overly prescriptive in the application of flood risk management. The specific set of measures that might be suitable in a particular location should only be adopted after serious consideration – and consultation with stakeholders. Action to create an integrated approach will involve identifying technically feasible sets of measures designed to reduce flood risk.

Integrated urban flood risk management strategies are naturally designed to fit in with water-related planning issues and can be part of a wider agenda such as urban regeneration or climate change adaptation. Action to reduce flood risk should be carried out through a participatory process involving all those stakeholders that have an interest in flood management, including those people at risk or directly impacted by flooding. The measures selected will need to be negotiated by stakeholders, and to be adaptable to natural, social and economic conditions which can be expected to change over time.

Villagers work together to build flood defenses to keep the floodwaters out of their community, 2010, Pakistan. Source: Gideon Mendel

Implementing integrated urban flood risk management

A Guide to Integrated Urban Flood Risk Management argues for an integrated approach to urban flood risk management, which combines structural and non-structural measures. Such integrated urban flood risk management is holistic in scope, strategic in content and collaborative in nature.

An integrated approach can be difficult to achieve where municipal managements suffer from a lack of technical capacity, funding or resources. The interests of stakeholders also vary, leading to different incentives and motives for action. Very often, for instance, residents are unwilling to move from already-developed locations in floodplain areas, which are vulnerable and contravene the land use regulations drafted by decision makers and planners. This situation can involve poorer residents, living on riverbanks close to economic opportunities, or wealthier people who have houses on seafronts

Implementation requires wider participation and a change in traditional management methods to be successful. At political and institutional levels, actions to reduce flood risk need to employ tools and techniques to extrapolate current trends and drivers into the future, to assess alternative scenarios, and to build strategic, integrated approaches. Repeating past mistakes can have disastrous consequences for the present and the future.

It is a fundamental requirement to identify the information, experience and methods that different stakeholders, including practitioners and residents, can provide – and to design measures using such experience and knowledge. It is also important to be aware of the context within which urban flood risk management operates. It can fall between the dynamics of decision-making at national, regional, local/municipal and community levels.

Integrated flood risk management therefore requires greater coordination between city governments, national governments, ministries, public sector companies, including utilities, along with meteorological and planning institutions, civil society, non-government organizations, educational institutions and research centers, and the private sector. It is essential to understand the capacities and incentives of these actors, including how they choose or are able to use their own limited resources under high levels of uncertainty. Government decisions about the management of risk are balanced against competing, often more pressing, claims on scarce resources as well as other priorities in terms of land use and economic development.

Getting the balance right between structural and non-structural measures is also a challenge. Policy makers require a clear vision of the alternatives and methods and tools to assist them in making choices. Decisions regarding flood risk management are complex and require wide participation from technical specialists and non-specialists alike. Tools and techniques exist which allow policy makers and their technical specialists to decide between alternatives, and to assess their costs. There is clearly a role for tools which can predict the outcome of decisions, communicate risk and create linkages between stakeholders. Examples are risk and hazard maps or simulation and visualization techniques which can illustrate the impacts of decisions to multiple stakeholders, and cost-benefit analyses which can make the decision-making process more transparent and accountable.

The right metrics, realistic simulation games, good risk data and data visualization tools help. But underlying such tools there has to be a fundamental understanding, which is often lacking, of the physical processes involved in flooding and the expected outcome of the flood management measures which are undertaken.

While the implementation and outcomes of flood risk management measures can be defined in purely economic terms, the judgment made by policy makers, urban planners and technical specialists must also consider broader issues. They need to consider many aspects such as the impact of measures on environmental degradation, biodiversity, equity, social capital/capacity, and other potential trade-offs. It is important to recognize that the residual risk never reduces to zero, that the cost of reducing the risk may exceed the benefits of doing so, and that funds may not be available to invest in measures. In addition, policy making in the era of urbanization and climate change must deal with the large uncertainty associated with future predictions of flood patterns. Such uncertainty can lead to indecision.

Decision-making needs instead to be robust. Evaluation of the costs and benefits of each measure, or combination of measures, must be integral to a wider strategy which sets future targets for investment in measures and prioritizes spending on the most urgent and effective of these activities. Combining alternatives that perform well under different scenarios then becomes a preferred strategy rather than finding the optimal solution, as illustrated in Figure 10. This will lead to the preference for flexible and so-called no regret approaches that will include measures which will be cost effective regardless of changes in future flood risk.

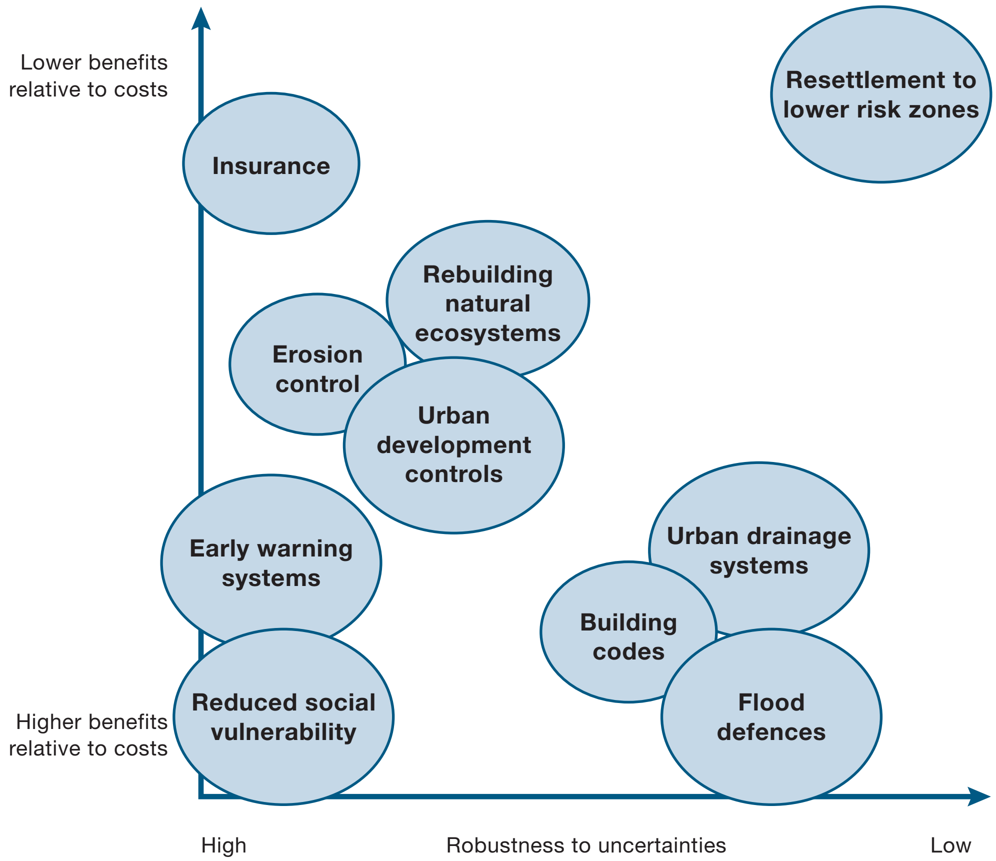

Figure 10: Relative costs and benefits of flood management options.
Source: Adapted from Ranger and Garbett-Shields 2011

Many non-structural measures tend to be inherently flexible, for example early warning systems or evacuation plans. Structural measures are seen as less flexible, but flexibility can sometimes be incorporated, such as in the installation of wider foundations for flood defenses so that they can be raised later without strengthening the base. The purchase of temporary flood defense barriers can also be seen as a flexible alternative as they can be deployed when and where necessary, as flood risks change. Such no regret measures yield benefits over and above their costs, independent of future changes in flood risk. Further examples here are forecasting and early warning systems which are not sensitive to future flood risk and are relatively low in cost to set up; improved solid waste management systems which have many benefits for environmental health regardless of flood risk; and environmental measures that have amenity value.

Identifying which institutional arrangements are most effective in the delivery of urban flood risk management measures is also fundamental to success. Countries – and cities – with well-performing institutions are better able to prevent disasters. Nevertheless, there is often lack of suitable institutional arrangements and lack of a suitable policy framework to encourage integrated and coordinated urban flood risk management. This mismatch between the governance of official disaster management mechanisms and what is actually needed for implementing integrated flood risk management is a major constraint to effect change. Where the role of institutions is not well established or clear, reforms are required so that institutions complement each other and complement existing systems to create efficiency in delivery of measures and faster uptake. Informal institutions and social networks also have a crucial role to play. Valuable lessons can be drawn from grassroots experiences of dealing with flooding at the household and community level.

Integrated urban flood risk management is a multi-disciplinary and multi-sectoral intervention that falls under the responsibility of diverse government and non-government bodies. Flood risk management measures need to be comprehensive, locally specific, integrated, and balanced across all involved sectors. Due to spatial proximity, local authorities are able to make well-informed decisions. Nevertheless, wider supportive political and organizational underpinnings are vital to ensure the success of integrated flood risk management.

Under the pressure of rapid urbanization, urban governance and decision-making often fall short of what is needed to adequately respond to the challenge of flooding. Enforcement of standards and regulations is often incomplete or even absent. Regulatory frameworks often demand unrealistic minimum standards while at the same time there is lack of adequate mechanisms for the enforcement of regulations. Funding is often limited too.

It is vital, then, to link urban flood risk management with poverty reduction and climate change adaptation initiatives, and with more specific issues of urban planning and management, such as housing provision, land tenure, urban infrastructure delivery and basic service provision. Robust solutions can contribute to flood risk reduction, while at the same time create opportunities to promote better and more sustainable and resilient urban development.

Figure 11 in the next page illustrates the process for Integrated Urban Flood Risk Management. It covers five steps from understanding flood hazard and identifying the most appropriate measures, to planning, implementing and finally evaluating the strategy and its measures.

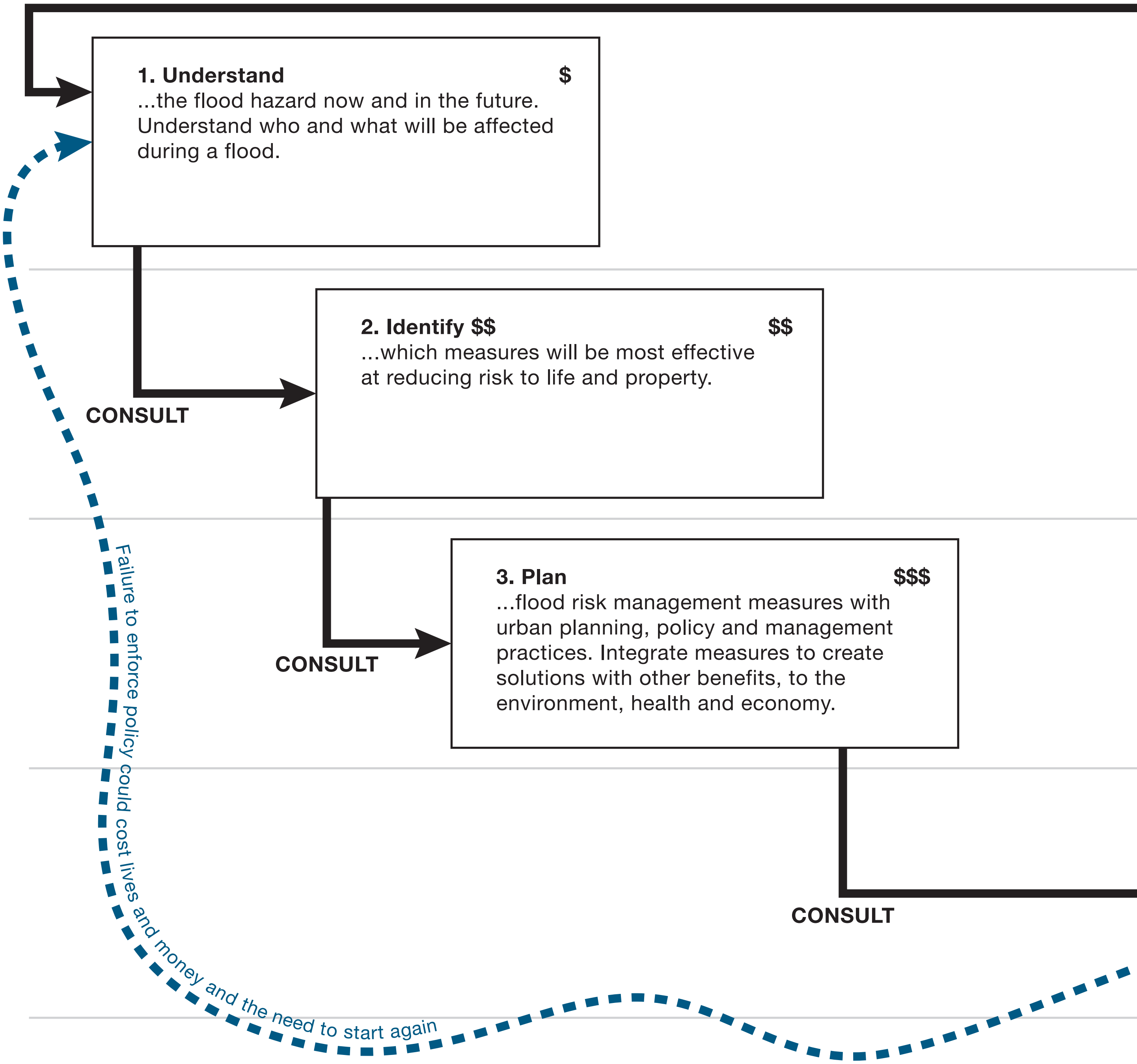

Figure 11: The five stages of integrated flood risk management.
Source: GHK Consulting and Baca Architects

IMPROVE: seek to reduce risk, raise awareness and improve implementation

Stage 1: Understanding the hazard is essential in designing measures and solutions which can prevent or limit damage from specific types of flood.

Stage 2: An integrated flood risk management approach is a combination of flood risk management measures which, taken as a whole, can successfully reduce urban flood risk.

Stage 3: Urban flood risk management requires the development of a comprehensive long-term integrated strategy which can be linked to existing urban planning and management policy and practices.

4. Finance & Implement **$$$$**
...measures to reduce risk.
Prioritize ‘no regrets’ measures and easy wins.

Stage 4: Integrated urban flood risk management is a multi-disciplinary and multi-sectoral intervention that falls under the responsibility of diverse government and non-government bodies.

CONSULT

5. Evaluate **$**
...how effectively the measures are working and what could be changed in the future.

Stage 5: Evaluation is important in improving the design and implementation of flood risk management measures, both structural and non-structural.

Twelve key principles for integrated urban flood risk management

1. Every flood risk scenario is different: there is no flood management blueprint.

Understanding the type, source and probability of flooding, the exposed assets and their vulnerability are all essential if the appropriate urban flood risk management measures are to be identified. The suitability of measures to context and conditions is crucial: a flood barrier in the wrong place can make flooding worse by stopping rainfall from draining into the river or by pushing water to more vulnerable areas downstream, and early warning systems can have limited impact on reducing the risk from flash flooding.

2. Designs for flood management must be able to cope with a changing and uncertain future.

The impact of urbanization on flood management is currently and will continue to be significant. But it will not be wholly predictable into the future. In addition, in the present day and into the longer term, even the best flood models and climate predictions result in a large measure of uncertainty. This is because the future climate is dependent on the actions of unpredictable humans on the climate – and because the climate is approaching scenarios never before seen. Flood risk managers need therefore to consider measures that are robust to uncertainty and to different flooding scenarios under conditions of climate change.

3. Rapid urbanization requires the integration of flood risk management into regular urban planning and governance.

Urban planning and management which integrates flood risk management is a key requirement, incorporating land use, shelter, infrastructure and services. The rapid expansion of urban built up areas also provides an opportunity to develop new settlements that incorporate integrated flood management at the outset. Adequate operation and maintenance of flood management assets is also an urban management issue.

4. An integrated strategy requires the use of both structural and non-structural measures and good metrics for "getting the balance right".

The two types of measure should not be thought of as distinct from each other. Rather, they are complementary. Each measure makes a contribution to flood risk reduction but the most effective strategies will usually combine several measures – which may be of both types. It is important to identify different ways to reduce risk in order to select those that best meet the desired objectives now – and in the future.

5. Heavily engineered structural measures can transfer risk upstream and downstream.

Well-designed structural measures can be highly effective when used appropriately. However, they characteristically reduce flood risk in one location while increasing it in another. Urban flood managers have to consider whether or not such measures are in the interests of the wider catchment area.

6. It is impossible to entirely eliminate the risk from flooding.

Hard-engineered measures are designed to defend to a pre-determined level. They may fail. Other non-structural measures are usually designed to minimize rather than prevent risk. There will always remain a residual risk which should be planned for. Measures should also be designed to fail gracefully rather than, if they do fail, causing more damage than would have occurred without the measure.

7. Many flood management measures have multiple co-benefits over and above their flood management role.

The linkages between flood management, urban design, planning and management, and climate change initiatives are beneficial. For example, the greening of urban spaces has amenity value, enhances biodiversity, protects against urban heat island and can provide fire breaks, urban food production and evacuation space. Improved waste management has health benefits as well as maintaining drainage system capacity and reducing flood risk.

8. It is important to consider the wider social and ecological consequences of flood management spending.

While costs and benefits can be defined in purely economic terms, decisions are rarely based on economics alone. Some social and ecological consequences such as loss of community cohesion and biodiversity are not readily measureable in economic terms. Qualitative judgments must therefore be made by city managers, communities at risk, urban planners and flood risk professionals on these broader issues.

9. Clarity of responsibility for constructing and running flood risk programs is critical.

Integrated urban flood risk management is often set within and can fall between the dynamics and differing incentives of decision-making at national, regional, municipal and community levels. Empowerment and mutual ownership of the flood problem by relevant bodies and individuals will lead to positive actions to reduce risk.

10. Implementing flood risk management measures requires multi-stakeholder cooperation.

Effective engagement with the people at risk at all stages is a key success factor. Engagement increases compliance, generates increased capacity and reduces conflict. This needs to be combined with strong, decisive leadership and commitment from national and local governments.

11. Continuous communication to raise awareness and reinforce preparedness is necessary.

Ongoing communication counters the tendency of people to forget about flood risk. Even a major disaster has a half-life of memory of less than two generations and other more immediate threats often seem more urgent. Less severe events can be forgotten in less than three years.

12. Plan to recover quickly after flooding and use the recovery to build capacity.

As flood events will continue to devastate communities despite the best flood risk management practices, it is important to plan for a speedy recovery. This includes planning for the right human and financial resources to be available. The best recovery plans use the opportunity of reconstruction to build safer and stronger communities which have the capacity to withstand flooding better in the future.

A woman surveys the flooded suburb of Rocklea from the Ipswich Highway in Brisbane, Australia (2011). Source: Gideon Mendel

Chapter 1

Understanding Flood Hazard

Chapter 1. Understanding Flood Hazard

1.1. Introduction

Chapter Summary

This chapter addresses some of the most fundamental questions asked by those who need to understand the flood risk faced by their cities and towns:

Where is the flooding coming from? How severe is it? How frequent will the flooding be? Is it going to be much worse in the future?

The key messages from this Chapter are:

- Understanding the type and source of flooding are both essential if the appropriate flood risk reduction measures are to be identified.
- The tools and models used to assess and forecast flood hazard are invaluable in planning and operationalizing flood risk reduction measures.
- Even the best flood models and climate predictions result in a large measure of uncertainty. Flood risk managers must therefore consider measures that are robust to uncertainty and to different flooding scenarios.

A flood is defined by the Oxford English Dictionary as "An overflowing or irruption of a great body of water over land in a built up area not usually submerged." Floods are natural phenomena, but they become a cause for serious concern when they exceed the coping capacities of affected communities, damaging lives and property. Globally, floods are the most frequently occurring destructive natural events, affecting both rural and urban settlements. Urbanization has become the defining feature of the world's demographic growth, with the populations of cities, towns and villages swelling, particularly in developing countries. As a result, floods are affecting – and devastating – more urban areas, where unplanned development in floodplains, ageing drainage infrastructures, increased paving and other impermeable surfaces, and a lack of flood risk reduction activities all contribute to the impacts experienced. These problems are compounded by the effects of a changing climate.

In terms of disaster management, it is necessary to understand flood hazards during flood emergencies, as well as before an event actually takes place, in order to allow for mitigation, preparation and damage reduction activities. The management of flood risk requires knowledge of the types and causes of flooding. This understanding is essential in designing measures and solutions which can prevent or limit damage from specific types of flood. Equally important is the knowledge of where and how often flood events are likely to occur. This is a critical step in understanding the necessity, urgency and priority for flood risk mitigation.

Understanding flood hazard requires knowledge of the different types of flooding, their probabilities of occurrence, how they can be modeled and mapped, what the required data are for producing hazard maps and the possible data sources for these. A detailed understanding of the flood hazard relevant to different localities is also crucial in implementing appropriate flood risk reduction measures such as development planning, forecasting, and early warning systems.

As flood risk evolves over time it also becomes relevant to explore how these decisions will need to change in the light of anticipated climate changes. Information about the existing models used to account for climate change at different scales and the uncertainties regarding those results are both important issues which need to be accommodated in any decision making process.

Sections 1.2 and 1.3 describe the different types and sources of flooding, and their frequency and probability. Ways of quantifying, assessing and forecasting the flood hazard are then highlighted in Section 1.4 and 1.5. Finally, in Section 1.6 the issue of dealing with changing flood hazard in the expectation of climate change is discussed. The chapter concludes with technical annexes, which signpost further technical resources which can assist decision makers and practitioners in accessing the expertise to develop appropriate flood models.

1.2. Types and causes of flooding

Floods usually result from a combination of meteorological and hydrological extremes, such as extreme precipitation and flows. However they can also occur as a result of human activities: flooding of property and land can be a result of unplanned growth and development in floodplains, or from the breach of a dam or the overtopping of an embankment that fails to protect planned developments. In many regions of the world, people moving from rural areas to cities, or within cities, often settle in areas that are highly exposed to flooding. A lack of flood defense mechanisms can make them highly vulnerable. Land use changes can also increase the risk of flooding: urban development that reduces the permeability of soils increases surface runoff. In many cases this overloads drainage systems that were not designed to cope with augmented flows.

Descriptions and categorizations of floods vary and are based on a combination of sources, causes and impacts. Based on such combinations, floods can be generally characterized into river (or fluvial) floods, pluvial (or overland) floods, coastal floods, groundwater floods or the failure of artificial water systems. Based on the speed of onset of flooding, floods are often described as flash floods, urban floods, semi-permanent floods, and slow rise floods.

All the above-mentioned floods can have severe impacts on urban areas – and thus be categorized as urban floods. It is important to understand both the cause and speed of onset of each type to understand their possible effects on urban areas and how to mitigate their impacts. Table 1.1 summarizes the type and causes of flooding and they are further described below.

Table 1.1: Types and causes of floods

Types of flooding	Causes		Onset time	Duration
	Naturally occurring	Human induced		
Urban flood	Fluvial Coastal Flash Pluvial Groundwater	Saturation of drainage and sewage capacity Lack of permeability due to increased concretization Faulty drainage system and lack of management	Varies depending on the cause	From few hours to days
Pluvial and overland flood	Convective thunderstorms, severe rainfall, breakage of ice jam, glacial lake burst, earthquakes resulting in landslides	Land used changes, urbanization. Increase in surface runoff	Varies	Varies depending upon prior conditions

Coastal (Tsunami, storm surge)	Earthquakes Submarine volcanic eruptions Subsidence, Coastal erosion	Development of coastal zones Destruction of coastal natural flora (e.g., mangrove)	Varies but usually fairly rapid	Usually a short time however sometimes takes a long time to recede
Groundwater	High water table level combined with heavy rainfall Embedded effect	Development in low-lying areas; interference with natural aquifers	Usually slow	Longer duration
Flash flood	Can be caused by river, pluvial or coastal systems; convective thunderstorms; GLOFs	Catastrophic failure of water retaining structures Inadequate drainage infrastructure	Rapid	Usually short often just a few hours
Semi-permanent flooding	Sea level rise, land subsidence	Drainage overload, failure of systems, inappropriate urban development, Poor groundwater management	Usually slow	Long duration or permanent

1.2.1. Urban flooding

Urban floods are a growing issue of concern for both developed and developing nations. They cause damage to buildings, utility works, housing, household assets, income losses in industries and trade, loss of employment to daily earners or temporary workers, and interruption to transport systems. The damage caused by urban floods is on the rise. It is therefore important to understand the causes of and impacts different types of flooding have on urban areas.

Urban floods typically stem from a complex combination of causes. The urban environment is subject to the same natural forces as the natural environment and the presence of urban settlements exacerbates the problem. Urban areas can be flooded by rivers, coastal floods, pluvial and groundwater floods and artificial system failures, all of which are discussed in detail below. In cities and towns, areas of open soil that can be used for water storage are very limited.

All precipitation and other flows have to be carried away as surface water or through drainage systems, which are usually artificial and constrained by the competing demands on urban land. High intensity rainfall can cause flooding when drainage systems do not have the necessary capacity to cope with flows. Sometimes the water enters the sewage system in one place and resurfaces in others. This type of flood occurs fairly often in Europe, for instance the floods that affected parts of England in the summer of 2007.

In other places, such as Mexico City, constant urban expansion has reduced the permeability of the soil in groundwater recharge areas. This factor, combined with significant land subsidence due to over-exploitation of groundwater during the last century, has increased the risk of flooding. It is now common that floods in low-lying areas consist partially of sewage fluids.

Urban floods are also caused by the effects of deficient or improper land use planning. Many urban areas are facing the challenge of increased urbanization with rising populations and high demands for land. While there are existing laws and regulations to control the construction of new infrastructure and the variety of building types, they are often not enforced properly owing to economic or political factors, or capacity or resource constraints. This leads to obstruction in the natural flow path of water, which causes floods.

Decision makers and city managers may also be influenced by such issues before revealing the actual level of risk applying to an area to the public, which sometimes has much bigger negative impacts on the flood risk situation of the area. Unless there is awareness amongst residents and proper cooperation between decision makers, risk management authorities and the public in the process of flood risk management, it will be very difficult to control the deterioration of the global urban flood risk situation.

1.2.2. River or fluvial floods

River or fluvial floods occur when the surface water runoff exceeds the capacity of natural or artificial channels to accommodate the flow. The excess water overflows the banks of the watercourse and spills out into adjacent, low-lying floodplain areas.

Typically, a river such as the Mississippi in the United States or the Nile in North Africa floods some portion of its floodplains. It may inundate a larger area of its floodplains less frequently, for instance once in twenty years, and reaches a significant depth only once in one hundred years on average. The flow in the watercourse and the elevation it reaches depend on natural factors such as the amount and timing of rainfall, as well as human factors such as the presence of confining embankments (also known as levees or dikes).

River floods can be slow, for example due to sustained rainfall, or fast, for instance as a result of rapid snowmelt. Floods can be caused by heavy rains from monsoons, hurricanes or tropical depressions. They can also be related to drainage obstructions due to landslides, ice or debris that can cause floods upstream from the obstruction. Case Study 1.1 examines how severe flooding in China is caused by the Yangtze River.

Case Study 1.1: Floods in Southern China

In Southern China tropical air masses and cyclones of tropical origin accompanied by heavy precipitation influence the regional climate. In 1931 torrential rain caused the greatest flood since the beginning of hydrological observations in the Yangtze River, affecting 60 million people. In 1998 another large flood killed more than 4,000 people and caused economic losses estimated at US$25 billion.

The Yangtze River Basin is now host to more than 400 million people, and includes large urban areas like the cities of Wuhan, Changsha and Nanchang. Forty percent of China's gross domestic product is generated in the area. The increased frequency of flooding in the region has been attributed primarily to the reclamation of floodplains for agriculture, forcing flood waters into smaller areas and increasing the flood peak, and to increased erosion in the watershed leading to silting up of the central Yangtze lakes and floodplain areas that could otherwise retain flood waters and slowly release flow peaks.

In response to the 1998 flood event, the Chinese government decided to take action to reduce flood risk in the region. Instead of implementing conventional hard engineering measures to control floods in the Yangtze River, the Government adopted a new approach that includes restoration of 14,000 km2 of natural wetlands by 2030.

Floodplain restoration is a flexible, no regret approach that will be cost- effective regardless of changes in future flood risk.

Source: Pittock and Xu 2011.

1.2.3. Pluvial or overland floods

Pluvial floods also known as overland floods are caused by rainfall or snowmelt that is not absorbed into the land and flows over land and through urban areas before it reaches drainage systems or watercourses. This kind of flooding often occurs in urban areas as the lack of permeability of the land surface means that rainfall cannot be absorbed rapidly enough, flooding results. Pluvial floods are often caused by localized summer storms or by weather conditions related to unusually large low pressure areas. Characteristically, the rain overwhelms the drainage systems, where they exist, and flows over land towards lower-lying areas. These types of floods can affect a large area for a prolonged period of time: the 2007 floods in the Hull area in the UK were the result of prolonged rainfall onto previously saturated terrain which overwhelmed the drainage system and caused overland flooding in areas of the city outside the fluvial floodplain. Pluvial floods may also occur regularly in some urban areas, particularly in tropical climates, draining away quickly but happening very frequently, even daily, during the rainy season.

1.2.4. Coastal floods

Coastal floods arise from incursion by the ocean or by sea water. They differ from cyclic high tides in that they result from an unexpected relative increase in sea level caused by storms or a tsunami (sometimes referred to as a tidal wave) caused by seismic activities.

In the case of a storm or hurricane, a combination of strong winds that causes the surface water to pile up and the suction effects of low pressure inside the storm, creates a dome of water. If this approaches a coastal area, the dome may be forced towards the land; the increasing sea floor level typically found in inshore waters causes the body of water to rise, creating a wave that inundates the coastal zones. The storm surge usually causes the sea level to rise for a relatively short period of time of four to eight hours, but in some areas it might take much longer to recede to pre-storm levels.

Coastal floods caused by tsunamis are less frequent than storm surges, but can also cause huge losses in low-lying coastal areas. The 2004 Indian Ocean Tsunami was caused by one of the strongest earthquakes ever recorded and affected the coasts around the ocean rim, killing hundreds of thousands of people in fourteen countries.

1.2.5. Groundwater floods

Water levels under the ground rise during the winter or rainy season and fall again during the summer or dry season. Groundwater flooding occurs when the water table level of the underlying aquifer in a particular zone rises until it reaches the surface level. This tends to occur after long periods of sustained high rainfall, when rising water levels may cause flooding in normally dry land, as well as reactivate flows in bourns, which are streams that only flow for part of the year. This can become a problem, especially during the rainy season when these non-perennial streams join the perennial watercourses. This can result in an overwhelming quantity of water within an urban area. Groundwater flooding is more likely to occur in low-lying areas underlain by permeable rocks; where such an area has been developed, the effect of groundwater flooding can be very costly.

Groundwater flooding can also occur when an aquifer previously used for water supply ceases to be used; if less water is being pumped out from beneath a developed area the water table will rise in response. An example of this occurred in Buenos Aires, when pollution of groundwater led to a cessation of pumping. Drinking water was imported instead. The resulting water table rise caused flooded basements and sewage surcharge, which is a greater volume of combined water and sewage than the system is designed to convey (Foster 2002).

Since groundwater usually responds slowly compared to rivers, groundwater flooding might take weeks or months to dissipate. It is also more difficult to prevent than surface flooding, though in some areas water pumps can be installed to lower the water table. Flooding can also therefore occur in the event of the failure of pumping systems and may underlie the phenomenon of semi-permanent flooding, discussed below in 1.2.8.

In many cases groundwater and surface flooding are difficult to distinguish. Increased infiltration and a rise in the water table may result in more water flowing into rivers which in turn are more likely to overtop their banks. A rise in the water table during periods of higher than normal rainfall may also mean that land drainage networks, such as storm sewers, cannot function properly if groundwater is able to flow into them underground. Surface water cannot then escape and this causes flooding.

1.2.6. Failure of artificial systems

As mentioned above, human-made systems which contain water have the potential to fail, and the resulting escape of water can cause flooding. Examples of this include burst water mains or drainage pipes, as well as failures of pumping systems, dams or breaches in flood defenses. This type of flooding is not only confined to locations usually considered at risk of flooding, although low-lying areas and areas behind engineered defenses are at greater risk. Often the onset will be rapid, as failure of a system will lead to an escape of water at high pressure and velocity: dam failure, for example, may be devastating as the volume and speed of water is typically large. Failure of embankments, levees or dikes also has the potential to cause devastating floods, which may persist for a long time where the water has few escape routes. Between April and October of 1993 a large flood affected the US Midwest along the Mississippi and Missouri rivers and their tributaries. Many levees had been constructed along these rivers to protect residential areas and agricultural land, but many of these failed, contributing to widespread flooding. Fifty lives were lost and the economic damages were estimated to be US$15 billion (Larson 1993).

1.2.7. Flash floods

The US National Oceanic and Atmospheric Administration (NOAA) defines a flash flood as one whose peak appears within six hours from the onset of a torrential rainfall. Flash floods can be caused by local convective thunderstorms, or by the sudden release from an upstream impoundment created behind a dam, landslide, glacier or ice-jam. Factors that contribute to this type of flooding are, in addition to rainfall intensity and duration, surface conditions and the topography and slope of the receiving basin. For instance, in areas with steep slopes, heavy rain collected on the slopes can end up in a river bed that originally held very little or no water at first. The water level increases rapidly in the river and finally floods the area.

Urban areas are notably susceptible to flash floods because a high percentage of their surfaces are composed of impervious streets, roofs, and car parking areas where runoff occurs very rapidly

Flash floods can be particularly dangerous because they occur suddenly and are difficult, if not impossible, to forecast. They typically affect a more localized area compared to other floods, but can still cause serious damage as the water may be travelling at high speed and carrying large amounts of debris, including rocks, trees and cars.

In November 2009, flash flooding affected the city of Jeddah in Saudi Arabia. In four hours, more than 90 mm of rain fell, nearly twice the yearly average and the heaviest rainfall recorded in Saudi Arabia in a decade. More than a hundred lives were taken and business losses were estimated at US$270 million.

Another type of flash flooding is known as a Glacial Lake Outburst Flood (GLOF). Glaciers are very susceptible to rises in temperature, which can cause accelerating melting of glacial ice leading to the formation of lakes. If the material damming or capping the lake is eroded, or otherwise fails, the burst causes floods downstream in the valleys. The damage caused by these floods depends on factors such as the depth of the lake, the nature of the outburst, the geomorphology of the river valleys and the characteristics of the elements exposed to the flash flood. This type of flood is a particular hazard in Nepal and Hindu-Kush Himalaya region where for instance, 24 GLOF events have been documented. One of them, caused by the outburst of the Dig Tsho Glacial Lake in 1985, resulted in major financial losses and damage to infrastructure, including a nearly completed hydroelectric power plant located 11km from the breach, caused damage for tens of kilometers downstream, and resulted in the loss of five lives (ICIMOD 2011; Matambo 2011).

1.2.8. Semi-permanent flooding

In some cases urban settlements are built on land which is flooded regularly and for long periods of time. Often these areas may lie below sea level or where the water table is close to the surface. This is usually the case where settlements are informal, unplanned and built on less expensive land due to rapid urban expansion and the poverty of the inhabitants. A typical scene of flooding is illustrated in Photo 1.1.

Photo 1.1: Stagnant water seven months after the 2010 floods in Baguida, Lome.
Source: K. Ayeva

Semi-permanent flooding may also occur where settlements are in the vicinity of failed human-made structures awaiting repair. In New Orleans, for instance, following the failure of levees damaged by Hurricane Katrina, some residents remained in homes that were standing in water for over six weeks (Kates et al. 2006). Sea level rise and land subsidence have the potential to create many more such areas in the future.

1.3. The probability of flooding

A sound understanding of the likelihood of occurrence of a flood hazard is a fundamental step in dealing with flood risk. Risk from flooding can be conceptualized into four stages as in Figure 1.1 below:

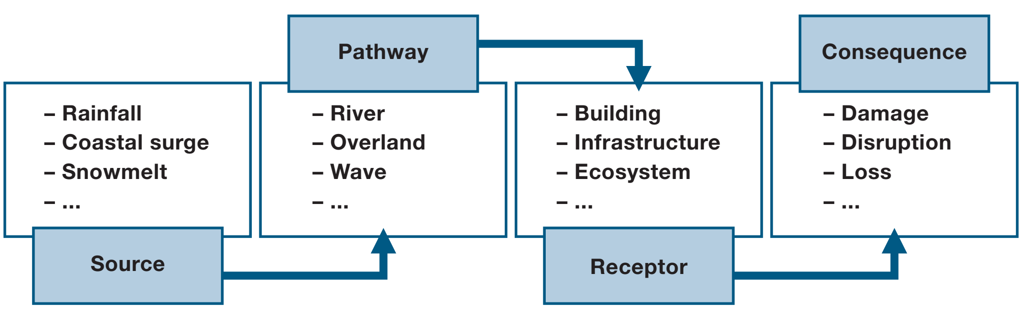

Figure 1.1: The Source, Pathway, Receptor Model

This model breaks down the process of flooding into the identification of a source of the flood water, the pathway which is taken by it, and the receptor of the flooding, which is the human settlement, building, field or other structure or environment that is exposed to the consequences. Flood hazard encompasses the first two of these steps, the source of flood water and the pathway by which it has the potential to damage any receptors in its path. To fully evaluate risk, the degree of exposure and the nature of exposed receptors and their potential to sustain or resist damage also need to be considered. This section deals only with the hazard, focusing on its nature, source and pathway, together with the probability of an event.

Probability in itself can be a difficult concept to translate from the purely scientific generation of hydro-meteorological models into a description of hazard that lay people can comprehend and decision makers can use to evaluate their real options. This section explains different methods of calculating the probability of occurrence of flooding and clarifies some of the concepts of hazard and their communication.

It is important to distinguish between the probability of occurrence of a weather event and the probability of occurrence of a flood event. Flooding is primarily driven by weather events which are hard to predict due to what is termed their chaotic nature. In other words, despite the great advances in weather forecasting, it cannot be determined with certainty when and where rain will fall or storms will form. This means that it is impossible to know exactly when and where a flood will occur in the future, nor how high (either in water level or discharge) the next flood will be. Hazard predictions are commonly given in terms of probabilities, computed using historical data for the area of interest.

This section now describes the use of frequency analysis and hydrological modeling in the estimation of flood probability, through to providing and communicating flood hazard forecasts.

1.3.1. The probability of occurrence of floods

Flood forecasts for a natural drainage area or a city are usually obtained by analyzing the past occurrence of flooding events, determining their recurrence intervals, and then using this information to extrapolate to future probabilities. This common approach is described below in simplified form for fluvial flooding.

The probability of occurrence for pluvial, groundwater, flash, and semi-permanent floods is much more difficult to estimate, even if historical data is available. This is due to the fact that the causes of these types of floods are, as seen above, a combination of a meteorological event such as heavy rainfall and other factors such as insufficient drainage capacity, mismanagement of key infrastructure and other human factors.

In the case of coastal floods caused by seismic activities, predicting their probability is as difficult as predicting the occurrence of an earthquake. For coastal floods caused by storms or hurricanes, their probability of occurrence can, in principle, be computed using historical data or numerical simulations of key variables such as wind speed, sea level, river flow and rainfall.

1.3.1.1. Recurrence interval

The recurrence interval or return period is defined as the average time between events of a given magnitude assuming that different events are random. The recurrence interval or return period of floods of different heights varies from catchment to catchment, depending on various factors such as the climate of the region, the width of the floodplain and the size of the channel. In a dry climate the recurrence interval of a three meter height flood might be much longer than in a region that gets regular heavy rainfall. Therefore the recurrence interval is specific to a particular river catchment.

Since only the annual maximum discharge is considered, the amount of data available to perform the return period calculation can be very limited in some cases. In Europe and Asia, partial records extending over centuries may be found, as for instance in the case of sea floods in the Netherlands. In other places, data may be scarce and records are rarely longer than for 50 years. This poses an important limitation to the calculation of recurrence intervals which must be taken into account when evaluating and communicating uncertainties in flood probability estimations.

Once the recurrence intervals are determined based on the historical record, some assumption about the flood frequency distribution has to be made in order to extrapolate or interpolate to events that have not been recorded historically. To achieve this, an assumption about the distribution of flood frequency has to be made. In this way the recurrence interval for any discharge (and not just those present in the observational record) can be inferred.

1.3.1.2. Flood probability

The recurrence interval, as discussed above, refers to the past occurrence of floods, whilst flood probability refers to the future likelihood of events. The two concepts are related because the recurrence interval of past events is usually used to estimate the probability of occurrence of a future event:

For any discharge, or alternatively, any recurrence period, the probability of occurrence is the inverse of the return period p=1/T

Using the relationship between return period T and flood probability p, it is clear that a flood discharge that has a 100-year recurrence interval has a one percent chance of occurring (or being exceeded) in a given year. The term 'one hundred year flood' has often been used in relation to floods with a 100-year recurrence interval (Defra 2010; Dinicola 1996). This can be misunderstood, as a 100-year flood does not have a 100 percent chance of occurring within a 100 year period. The probability of a 100-year flood not occurring in any of the next 100 years is 0.99100=0.366. Therefore the probability of one of these floods occurring is 0.636, closer to two-thirds.

1.3.1.3. Discharge, stage and inundation

In the case of fluvial floods, measures which are commonly used to describe the severity of a flood are discharge, stage, and crest (or peak). Discharge (or flow) is the volume of water that passes through a given channel cross-section per unit time (usually measured in cubic meters per second). Stage is the level of the surface of the water (usually expressed as height above a reference level, often the sea level). As discharge increases, stage increases, but this relationship is not linear and is specific to each river and catchment. The crest or peak is the highest stage reached during a flood event. Stage as used in this context is different from "flood stage," a term sometimes used to describe when over bank flows are of sufficient magnitude to cause considerable inundation of land, roads or significantly threaten life and property.

The relationship between discharge and stage at a particular location is empirical and usually represented graphically by a rating curve which is obtained using observed data for both parameters. These curves are at best approximations because the relationship between discharge and stage is non-linear; interpolation of discharges that have been not been observed cannot, therefore, be accurately inferred. There may also be significant scatter in the data, and it also should be noted that rating curves can change over time, due to both natural and human-induced changes in the geomorphology of the watercourse.

Once stage is known, the next step is to determine the corresponding inundation area. This is not straightforward: a flood that raises the water level by two meters in a steep canyon might not have a significant impact, while on a broad floodplain the water could cover a great area. The potential for damage caused by a flood, therefore, depends not only on the discharge and stage, but also on the local topography. To establish the inundation area corresponding to a given stage, a topographic map is necessary, allowing the flood probability for any given discharge to be illustrated by means of an inundation map for the corresponding stage.

Often, even for fluvial flooding, the combined effects of river flow with one or more additional factors such as tide, surge, rainfall and possibly waves might be needed to determine the overall river water level, and the resulting likelihood of out-of-bank flow and flooding.

In coastal engineering, the combined effects of sea level and waves determine the overall loads on coastal structures, and consequent likelihood of damage or severe overtopping and flooding. In urban drainage of coastal towns, the combined effects of sea level and high intensity rainfall are of interest in determining the probability of tide-locking of drains. In cases where the probability of flooding depends on two or more variables, these probabilities need to be jointly estimated.

1.3.2. Uncertainties in flood probability estimations

The approach described above to compute probability of flooding is based on a series of assumptions that are questionable in most practical cases. These assumptions are as follows (Klemeš 1993, 2000):

- A long and high quality observational record is available
- There is no serial correlation between flood events
- The physical system is stationary (i.e., not subject to changes) and, as a result, the observational record is a representative sample of all possible flood events
- The frequency distributions built from the historical time series represent instantaneous probability distributions at any point in time.

It is important for decision makers to understand that these assumptions exist.

The impact they may have on the robustness of flood predictions if the scale of uncertainty would lead to changes in the most effective flood mitigation measures is also of significance. The impacts of two of the above assumptions, quality of data and of the so-called stationarity of the system, are now examined in more detail.

1.3.2.1. Quality of historic record

The value of inference based on historic observations is naturally dependent on the availability and quality of data. If they are to provide useful statistics, hydrological data must be accurate, representative (representing the range of possible values occurring over time), homogeneous (measuring the same quantities over time) and of sufficient length. Data rarely meet these specifications: the magnitude of a particular return period event on a river may change following the observation of a significant flood event, or an improvement in the quality of the data available. For example, if measured flows change by a small amount, due to improvements in measurement techniques, the recurrence interval for a particular value of the discharge, or the magnitude of the event for a particular return period, can change significantly. Similarly, the recurrence interval will be sensitive to the incorporation of any new data (Dinicola 1996).

The use of historical events should take into account the causes of the flood. Estimates generated from one type of event cannot warn of the possibility of other possibly rarer flood type. For example in Eastern Canada most annual maximum discharges are generated by snowmelt, but there is the possibility of a hurricane striking and causing a much larger flood than conceivable via the snowmelt mechanism alone (Klemeš 1989). It is also important to recognize that the extrapolation from historical records, (in many cases less than 50 years duration) to the 1,000 or 10,000 year event will be beset with problems. The prediction of such high impact but low probability events is critical for the design of facilities such as toxic waste dumpsites or nuclear power plants. Making judgments of this nature using a best fit probability distribution may lead to absurdities, as the conditions under which a flood of the corresponding magnitude could occur are physically impossible. Moreover, the same probability distribution can be a best fit for historical records coming from two different climatic regions: one dominated by snowmelt flows and the other by convective storms. There is no good reason to assume that a 1,000 year flood, for instance, will be of similar magnitude in both cases, even though that will be the mathematical prediction. Without an analysis of the physical causes of recorded floods, and of the whole geophysical, biophysical and anthropogenic context that determines the potential for flood formation, predictions based solely on the fitting of a probability distribution, may under-estimate or over-estimate the flood hazard (Klemeš 1989, 1993, 2000).

1.3.2.2. Assumption of stationarity

The greatest source of uncertainty in the estimation of future urban flood probabilities is the assumption of stationarity: that the occurrence and recurrence intervals of floods in the observed past are assumed to represent occurrence in the future, thus permitting extrapolation. This assumption presupposes that the system is stationary, and that the observed record provides an exhaustive sampling of all possible events. That is clearly invalid if, for instance, drainage basins are changed by human activities and other events, or if rainfall patterns are affected by local or global climate variations (Klemeš 1989, 1993, 2000).

Two potential major sources of non-stationarity with regard to urban flooding are the rapid development of floodplains as urbanization proceeds, and the changes in weather patterns associated with climate change. There are other changes which can change flood probabilities such as the effects of mitigation measures. An example is the completion of the Howard Hanson Dam on the Green River in Washington State in the US in the 1960s which reduced the magnitude of the 1 in 100 year flood some 30 kilometers downstream at Auburn, Washington, by nearly a half (Dinicola 1996). Major flood events can also change the physical conditions for future flooding, as they may alter the flow or cross-section of rivers.

In summary, these limitations suggest that flood probabilities for short-term projections of events of similar magnitude to those previously observed are more robust in catchments with long historical records. Extrapolation beyond and outside the historical record should be approached with great caution, particularly where a changing climate may make a significant difference to the pattern and frequency of future events. In such cases, the use of flood probabilities to estimate flood hazard should be carried out with a full understanding of the uncertainties involved. The optimal approach to flood management incorporates adaptations that are robust (meaning insensitive) to these uncertainties as a way forward.

1.4. Flood hazard assessment

The concept of hazard is defined as the potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (UNISDR 2004).

Hazard events have a probability of occurrence within a specified period within a given area and have a given intensity. Studies related to analysis of physical aspects and phenomena through the collection of historical or near real time records are called hazard assessment. For a better understanding of the nature of flooding, three main aspects are taken into consideration: the probability of occurrence, the magnitude and intensity of occurrence and the expected time of next future occurrence (ADPC 2002). Hazard assessment and hazard maps, as distinct from risk maps, are now considered. Risk maps are discussed in Chapter 2 in Section 2.4 after discussion of the receptors affected by and the consequences of flooding.

Flood hazard maps are important tools for understanding the hazard situation in an area. Hazard maps are important for planning development activities in an area and can be used as supplementary decision making tools. They should therefore be easy to interpret: the aim should be the generation of simple hazard maps which can be read and understood by both technical and non-technical individuals. There is, therefore, a need to generate maps based on user-specific requirements, whether for individual or institutional purposes. Flood hazard maps are characterized by type of flooding, depth, velocity and extent of water flow, and direction of flooding. They can be prepared based on specified flood frequencies or return periods, for example, 1:10 years, 1:25 years, 1:100 years, or to more extreme events such as the 1:1000 year return period for different scales.

1.4.1. Probability of flood into hazard estimation

Flood hazard is determined by the conjunction of climatic and non-climatic factors that can potentially cause a flood: the magnitude of a fluvial flood will depend on physical factors such as intensity, volume and timing of precipitation. The antecedent conditions of the river and its drainage basin (such as the presence of snow and ice, soil type and whether this is saturated or unsaturated) will also have an impact on the development of the event, as will human-made factors such as the existence of dykes, dams and reservoirs, or the loss of permeability caused by urban expansion into floodplains.

Flood hazard is usually estimated in terms of a rainfall event or 'design flood' such as the 100 year flood discussed above. The estimation of flood probability or hazard combines statistics, climatology, meteorology, hydrology, hydraulic engineering, and geography. The standard approach described in Section 1.3.1 assumes that the flow data is sufficient to compute the design flood using statistical methods. In places where these data are not available because there are no gauges, or are of poor quality, other approaches are used. Data from a neighboring watercourse may be interpolated to the site of interest, or, if precipitation data are available, a design rainfall event can be computed, and a rainfall-runoff model used to estimate river flow. This is then fed into a hydraulic model that computes the depth and extent of the resulting flood. Finally, this information is combined with topographic, infrastructure, population and other geographic data in order to compute the flood hazard. Table 1.2 below illustrates the range of model types used; the 'generation' denotes the level of sophistication inherent in the model, progressing from 'first generation' models including a number of simplified assumptions, through to the more advanced generations with fewer simplifying assumptions.

Table 1.2 Types of flood models

Type of models	Useful in areas	Advantages	Disadvantages
First Generation with 2DH grid	Good for estimation of duration of flood, volume propagation, Useful in compact channels	Low to medium cost, simple calculation, low runtime (minutes to hours)	Does not give good results for vast areas or vast floodplains
Second generation 1D/2D and 2D and Finite element models	Good for broad scale modeling, urban inundation ,useful for compound channels	Medium to high cost, accuracy and run time (hours to days), , can get outputs like percolation and seepage other than depth, velocity and volume	Broad scale application requires coarse grid otherwise the computational time becomes immense, high data demand

Third generation models	Good for showing breaching in 3D and flood propagation in 2D, useful for local predictions	High cost, accuracy, computation time (days) , flow velocity and flood boundaries accurately simulated	High run time, high demand for data, high cost
Erosion models Vellinga (1986)	Predicts final erosion profile based on wave height and storm surge water level	Can be used in coasts of different morphology	Does not include wave period
Komar et al (1999, 2001)	Predicts maximum erosion during an extreme event	Simplistic model	Does not take into account the storm duration
Sheach Model	Analytical more versatile	Estimation of cross shore transport rate in different shore zones	Demands high level of data, huge dataset
TIMOR3 and SWAN	Process based model, useful for short term	Detailed morpho-dynamic result	Not efficient to calculate initial response

Source: Floodsite Report T03-07-01 2008

1.4.1.1. Communication of flood hazard in the context of integrated flood risk management

The UN International Strategy for Disaster Reduction (UNISDR) states that public awareness is a primary element of risk reduction, and defines a set of basic principles that should underline public awareness campaigns: they should be designed and implemented with a clear understanding of local perspectives and requirements; they should target all sections of society including decision makers, educators, professionals, members of the public and individuals living in exposed areas; messages should be designed in a way that can reach the different target audiences; and special disaster awareness campaigns and events should be used to sustain any efforts (UNISDR 2004).

Traditionally, flood risk management has consisted predominantly of structural measures, such as the construction of retention basins and dykes. The planning and implementation of these types of measures has been, for the most part, the responsibility of governments. The increasingly prominent role of non-structural measures such as early warning systems requires a much greater involvement of the public, including clear communication of flood risks and a dialogue about mitigation options as key elements of any integrated flood risk management plan (Merz 2010). Both types of measure are discussed at length in the following two chapters.

In practice, numerous projects have demonstrated the benefit of involving affected people in flood risk management: in Switzerland, for example, an approach that involves local stakeholders has been developed for municipalities. By means of workshops moderated by risk experts, the knowledge and experiences of local stakeholders (members of authorities and organizations involved in disaster mitigation and disaster management, and people who have been affected by floods) are systematically collected and structured. These are then used to derive representative damage scenarios, to assign probabilities to the scenarios, to establish a risk profile of the community and to discuss response actions. This approach guarantees that local characteristics are taken into account in the management plan, but also triggers a dialogue that improves the understanding and acceptance of the derived safety measures (Merz 2010).

The need for the communication of the large uncertainties present in any flood risk estimate to the wider non-hydrological community presents a challenge. As mentioned previously, the actual meaning in probability terms of the “one-hundred year event” is frequently misunderstood. Instead of a flood with a probability of occurrence of one percent in any given year, it is sometimes assumed to be a flood that can only occur once every 100 years, or one that recurs regularly on a 100 year cycle.

Another source of confusion when communicating flood risks is the fact that two events reported as having the same return period due to re-assessment after the occurrence of the first event can have different magnitudes and consequently affect the same people in different ways. When the uncertainties are very large or poorly understood, owing to a lack of data or process understanding, the communication of risk in terms of flood probabilities and their use in flood management decisions can be misleading. In these cases, focusing the communication exercise on the consequences of flooding might be more appropriate.

1.4.2. Data requirements for flood hazard assessment

Both qualitative and quantitative flood data can be used for either modeling or analysis. Quantitative data can be exemplified by hydro-meteorological data, while qualitative data can include descriptions of the type of areas affected, depth, and velocity. Data can be collected from the local municipality; governmental environment ministries and environmental agencies; weather and meteorological offices (local or regional); reports from the media and document archives; and through Participatory Rural Appraisal (PRA) tools. Hydrological data can be obtained from monitoring stations and gauging stations (where available), as well as satellite imageries (in real time or post-flood scenario) which can be obtained from national or international organizations involved in collection and storing of satellite images (for example the National Aeronautics and Space Administration (NASA), European Space Agency (ESA), and Indian Institute of Remote Sensing (IIRS). Photographs for post-flood analysis can be obtained either from the media or from local authorities.

An example of collaborative data collection is demonstrated by the Manila Typhoon Ondoy flood map. The Manila Observatory developed an interactive map showing the maximum flood depths noted in various locations in the city of Manila, the Philippines. The most important component of this project is that everyone living in the flood-affected areas was requested to collect the flood data and submit it online. The collected data has been used to validate flood simulations and identify future floods in Manila (Manila Observatory 2010). The growing awareness on the damaging impacts of disaster has resulted in a similar platform set up by the National Institute of Geological Studies that allows reporting across the entire country. While these platforms allow citizen's feedback, a weakness of these methods is that the collected data warrant further validation. As with all types of flood hazard mapping, it is important for any data to be updated regularly, since any changes will have impact on the final output.

Major international institutions involved in collection and archiving of disaster data include: the Global Emergency Events Database (EM-DAT) supported by the Centre for Research on Epidemiology of Disaster (CRED); the World Health Organization (WHO); the Nat-Cat SERVICE provided by Munich Re; Relief Web supported by the UN Office for the Coordination of Humanitarian Affairs (UNOCHA); and the Global Disaster Information Network (GDIN). Most of the historical data from the international organizations are freely available, with the exception of real time hydro-meteorological data.

The method of data capture and its quality determines the final products of hazard assessment. Guidelines are provided by the Federal Emergency Management

Agency (FEMA 2003) regarding practical aspects of ground surveys and control points; measurement of hydraulic structures; photogrammetric mapping using aerial photographs and satellite imageries; use of LIDAR (LIght Detection And Ranging) technology; and quality of spatial data sets, which are used as base maps for the production of final risk maps. There are similar guidelines for data capture standards.

The most important element of any hydraulic mapping is the production of a Digital Terrain Model (DTM) which demands accurate elevation data. Techniques like photogrammetry, LIDAR and SAR (Synthetic Aperture Radar) are used along with traditional topographic maps and surveying methods using DGPS (also known in this context as 'ground truthing'). They all have their limitations: data validation in larger areas, feasibility and cost effectiveness can become major issues. Remote sensing based methods are popularly used for generation of high resolution DTMs, but it should be kept in mind that errors resulting from data capture and data accumulation may still affect the accuracy of the final flood hazard maps.

Floodplain topography is another important aspect of flood hazard assessment. Traditionally, topographic and bathymetric data were obtained from land surveying and bathymetric surveying, including technology such as Real Time Kinematic GPS (RTK-GPS) for coastal topographic measurement and underwater surveying. LIDAR technology is becoming increasingly popular for characterization of changing coastal topography worldwide. Techniques like SHOALS (Scanning Hydro-Graphic Operational Airborne LIDAR Survey) are useful in measuring both topography and bathymetry at the same time, thereby reducing the uncertainties in data due to time difference in data capture (Lillycrop et al. 1996). The most common technology for updating bathymetric data is called Multi Beam Eco-Sounder Surveying (MBES).

Areas with limited or no data face particular challenges. Both remote sensing and use of GIS techniques are especially useful solutions. These techniques can also be used in areas where physical accessibility is a problem. Satellite imagery, aerial photographs, and LIDAR technology can generate data in real time and both historical and hazard maps can be generated from them. Un-gauged catchments can be assessed using regional datasets such as flood frequency curves or regional regression equations (WMO 1999).

The cost of data acquisition is always an issue of concern: purchasing expensive data and technologies like LIDAR and SAR must be set against the benefits of obtaining more accurate results for hazard analysis.

Case Study 1.2 discusses the use of data sources and GIS techniques for hazard assessment in Senegal.

Case Study 1.2: Spatial analysis of natural hazards and climate variability risks in the peri-urban areas of Dakar

A pilot study was carried out in 2009 by the World Bank to identify natural risk hazards in the peri-urban areas of Dakar, Senegal. The Dakar Metropolitan Area covers less than one percent of Senegal's national territory, but houses about 50 percent of the country's urban population. Dakar is a low-lying, peninsula-like area with a long coastal line. Flooding, coastal erosion, and sea level rise are causing major disruption in the city. Significant flood events have been reported in this past decade in 2008, 2007, 2003, 2002, and 2000.

Much of the population growth in Dakar takes place in unplanned peri-urban areas, which are particularly vulnerable to natural hazards. Administrative and governance arrangements in the Dakar Metropolitan Area are unclear, further complicating city management. Systematic attention to hazard risk management in peri-urban areas and the strengthening of institutional capacities are necessary to manage hazard risk. One of the objectives of the pilot study was to propose a new methodology for quick assessment of natural hazard risk, utilizing new tools for spatial analysis based on Geographic Information Systems (GIS) data.

Hazard maps were combined with population maps, land price data and land cover information to measure the exposure of different variables with regards to potential flood, coastal erosion and coastal inundation. Spatial analysis also generated statistical results and maps to identify potential hotspot areas, as well as built-up and non-built-up areas exposed to hazard risks.

The study concluded that this approach and methodology can be adapted to other local contexts and needs and can be further developed to:

- Consider a broader range of natural hazards
- Analyze the economic impacts of hazards in more detail
- Consider different relationships between building density and population density depending on whether the area is planned or unplanned
- Add information (via layering) such as major infrastructure (roads, electricity networks, drainage and sanitation systems).

Lastly, this methodology allows for better understanding of flood hazard risk, in particular in peri-urban areas, and enables a better integration of flood risk management with land use planning.

Sources: Wang et al. 2009; GLIDE Disaster Data.

1.4.3. How to prepare a flood hazard map (Riverine)

Production of hazard maps is the first step towards flood risk assessment. Their purpose is to better understand and communicate flood extent and flood characteristics such as water depths and velocity. Multiple stakeholders such as city managers, urban planners, emergency responders and the community at risk can use hazard maps in planning long term flood risk mitigation measures and the appropriate actions to be taken in an emergency.

Method

For accurate estimation of flood hazard, selection of appropriate data, type of model, schematization, proper parameterization, calibration and validation of results are all important steps. A step by step process for achieving this is outlined below. This incorporates the factors to be considered at each stage.

1. **Data collection and integration for generation of digital terrain and surface models**
2. **Calculation of return period of flooding**
3. **Modeling flood scenarios using 1D, 2D or 1D2D hydraulic models (flood modeling software required)**
4. **Model result validation**
5. **Flood maps prepared and distributed to different user groups**
6. **Monitoring and regular updating of maps**

1. Data collection and integration for generation of digital terrain and surface models

Data that can be used for generating Digital Terrain Model (DTM) and Digital

Surface Model (DSM) includes laser scan terrain data; geographical survey data; ortho-photos; satellite images; human-made objects and terrain in digitized format; river cross section data; discharge data; and bathymetric data.

Digitization of the available data is the preliminary stage in the generation of digital surface models. Interpolation methods are then used based on the specific needs of the surface. Error correction follows, to ensure that the modelled surface matches reality as closely as possible.

The Digital Terrain and Digital Surface Models must accurately represent the terrain on which the model will base its results if reliable flood hazard modeling is to be obtained. A combination of laser-derived terrain data and geographical survey data (digitised contours) using GIS software will provide the best results, but laser-derived terrain data are expensive to obtain. The quality of output can be influenced by type of data, expertise, knowledge and understanding of the user, all of which will further have an effect on the end product.

2. Calculation of return period of flooding

The annual maximum flood series is the maximum volume flow rate passing a particular location (typically a gauging station) during a storm event. This can be measured in ft3/sec, m3/sec, or acre feet/hr) and is calculated using the following formula:

$$Tr = (N + 1)/ M$$

(where Tr = Return Period of flooding; N= Peak annual discharge;
and M = Rank, according to order of highest flow).

Where a number of tributaries exist within the catchment of interest, methods of gauging flows on each watercourse may be necessary. (For a detailed discussion of recurrence intervals and flood probability see Section 1.3.1.)

Output from the return period calculations will enable users to understand the 'exceedance probability' of given flood events. If actual annual maximum discharge data is unavailable then approximation will be needed. But it must be recognized that this may lead to uncertainties within the model and thus in the end product.

3. Modeling flood scenarios using 1D, 2D or 1D2D hydraulic models (flood modeling software required)

As shown in section 1.4.1 and in Table 1.2, various flood models are now available, with varying degrees of simplification and applicability; each has its own advantages and disadvantages, particularly in terms of the costs of the software and computer model runtime involved. Whichever one is chosen, schematization with the available input data, as above, is needed together with the boundary conditions for scenario generation according to the user's requirements. Calibration of the model should then be performed followed by validation in order to get results closer to the reality (for example, by comparison with known flood extents in historic events in the locality).

Model outputs are obtained in the form of water depth, water velocity and extent of flooding for different return periods depending upon the model chosen. Depending on the nature of the flooding under consideration, the flood model adopted should ideally be the closest to the technological 'cutting edge' that available resources permit. Where the number of actual observations is limited, a process known as 'parameterization' of the inputs is needed in order to get the output as close as possible to the natural event. The details of this critical exercise vary according to the model used. Output can also be affected by the internal formula used by the model in performing the modelling process.

4. Model result validation

Validation of results by means of surveying, also known as 'ground truthing' of the model, is extremely important to ascertain the quality of the model output. Additional validation, using actual event data, provides another way of testing how appropriately the hazard model has performed.

Both the above checking processes are required in order to improve the precision of the model outputs and thereby the usefulness of the final map product.

5. Flood maps prepared and distributed to different user groups

Model outputs can be exported in a variety of GIS formats (raster or vector) which can then be used to generate maps, thereby translating the model results into a user-friendly format. Hazard maps in different formats are helpful for different kind of users (in terms of scales, size, the amount of information, and the level of generalization). The appropriate software will permit outputs to be tailor-made in order to adhere to specific user requirements.

Most of the models and software used for flood hazard assessment are quite expensive to buy and are not freely available to the public. Due to their high price they are an impractical consideration for many developing nations. Therefore there is a need for high quality open source software which will be able to serve these highly sophisticated models to the extent that they can provide a general idea of the areas under threat.

Some of the open source software freely available for analysis and visualization purposes is as follows:

- Flow map designed by Utrecht University in the Netherlands is specifically designed to display flow data and works under Windows platform.
- GRASS is the most popular and well known open source software application which has raster and vector processing systems with data management and spatial modeling system. It works with Windows, Macintosh, Linux, Sun-Solaris, HO-Ux platforms.
- gvSIG is another GIS software application written in Java and works in Windows, Macintosh and Linux platforms.
- Ilwis is a multi-functionality GIS and Remote sensing software which has the capacity of model building. Regular updates are available for this software.
- Quantum GIS is a GIS software which works with Windows, Macintosh, Linux and Unix
- SPRING is a GIS and Remote sensing image processing software with an object oriented model facility. It has the capacity of working with Windows, Linux, Unix and Macintosh.
- uDig GIS is yet another open source desktop application which allows viewing of local shape files and also remote editing spatial database geometries.
- KOSMO is a popular desktop application which provides a nice graphic user interface with applications of spatial database editing and analysis functions.

Interactive visualization tools:

- Showing sea level rise: http://globalfloodmap.org/South_Africa
- Global Archive map of extreme flood events (1985-2002): http://floodobservatory.colorado.edu/Archives/GlobalArchiveMap.html

A major step taken by Deltares, a leading research institute based in the Netherlands, is to release specific modules of the Delft 3D model (FLOW, Morphology and Waves) as open source to bring experts all over the world together to share their knowledge and expertise. It is a robust, stable, flexible and easy to use model which is internationally recognized. For more information please see the following link: http://oss.deltares.nl/web/opendelft3d/home

However it is observable that uncertainty exists in every stage of hazard assessment. Uncertainty exists in every stage of data accumulation, model selection, input parameters, operational and manual handling of the model till the final output is obtained. Each element contributes to the uncertainty in accuracy of the final output. Therfore it is necessary to consider the impact that uncertainty has on the output of a model and is essential to reduce it as much as possible.

6. Monitoring and regular updating of maps

Typically, for public access purposes, general maps with limited information are produced using GIS software, showing only the flood extent and perhaps protection measures where these exist. For use by local authorities for decision making more detailed information will be required, such as municipality level maps with real estate data. For professional bodies, maps with still more detailed supplementary data can be generated, going down to individual household plot level if required.

Flood hazard maps must be updated regularly with both field information (for example, major building developments or road construction that significantly alter the terrain) as well as other relevant data, such as any changes in the peak recorded flows from gauging stations following extreme events. Monitoring of the hazard map's performance in use is also required (for example, where data from actual events following map production are found to exceed the modelled predictions).

Known uncertainties in the model need to be incorporated into the decision making processes of the local authorities; revisions to the maps following any amendments to input data will also be required. A process to ensure that the superseded copies are taken out of use is further needed, such that future decisions are made on the basis of the updated information.

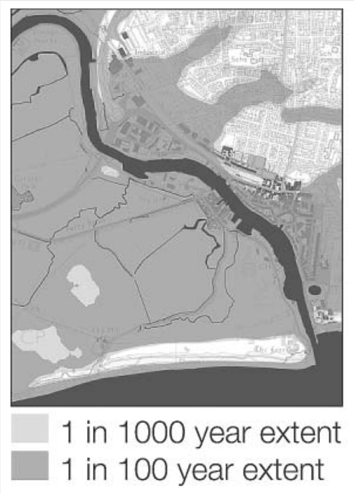

Figure 1.1: Flood hazard map:
Source: The Defra funded LifE Project by Baca.

1.4.4. How to prepare a flood hazard map in the coastal zone

Hazard maps for the coastal region are different from the hazard map preparation for non-coastal areas. These maps are particularly suitable for coastal areas where flooding is mainly caused by storm surges. With the changing nature of climate and sea level rise this type of mapping is very important for any coastal urban area. The coastal topography and the depth of water in the shallow water zone area are two most important aspects which make the modeling of coastal flooding possible.

These maps are important for city managers who can have a better understanding of the possible hazardous areas and take appropriate actions. The process described below is a guide for preparing coastal hazard maps. However there are other important aspects like differences in meteorological conditions and unique physical processes which differ in different parts of the world which are not specifically addressed here. A user should keep in mind that some procedures may be applicable to specific settings. With this kind of coastal hazard map, the severity of an event can be anticipated to some extent, which is extremely helpful for planning purposes.

Method

The following section will outline the techniques and methods useful to evaluate flood risk in a coastal environment. The different variables responsible for causing flood risk need to be evaluated properly for producing hazard maps. The major technical aspects in estimation of flood hazard for storm surges in coastal areas are similar to any other kind of hazard estimation following data collection, model schematization, model parameterization and output visualization. However there are certain factors that should be taken into account for each stage of hazard assessment and finally production of maps. The factors that are considered for each step of this process are listed below.

1. **Data collection to characterize coastal domain and generation of digital terrain model**
2. **Characterization of Morphology and bathymetry of coastal fringe**
3. **Data generation for water levels of different probability of occurrence**
4. **Modelling event in coastal zone (numeric and analytical models)**

1. **Data collection and integration to characterize coastal domain and generation of digital terrain model**

The first step of producing a hazard map is collection of appropriate data. Database generation is either performed using historical information or prepared from scratch by collecting required information through surveying. The type of data to be collected is morphology of coastal fringe, cross section of the water bodies and bathymetry data. The instruments for collection of data can be either ground survey of control points using DGPS, measurement of hydraulic structures, and topographic mapping using photogrammetry, SAR and LIDAR. Ground truth methods are however very expensive and time consuming and difficult to obtain in inaccessible terrains. Therefore remote sensing methods are recommended. The scanned data obtained through remote sensing and the surveyed data are processed and combined to generate grids for generation of digital terrain models. The process of interpolation is used to create the surface for their generation. Error correction is necessary to gain accuracy. Accurate topographic information in both vertical and horizontal dimensions is also necessary. The models also depend on the data quality, with data capture standards highly essential for the quality of output. Generated DTM is essential for delineation of floodplains. To incorporate other factors existing within the coastal region land use data are sometimes used for understanding the total damage effect.

2. **Characterization of Morphology and bathymetry of coastal fringe**

The two different domains of data that are required for characterization of the morphology of the coastal fringe are the sub-aerial part and the sub-aqueous part. The sub-aerial part consists of topographic data, and the subaqueous part consists of bathymetric data. They are important for understanding the level of existing barriers and the intensity of storm surges to the hinterland. Changes in beach slope can also bring changes in level of overtopping. Since the coastal morphology is dynamic and variable in nature, consideration has to be made to reduce the level of uncertainty as much as possible. It is also recommended that coastal morphology should be updated at frequent intervals to obtain the pre-storm morphology as accurately as possible. Topo-bathymetric data gathering can be done using Kinematic GPS, land surveying for the sub-aerial part and bathymetric survey for the subaqueous part through LIDAR survey. LIDAR survey is gaining more importance worldwide although it is expensive and requires expertise and high end technology. It should be kept in mind that both the surveys have to be done at the same time and using the same datum. The end product is affected by the changes in morphology: for instance modification of wave and surge propagation can affect flood intensity. Variations in result may be observed due to changes in beach crest and dune.

The sub-aqueous part of data collection and generation of a database is important to describe the process of coastal changes for characterization of bathymetry of the area. It is generally not very easy to keep updating the bathymetry because of its highly dynamic nature. It is neither cost effective nor time efficient. Scanning of bathymetry is better in clear water where accuracy can go up to a level of +- 15cm (Lillycrop et al., 1996). In turbid water it is much less, and is often not acceptable for modeling. The range of surveyable depth based on the turbidity of water lies between 50 m to 10 m. Bathymetric data for the nearshore region is important for underwater morphology to model the nature of wave propagation near the shoreline.

3. Data generation for water levels of different probability of occurrence

The method employed in calculating the water levels for different probability of occurrence are based on the nature of available data. It can be done through direct calculation from the existing database which is known as the response approach or by attributing contribution of each variable component (astronomical, meteorological, and wave induced) to calculate the joint probability which is known as the event approach. The response approach uses existing time series of water level data. The problem with such historical data is that they generally do not reflect the wave-induced contribution. The case of the response approach includes one or more than one combination of water level and wave conditions. For instance, the joint probability (combined wave tide effect) is calculated using the following formula:

$$P_{c.k}(H_{I,}C_I) = P_{H.I}\,(H_I)\times P_{c.j}\,(C_j)\,(K-1,\,i\times j)$$

Where wave height is PH.I (HI), tidal elevation is PC.j (Cj), event is k=1

It is important not only to define the level of water but also to include the duration of the event, i.e., the time dimension. The result may vary based on the type of approach used. The response approach is recommended when the different variables are not directly correlated. When simultaneous wave conditions and water levels exist, adding individual contribution to the total calculation (i.e, the event approach) is more effective and accurate.

4. Modelling event in coastal zone (numeric and analytical models)

Several models are available for modelling flooding in a coastal region. The run up estimation is performed based on characteristics of zones i.e., offshore, near-shore, shoreline response and flood inundation zones. Based on the nature of coastal structures, the wave impact is affected and by using an appropriate formula wave, the run up can be estimated. Coefficients that are accounted for wave run up estimation are beach slope, beach roughness, beach permeability and percolation and wave obliquity. The wave overtopping discharge is then calculated based on the mean discharge of water per linear meter of width of beach moving towards land. Fema (2003) proposes the use of discharge rate formula for calculation of sloping surfaces. This is then converted to the volume of water entering the hinterland to understand the actual amount of water that will be overtopping the barriers. Barrier configurations are incorporated in the model using the morphological data. Scenarios based on zonal wave generation, surges, tides, and wave-wave interaction are generated through models. There are different numerical and analytical types of models that are used for flood modelling in a coastal area. Numerical models are considered to be more versatile than the analytical models. One of the most common models used by modellers was introduced by Vellinga (1986). Other models like those introduced by Komar et al (1999, 2001), Sheach Model and TIMOR3 and SWAN are also used frequently. More sophisticated models like Delft 3D are also used to complement other models especially for beach erosion and breach scenarios. Scenario-based (overtopping, overflowing, breaching) flood parameter maps are generated and parameter maps are obtained as an output from the models. Outputs vary based on the type of model used, accuracy of data, model calculation and parameter used for modelling.

5. Calibration and validation of model:

Model calibration is performed during the output generation phase and calibrated results are validated with existing data to confirm the accuracy of results. Transport coefficient values are sometimes applied as calibration parameter in some of the models to estimate the level of uncertainty in the calculated variables. Models sometimes recommend default values for calibration based on calibrations in numerous applications. The result is a model output with reduced level of uncertainty.

6. Generation of flood hazard maps

Publication of the resultant parameter maps from the model output are done using GIS applications. It is important that uncertainty is represented on the generated maps so that users are aware of the zone of uncertainty. Zone of uncertainty should be taken into account for policy making purposes as this still remains a major source of conflict.

7. Monitoring and update

As mentioned earlier, flood hazard maps should be updated with field information and other relevant data. Remote sensing methods are useful for dynamic areas like coastal zones to keep the database updated. Monitoring is required so that uncertainties in the model can be incorporated in the decision making processes for applicable mitigation processes.

Common Problems with producing Maps

Lack of data, appropriate modelling software and skilled personnel are common problems encountered. Where data is not available, hazard maps can be produced from participatory processes, historic event records (such as newspapers from the time, where these exist, or flood depths marked on historic buildings and structures, photographs from previous events) and digitised.

Time and Cost to Produce Maps

The effort and resources necessary to produce flood maps will be dependent on the available data, and the type of map required. As expected there will be a trade-off between financial cost and other resources and the precision, currency and functionality of maps. Where high resolution data is available to purchase, maps of flood extent can be produced almost instantly. Once all the required data is available, modelling to mapping can take a matter of weeks for a well-defined area. Consultants can be employed for a one-off mapping exercise removing the need to develop expertise and buy modelling software.

However, in general the biggest investment in cost and/or time will be in obtaining the data required and validating the model outputs. Experience shows that digitizing data is laborious and time consuming and that, particularly in urban flood mapping, seemingly small inaccuracies in mapping can result in large inaccuracies on the ground. Often urban environments are the areas where air survey techniques perform badly due to complex ground coverage and therefore ground based surveys or extensive historic records are needed. If large areas with complex river formations are modelled there are often boundary issues where models of individual flows may merge.

For a robust up-to-date mapping and zoning system which can support both emergency planning and land use regulation, long-term investment in skills and capacity to maintain and update models and maps is required. This investment can form part of a wider land use planning or emergency management capacity.

1.4.5. Further Reading

FLOODsite. 2008. “Review of Flood Hazard Mapping.” Integrated Flood Risk Analysis and Methodologies. No: T03-07-01, Wallingford, UK.

Neelz, S. and Pender, G. 2010. “Benchmarking of 2D hydraulic modeling packages.” Bristol, Environment Agency.

WMO. 1999. “Comprehensive Risk Assessment for Natural Hazards.” WMO/TD No. 955. Geneva, WMO.

1.5. Short term and real time flood forecasting

Short term and real time flood forecasting has a different role from flood hazard assessment. Hazard assessment is primarily aimed at making plans to reduce flood hazard and control exposure. Flood forecasting is an essential tool for providing people still exposed to risk with advance notice of flooding, in an effort to save life and property. Over recent decades in the UK, for instance, there have been great advances in flood forecasting and warning systems, in terms of improvements in technique, accuracy, forecast lead time and service delivery. Rather than estimating the probability and intensity of future events, short term forecasting of flood events stems from the translation of current weather and catchment conditions into predictions of where and when the flood waters will arrive.

The models and tools required for hazard assessment and flood forecasting purposes overlap somewhat. Some of these have been covered in Section 1.4.2. More are examined in Section 1.5.3 below, where the approaches in different countries are discussed. Different flood forecasting service models exist based on the needs of end users: a system may be developed for the public or strictly dedicated to the authorities. There is no single consistent approach worldwide but the basic principles of a good warning system are shared by all. These comprise:

- Better detection in times of need well before the actual event occurs
- Interpretation of the detected phenomena and forecasting this to the areas likely to be affected
- Dissemination of the warning message to the relevant authorities and public via the media and other communication systems.

The fourth and final aspect is to encourage the appropriate response by the recipients by preparing for the upcoming event. This can be improved through flood response planning by people at risk and their support groups.

1.5.1. Uncertainty in flood forecasting

Models, by definition, are approximations of reality. As described earlier, all models suffer from a certain level of approximation or uncertainty in spite of powerful computing systems, data storage and high level technologies. Decision makers have to consider the effects of uncertainties in their decision-making process. Errors in forecasting of an event, for example stage or time of arrival, may lead to under-preparation (at the cost of otherwise avoidable damage) or over-preparation (resulting in unnecessary anxiety). The balance between failure to warn adequately in advance and the corrosive effects of too many false alarms must be carefully managed.

The reliability of flood forecasting models relies on the quantification of uncertainty. All natural hazards are uncertain. The various sources that give rise to uncertainty in forecasting and early warning can be classified (Maskey. 2004) as:

- Model Uncertainty
- Parameter Uncertainty
- Input Uncertainty
- Natural and Operational Uncertainty.

It is necessary to gain a better understanding of the options available to deal with the uncertainties within the system arising from these different sources. For example:

- Model uncertainty can be reduced by a combination of different approaches for different models and the generation of best optimized result
- Input uncertainty can be minimized through improvement in spatial-temporal density of data, enhancing processing speed, stochastic (random element) simulation, and detailed knowledge of error structure
- Natural or operational uncertainty must be highlighted by reporting on the quality and reliability of data.

These methods can reduce uncertainty but can never eliminate it.

In order to produce a forecast, the initial conditions are typically determined by means of observations from rain gauges; these may, however, be unevenly spaced throughout the catchment, leading to uncertainty as to the total volume of rainfall. Where hydrologically important areas (such as steep slopes) are unrepresented, the model may utilize an interpolation method (introducing another element of uncertainty) in order to estimate run-off volume and peak flows. More sophisticated modeling can address these issues, but this in turn may demand high processing speeds and lengthy run-times.

To offset some of this uncertainty, operational flood forecasting systems are moving towards Hydrological Ensemble Prediction Systems (HEPS), which are now the ‘state of the art’ in forecasting science (Schaake et al. 2006; Theilen et al. 2008). This method formed part of initiatives such as HEPEX (Hydrological Ensemble Prediction EXperiment) which investigated how best to produce, communicate and use hydrologic ensemble forecasts for short, medium and long-term predictions. Despite its demonstrated advantages the use of this system is still limited: it has been installed on an experimental basis in France, Germany, Czech Republic and Hungary.

To deal with the uncertainty in spatio-temporal distribution and prediction of rainfall for extreme events, especially through radar derived data, a promising approach has been to combine stochastic simulation and detailed knowledge of radar error structure (Germann et al. 2006a, 2006b, 2009; Rossa et al. 2010). Radar ensembles have the potential benefits of increasing the time for warning especially for flash floods (Zappa et al. 2008). Advanced techniques, such as disdrometer networks (equipment capable of measuring the drop size, distribution and velocity of different kinds of precipitation) and LIDARs are being used to capture small scale rainfall phenomenon, whilst satellite remote sensing is more appropriate for regional and global level applications. A combination of all these methods and blending information is considered to be the most promising way forward.

Case Study 1.3 highlights a web-based flood forecasting initiative in India.

Case Study 1.3: Flood forecasting in India: a web-based system (WISDOM)

The Central Water Commission (CWC) in India developed a website to facilitate the process of making information about hydrological and hydro-meteorological data (i.e., meta-data) available to the public. The WISDOM website provides a flood warning service to non-registered users. Registered users can access and request the available data in their preferred format by selecting from the following options:

- List-based selection of the data made by either state/district/tahsil or by basin/major river/local river, and by Data Storage Centers (DSC) of any agency for both surface water and groundwater.
- Map-based selection can be made either by state boundary, surface water basin or by groundwater basin.

After the selection of the preferred parameters, an electronic Data Request File (DRF) is e-mailed to all the concerned DSCs. Once payment is made, the DSC of the respective agency will send the data to the user through e-mail, soft copy, or hard copy in the requested format.

Web-based systems such as WISDOM are an effective way to disseminate widely scientific information, such as hydrological and hydro-meteorological data, to a range of users and to facilitate better flood forecasting and research on the issue.

Source: CWC: http://www.cwc.nic.in/

1.5.2. Constraints in developing better forecasting systems

Commonly faced problems in the development of short term and real time forecasting are lack of surface measurement stations for rainfall and other land surface parameters and lack of aggregation between upstream and downstream data sharing in real time. Where upstream countries lack the necessary financial resources for real time monitoring, or treaties do not exist, the non-cohesiveness of the system limits the flood forecasting lead times. As a lower riparian country, Bangladesh suffers from such delays due to challenges related to real time data and information sharing for flood forecasting across national boundaries.

A notable exception is the Mekong River Commission (MRC) in Southeast Asia, which, as seen in Case Study 1.4 below, has a well-integrated system of data collection, monitoring and dissemination on a regular basis to its member countries. Satellite remote sensing technologies are being used to derive surface parameters in real time, thus enhancing the chances of increasing the forecast lead time.

Although data are available to all from the Global Data Processing and Forecasting System (GDPFS), discussed below, resources and technical capacity to use the data may still be lacking. Where access to technology is limited, there exists a continuing conflict between cost and reliability and a need for prioritization and leadership both by the government and the responsible local authorities. In these cases it is important to integrate the locally available resources in sustainable capacity. To progress, the aim should be to move towards an adapted system which can be maintainable and accessible by both technical and non-technical persons for the long term. Data sharing and regular communication throughout the catchment is just as important for establishment of a better forecasting and warning system as the latest technology.

Case Study 1.4: Mekong River Commission: Mekong Flood Forecast

The Mekong River Commission (MRC) was formed in 1995 by an agreement between the governments of Cambodia, Lao PDR, Thailand and Vietnam. The four countries agreed on joint management of their shared water resources and development of the economic potential of the river. The MRC has made available data about water levels along the main stream of Mekong River. Users have access to a range of data and information of 22 hydrological stations, such as observed and forecast water levels on the mainstream Mekong River. Data are available online on a weekly basis.

The MRC Mekong Flood Forecast is in general more accurate for downstream locations, as there is limited access to upstream monitoring stations contributing to the forecast. The accuracy of forecasts is highest for short-term prediction (1-3 days) as the daily input parameters are certain, but it decreases as forecasts look further ahead in time. Data and information from the stations is supplied as a service to the governments of the MRC member states so that it may be used as a tool within existing national disaster forecast and warning systems.

MRC's program significantly enhanced capacities in flood risk management among member states, especially through mechanisms such as the flood forecasting system, and has promoted trans-boundary cooperation and coordination. Over the past years, cooperation in flood forecasting and exchange of data and information between the riparian countries through MRC has made significant progress and there is now much more awareness about the importance of joint flood risk management.

Source: The Mekong River Commission:
http://www.mrcmekong.org; MRC 2010.

1.5.3. Flood forecasting systems

National Meteorological and Hydrometeorological Services (NMHS) are responsible for monitoring, detecting, forecasting and developing hazard warning for water related hazards in 187 member nations, supported by the WMO. The Global Observing System (GOS), also supported by the WMO, coordinates regular and systematic observation of climatic and water phenomena from around the globe. The Global Telecommunication Systems (GTS) is the supporting network for exchange of information. Through this, the WMO has developed the Global Data Processing and Forecasting System which provides alerts and bulletins to local NMHS member states.

This system is not universal and therefore in many cases, especially in African, Asian and Caribbean regions, there is a lack of fully-fledged flood monitoring and warning systems. In tropical areas, such as the Indian Ocean Commission (COI) region, the flood monitoring system is typically closely linked with the cyclone warning system. Many of the existing flood warning systems are part of stand-alone national warning systems without international coverage. Some of the rivers that are covered under international systems are the Rhine, Danube, Elbe, and Mosel in Europe; the Mekong River, Indus-Ganges-Brahmaputra-Meghna Basin in Asia; and the Zambezi in South Africa.

The International Flood Network (IFNeT), which was formed in order to facilitate international cooperation in flood management, provides flood warning information using satellite data through the Global Flood Alert System (GFAS). The National Oceanographic and Atmospheric Administration (NOAA) in the US provide seasonal forecasts based on the information from the major river basins using satellite data.

Most developed countries use reasonably sophisticated flood forecasting system as compared to developing countries. Near real time forecasting is possible using remotely sensed satellite data, for example NOAA-AVHRR images. Institutions like NASA and the US National Snow and Ice Data Centre (NSIDC) make data available to the public within 16 to 72 hours of acquisition. Some countries also use the WMO's GTS to acquire real time data. NASA and JAXA, the Japanese Space Agency, have collaborated on the provision of tropical rainfall data, as seen below in Case Study 1.5.

Some examples of operational flood forecasting systems, and their inception dates, are FEWS (flood early warning system) in Sudan (1990), FEWS Pakistan (1998), EFAS (1999-2003) covering many parts of Europe), NFFS and SFFS in the UK (2002) and the Community Hydrological Prediction System in the US (2009). The Bureau of Meteorology (BOM) in Australia (2010) has a system currently in the developmental stage. In Asia, the Asian Disaster Preparedness Centre (APDC) and Mekong River Commission are the major flood forecasting authorities.

There are two approaches to flood forecasting: deterministic or probabilistic. As an illustration of these methods, in England and Wales, the Environment Agency employs a mixture of deterministic and probabilistic flood forecasting method, whereby warnings are issued in areas where flooding is expected. In catchments that have very short lead times, it is difficult to respond well before an event actually occurs. A paradigm shift towards probabilistic flood forecasting, in which the likelihood of an event taking place is incorporated into the forecast, is currently in the experimental stages, with a view to providing better information to stakeholders and therefore increasing the time available for decision making.

Case Study 1.5: The Tropical Rainfall Measuring Mission (TRMM)

The Tropical Rainfall Measuring Mission (TRMM) is a partnership between NASA and JAXA, the Japanese Space Agency. It was developed to monitor and study tropical rainfall. TRMM observations have improved modelling of tropical rainfall processes and have led to better forecasting of inland flooding during hurricanes. The TRMM provides imagery and animations of hurricanes and shows precipitation coverage and rainfall estimates in land falling regions.

Precipitation data from the TRMM are made available within a few hours after being received by satellites and can be used to create rainfall maps to calculate precipitation rates in other weather systems or to perform Multi-satellite Precipitation Analysis (TMPA) analysis. Such scientific information allows for better understanding of the interactions between land masses, the sea and air, which impact global weather and climate.

All TRMM data are made publicly available by the NASA Goddard Earth Sciences Data and Information Services Center Distributed Active Archive Center (GES DISC DAAC). The online archive and other information about TRMM products can be found on: http://disc.sci.gsfc.nasa.gov/ and ftp://pps.gsfc.nasa.gov/pub/trmmdata/

Sources: NASA TRMM: http://trmm.gsfc.nasa.gov/

1.5.4. Considerations in designing a flood forecasting system

A flood forecasting system is essential for any urban area prone to flooding. It helps in forecasting the flow rate and water levels. It is an important component of flood warning – and the higher the accuracy of flood forecasting system, the easier it becomes for decision makers to decide whether they should issue a warning to the public. This also helps in extending the lead time that people get in moving to a safer location prior to the occurrence of a disaster. The components for designing an integrated system are outlined below in Table 1.3.

Table 1.3: Components for Designing of an integrated flood forecasting or warning system:

Actions	Considerations/ operations	Outputs/ Benefits
Data assimilation / acquisition	Remotely sensed meteorological and hydrological data (from gauging stations) Historical Data collection; Uncertainty reduction from data	Database generation. Collection of data from several sources and putting it together in one single hub makes it easier to work and share the resources

Data Communication	Standard data exchange digital formats; communication through reliable sources like line of site radio, satellite, cellular radio	Conversion and dissemination of data in a standard universal format This is helpful in using the data in a coordinated manner (coordination between national, regional and local organizations for data sharing)
Forecast (Other parameters included: environmental factors, historical flood data, economic and demographic factors)	Meteorological and hydrological forecasting using ensemble techniques (multiple forecast scenarios generated by several model runs) Debris flow models, Flash Flood Guidance, NWS river forecasting System	Scenario generation based on different parameters This is helpful in highlighting the effects of different factors or parameters used in the actions stage and their potential impacts on changing future conditions. Effective when performed in an integrated manner
Decision support	Advanced planning and action are the main considerations Inclusion of uncertainty in forecast in a non-technical manner	Different products based on the end user's requirements (e.g. tables, hydrographs, inundation maps) Important in decision making process as this gives a clear picture of priorities and areas of immediate attention
Dissemination	Inventory of user groups: user specific information Rapid action	Rapid dissemination of information to population at risk with sufficient lead time and in understandable format
Coordination / Response	End to end flood response program Vigilant authorities Understanding the importance of forecast and warnings	Better linked communication system to reach the population Important for fast and effective response

1.5.5. Further Reading

EXCIMAP (2007) Handbook on good practices for flood mapping in Europe, European exchange circle on flood mapping. http://ec.europa.eu/environment/water/flood_risk/flood_atlas/pdf/handbook_goodpractice.pdf.

1.6. Accounting for climate change and sea level rise

Climate change is likely to have implications for today's urban flood risk management decisions, but is one of many drivers that must be considered (e.g. urbanization, aging infrastructure, and population growth). Many decisions made today regarding flood risk management will have ramifications well into the future. Failure to adequately treat climate change in decision making today could lead to future unnecessary costs, wasted investments and risks to life. Decision makers therefore require long term projections of risk, as well as detailed hazard maps of current flood risk. The idea that climate change will cause huge changes in risk and therefore render current flood risk management practice obsolete in the future is widespread and justified in some cases. This makes it highly problematic for governments and individuals to make confident decisions and to critically assess their investments in risk management. Long-term infrastructure is an area where planning decisions are likely to be sensitive to assumptions about future climate conditions. This can lead to indecision, delay in investment and higher damages from flood events in the short term. It is, therefore, crucially important to explore the implications of climate change for future flood hazard and to look for ways to build those implications into decision making processes.

There exists a broad consensus that flood risk is already changing at a significant rate, and that the rate of change might intensify in the next coming decades (Pall et al. 2011). As discussed in Section 1.2, a variety of climatic and non-climatic variables influence flood processes. Some of the climatic variables that flood magnitudes depend upon are precipitation intensity, timing, duration, phase (rain or snow) and spatial distribution. In the case of floods caused by sudden snowmelt, temperature and wind speed are also key factors. In this section we focus on the climatic drivers of floods and briefly discuss their observed and projected changes.

1.6.1. Potential impacts of climate change on cities

Around half of the world's population now lives in urban areas and this figure is projected to reach 60 percent by 2030. Urban population and infrastructure is increasingly at risk to some of the possible negative impacts of climate change.

There is potential for increased flood risk from:

– Increased precipitation

- Drought leading to land subsidence
- Rising sea levels
- Rapid snowmelt

Urban centers located predominantly in low-lying coastal areas are particularly vulnerable to sea level rise, storm surge and heat waves, all of which are likely to worsen due to climate change. In 2005, 13 out of the 20 most populated cities in the world were port cities (Nicholls. 2007a).

Deltas are also widely recognized to be highly vulnerable to the impacts of climate change, particularly sea level rise and changes in runoff. Most deltas are undergoing natural subsidence that exacerbates the effects of sea level rise. This is compounded with some human actions, such as water extraction and diversion, as well as declining sediment input as a consequence of entrapment in dams. It is estimated that nearly 300 million people inhabit a sample of 40 deltas globally. The average population density is 500 people per square kilometer, with the largest population in the Ganges-Brahmaputra Delta and the highest density in the Nile Delta. Due to these high population densities, many people are exposed to the impacts of river floods, storm surges and erosion. Modeling studies indicate that much of the population of these 40 deltas will continue to be at risk primarily through coastal erosion and land loss, but also through accelerated rates of sea level rise (Nicholls. 2007b).

Estimation of impacts of sea level rise, increasing temperatures and changing rainfall patterns on cities, and the development of robust adaptation pathways, is complicated by a combination of the characteristics of the infrastructure to be protected and the uncertainty of local and regional climate projections. Adaptation measures have to take into account the fixed or long term life span of urban infrastructure already in place, and the long lead times for the planning of replacements, as seen in Case Study 1.6 below.

Case Study 1.6: Climate-proofing road infrastructure in Kosrae, Federated States of Micronesia

The primary purpose of this project implemented by the Government of the Federated States of Micronesia in the Pacific was to provide road access to the remote village of Walung in the southwest of the Kosrae Island. Construction of the 16 km long road started in 2004. The road is 7 to 10 m above sea level, with the lowest point at about 4 m. The weather and climate-related risks that affect the design of the road infrastructure are related to determining its hydraulic design features.

By 2005, 3.2 km of road were built with drainage works designed for an hourly rainfall of 178 mm with a recurrence interval of 25 years. Because of the lack of local hourly rainfall data, this value was actually derived using hourly rainfall data for Washington DC. At present however, the hourly rainfall condition is up to 190 mm – and by 2050 the hourly rainfall is expected to increase to 254 mm. In 2005, although 3.2 km were already built, it was decided that the design of the road be modified so the drainage works could accommodate the higher hourly rainfall of 254 mm.

This delayed the completion of the road. Moreover, due to the need to climate-proof, the costs of retroactively fitting the necessary adaptation were much greater than those envisaged in the original budget. However, accumulated costs, including maintenance and repairs, for the climate proofed design will be lower than if the road was constructed in the original design after only about 15 years.

This case demonstrates the importance of integrating climate change scenarios into current and future planning decisions. The location and nature of all necessary newly planned infrastructures should draw on projections of climate change. The key issue here is how to incorporate deep uncertainty into infrastructure design with long lead-in and lock-in periods and avoid damages that could impose unnecessary costs.

Source: ADB 2005.

Although individual extreme weather events cannot be attributed to climate change, recent studies have shown that anthropogenic climate change can increase the chance of some of those events happening (Pall 2011; Min 2011; Stott 2004). A recent IPCC special report on managing the risks of extreme weather events and disasters concludes the frequency of heavy precipitation, daily temperature extremes, intensity of tropical cyclones, droughts, and sea level will be increased (IPCC 2011).

Analysis of specific extreme events can serve to illustrate their possible impacts were they to become more frequent or intense in the future. One well-known such example is that of Hurricane Katrina which made landfall in coastal Louisiana in August 2005. One result of the hurricane was the loss of 388 square kilometers of coastal wetlands, levees and islands that flank New Orleans in the Mississippi River delta plain. As these areas collectively act as the first natural defense against storm surge, this attribute was also lost. Over 1,800 people died and the economic losses totaled more than US$100 billion. Roughly 300,000 homes, and over 1,000 historical and cultural sites, were destroyed along the coasts of Louisiana and Mississippi, whilst the loss of oil production and refinery capacity helped to raise global oil prices in the short term (Nicholls 2007).

1.6.2. Climate change and variability: observed and projected changes.

1.6.2.1. Observed changes

At continental, regional, and ocean basin scales, some significant changes in the climate system have already been observed:

The warming rate as demonstrated by global mean surface temperature over the last 50 years (0.13ºC ± 0.03 ºC per decade) is almost double that over the 100 years from 1906-2005 (0.07 ºC ± 0.02 ºC per decade). Moreover, the 10 warmest years on record have all occurred since 1998 (Trenberth 2007). At the end of the melt season in September 2010, the ice extent in the Arctic Sea was the third smallest on the satellite record after 2007 and 2009. Global mean sea level is rising faster than at any other time in the past 3,000 years, at approximately 3.4 millimeters per year in the period from 1993 to 2008 (WMO 2009).

Precipitation over land generally increased during the 20th Century at higher latitudes, especially from 300N to 850N, but it has decreased in the past 30 to 40 years in the more southerly latitudes between 100S and 300N. There was an increase of precipitation in this zone from around 1900 until the 1950s, but this declined after about 1970. Global averaged precipitation does not show any significant trend in the period 1951-2005, with significant discrepancies between different data sets, and large decadal variability.

Observed changes in weather extremes are all consistent with a warming climate. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (Solomon et al. 2007) stated that increases in heavy precipitation over the mid-latitudes have been observed since 1950. This includes places where mean precipitation amounts are not increasing. Since 1970, large increases in the number and proportion of strong hurricanes globally have also been recorded, even though the total number of cyclone and cyclone days decreased slightly. The extent of regions affected by drought has also increased due to a marginal decrease of precipitation over land, with a simultaneous increase in evaporation due to higher temperatures.

Increases in precipitation intensity and other observed climate changes during the last few decades, such as sea level rise, suggest that robust future projections for flood management systems cannot be based on the traditional assumption that past hydrological experience provides a comprehensive guide to future conditions (Bates el al. 2008). In the IPCC Summary for Policy Makers (IPPC 2007), the conclusion drawn is that it is likely that the frequency of heavy precipitation events has increased over most areas during the late 20th Century, and that it is more likely than not that there has been a human contribution to this trend (Solomon et al. 2007). It is expected that global warming will affect both atmospheric and ocean circulation in such a way that many aspects of the global water cycle will change.

1.6.2.2. Projected changes

The IPCC has identified a range of possible futures for the planet, depending on the levels of greenhouse gas emissions that may be expected. These are defined in the Special Report on Emissions Scenarios (SRES) (IPCC 2000). There are four groups of scenarios, termed 'families', which range from A1, covering the highest emissions envisaged, through A2 and B1, to the lowest emissions grouping, B2. Within each of the family groups, there are multiple scenarios depending upon the levels of individual variables chosen: for example, the A1 family encompasses scenarios 'A1T' and 'A1F1', amongst others.

The range of global mean temperatures projected by several of these scenarios suggests marginally higher temperatures even if emissions were held at their 2000 values. This continued rise further suggests that even if emissions were drastically reduced now, at least in the short term the world will become warmer (IPPC 2007) by about 0.5 degrees. The projection of temperature rise for the worst case scenario sees a potential six degree warming by 2100.

Projections of global mean temperature change and rainfall for the highest and the lowest emissions scenario overlap until the 2020s. For the 2020s, changes in global mean precipitation are masked by its natural variability in the short term. The picture is different for longer term projections, when the emissions path does matter (Solomon et al. 2007). Changes in global mean precipitation become distinguishable from its natural variability, and some robust patterns emerge, such as an increase in the tropical precipitation maxima, a decrease in the subtropics and increases at high latitudes. However, due to larger uncertainties in the simulation of precipitation, the confidence in precipitation response to greenhouse gas increases is much lower than the confidence in simulated temperature response (Stone 2008).

Clearly, regional changes can be larger or smaller than global averages and, in general, the smaller the scale the less consistent the picture when viewed across the ensemble of global climate model (GCM) projections, particularly for some climate variables. The Regional Climate Projections chapter of the IPCC's AR4 report (Christensen et al. 2007), presents projections at continental scales, and then goes down to sub-continental scales in the form of so-called Giorgi regions: for example, Africa is subdivided into Western, Eastern, Southern and Sahara regions. One key feature of these regions is that they are typically greater than a thousand kilometers square and therefore much larger than the spatial scales relevant for most impact studies.

The greatest amount of warming is expected, and has been observed, over the land masses. In particular, it is expected that significant warming will occur at higher latitudes. In spite of the fact that these are regions with the largest uncertainties in their projections, and by the 2020s some GCMs project very small (or even slightly negative) temperature changes; by the 2080s all GCMs project warming of one or more degrees with respect to the 1997-2006 decade (Stone 2008).

Precipitation changes are less consistent than temperature changes, partly because precipitation is much more variable than temperature, and partly because it does not respond as directly to increases in concentrations of greenhouse gases' as temperature does.

The changes in annual means projected for the 2020s indicate that the largest potential changes – and simultaneously the largest uncertainties – occur in areas where precipitation is low, such as deserts and Polar Regions. By the 2080s projections show even greater variability, but some patterns emerge, such as the fact that precipitation in the Polar Regions is projected to increase. This is related to the fact that models project a retreat of sea and lake ice, allowing surface waters to evaporate directly (Stone 2008).

At the regional level, then, the seasonality of changes has to be considered, since clearly changes in annual averages do not uniquely determine the way in which the frequency or intensity of extreme weather events might change in the future. In Europe for example, where the annual mean temperature is likely to increase, it is likely that the greatest warming will occur in winter in Northern Europe and in summer in the Mediterranean area (Christensen et al. 2007).

Levels of confidence in projections of changes in frequency and intensity of extreme events (in particular regional statements concerning heat waves, heavy precipitation and drought) can be estimated using different sources of information, including observational data and model simulations. Extreme rainfall events, for example, are expected to be unrelated to changes in average rainfall. Average rainfall amount depends on the vertical temperature gradient of the atmosphere which, in turn, depends on how quickly the top of the atmosphere can radiate energy into space; this is expected to change only slightly with changes in carbon dioxide concentrations. On the other hand, extreme precipitation depends on how much water the air can hold, which increases exponentially with temperature. Thus it is reasonable to expect that in a warmer climate, short extreme rainfall events could become more intense and frequent, even in areas that become drier on average. Some studies have found that in regions that are relatively wet already, extreme precipitation will increase, while areas that are already dry are projected to become even drier, due to longer dry spells.

Projections of extreme events in the tropics are uncertain, due in part to the difficulty in projecting the distribution of tropical cyclones using current climate models with too coarse a spatial resolution, but also due to the large uncertainties in observational cyclone datasets for the 20th Century. For instance, some studies suggest that the frequency of strong tropical cyclones has increased globally in recent decades in association with increases in sea surface temperatures. These results are consistent with the hypothesis that, as the oceans warm, there is more energy available to be converted to tropical cyclone wind. However, the reliability of estimating trends from observational data sets has been questioned based on the argument that improved satellite coverage, new analysis methods, and operational changes in the tropical cyclone warning centers have contributed to discontinuities in the data sets and more frequent identification of extreme tropical cyclones after 1990 (Fussel 2009).

Global mean sea level has been rising; there is high confidence that the rate of rise has increased between the mid-19th and the mid-20th centuries. However, even though the average rate was 1.7 ± 0.5 millimeters per year for the 20th Century, the data shows large decadal and inter-decadal variability and the spatial distribution of changes is highly non-uniform. For instance, over the period 1993 to 2003, while the average rate of increase was 3.1 ± 0.7 millimeters per year, rates in some regions were larger while in some other regions sea levels fell (Solomon et al. 2007). Factors that contribute to long term sea level change are thermal expansion of the oceans, mass loss from glaciers and ice caps and mass loss from the Greenland and Antarctic ice sheets.

The present understanding of some important effects driving sea level rise is too limited. Consequently the IPCC AR4 (Solomon et al. 2007) does not assess the likelihood, nor provide a best estimate or upper bound, for sea-level rise. Model based projections of global mean sea-level rise between the late 20th century (1980-1999) and the end of this century (2090-99) fall within a range of 0.18 to 0.59 meters, based on the spread of GCM results and different SRES scenarios. These projections do not, however, include the uncertainties noted above (Bates et al. 2008). Sea level rise during the 21st Century is expected to have large geographical variations due to, for instance, possible changes in ocean circulation patterns. Even though it is expected that significant impacts in river deltas and low-lying islands might occur, the range of the plausible impacts are, therefore, yet to be specified.

1.6.2.3. Uncertainties in projections

There are different sources of uncertainties in climate change projections. These are partially due to the fact that the future socio-economic development is inherently unknown, but also as a consequence of the incomplete knowledge of the climate system, and the limitations of the computer models used to generate the projections (Stainforth 2007). The relative and absolute importance of different sources of uncertainties depends on the spatial scale, the lead-time of the projection, and the variable of interest. At shorter time scales, in many cases the natural variability of the climate system and other non-climatic risks would have a higher impact than climate change. For example, during the next few years, changes in urbanization and urban development in unsuitable areas could increase significantly the risk of flooding independently of climate change. On longer time scales, it is expected that climate change might play a more significant role. In this context, any strategy adopted to manage climatic hazards has to take into account the fact that projections of climate change include high levels of uncertainty and, even more importantly, acknowledge that in many cases, particularly at local scales, current tools to generate projections cannot tell us anything about future changes (Oreskes et al. 2010; Risby et al. 2011). The Kolkata Case Study below is a useful one, as it shows how to identify the underlying causes of flooding using hydrological, hydraulic and urban storm models.

Case Study 1.7: A megacity in a changing climate

The Kolkata Metropolitan Area (KMA) in India has a population of around 14.7 million and ranks amongst the 30 largest cities in the world. The city experiences regular floods during monsoons. According to the OECD report on "Ranking of the World's Cities Most Exposed to Coastal Flooding Today and in the Future", in the 2070s Kolkata will rank first in terms of population exposed to coastal flooding amongst port cities with high exposure and vulnerability to climate extremes. Potential threats to Kolkata include:

- Natural factors associated with its flat topography and low water relief of the area
- Unplanned and unregulated urbanization
- Lack of adequate drainage and sewerage infrastructure that have not been upgraded during the growth of the city
- Obstruction due to uncontrolled construction in the natural flow of the storm water, reclamation of and construction in natural drainage areas such as marshlands
- Climate change aspects, such as an increase in the intensity of rainfall, sea level rise and increase in storm surges which may increase the intensity and duration of flood events.

To identify the underlying causes of flooding in the KMA, hydrological, hydraulic and urban storm models were used. These incorporated historical rainfall data from 1976 to 2001 and assumed climate change effects, as follows:

- To estimate the water flow in the Hooghly River, water flow was modeled using the rainfall and temperature data obtained from the India Meteorological Department for the whole catchment area during the past 35 years. This modeling generated daily flow series at various locations along the river
- A hydraulic model was used to generate flood waves moving through the

river channel. Output from the model provided water surface profiles all along the river, coupled with change in flow depth during the flood period

- By incorporating the existing urban characteristics, an urban storm model was used to simulate the flooding that will result once river flooding is combined with the local rainfall and drainage capability of the KMA area.

By assessing all three sources of flooding and incorporating climate change in the analysis, technical specialists can present a better representation of risk in the targeted area, and decision makers can avoid choosing inadequate measures.

Sources: World Bank 2011; Nicholls et al. 2007a.

1.6.3. Incorporating climate change scenarios in probability analysis and flood risk management

A comprehensive modeling approach to assess changes in flood hazard due to climate change requires the combined simulation of all the domains: atmosphere and ocean, catchment river network, floodplains and indirectly affected areas. Considerable uncertainty is introduced on each of the modeling steps involved, including uncertainties about the greenhouse gas emission scenario, in the representation of physical processes in the global climate model, in the characterization of natural variability, in the method of downscaling to catchment scales, and in hydrological models' structure and parameters.

The uncertainty associated to a complete model chain, therefore, grows in each step and becomes very large, particularly at the scale relevant for decision-making. Some authors refer to this effect as an 'explosion of uncertainty' caused by the accumulation of uncertainties, through the various levels of the analysis carried out to inform adaptation decisions (Dessai 2009). Moreover, in many cases different results are obtained using different model set ups, indicating that results are highly conditional on the assumptions made for the modeling exercise (Merz 2010).

It is interesting to notice that the uncertainties present in the estimation of the impacts of climate change at local scales (i.e., a river flow in a particular catchment), have common characteristics with the uncertainties in the estimation of flood probabilities based on historical records. In both cases the estimates strongly depend on modeling assumptions and gaps in the understanding of relevant processes. Accurately predicting changes in flood hazard is, therefore, highly uncertain: climate change and other dynamic processes such as land use changes only increase the uncertainty with which flood risk management has to cope.

Flood hazard not only changes due to the natural and human induced variability of the climatic factors involved, but also due to the dynamics of societal factors. The contribution of the different drivers is largely unknown. In the short term, rapid economic, social, demographic, technological and political changes seem more important and immediate than climate change. Consequently, the effects of climate change on flood hazard should be considered in the context of other global changes that affect the vulnerability of flood-prone settlements Very importantly, flood risk management should be a constantly revised and updated process (Merz 2010).

Finally, flood risk is dynamic and the large uncertainties associated with the estimates of future risk make its management under climate change a process of decision-making under deep uncertainty. It is necessary to take a robust approach. Some risk management options that increase the robustness of urban flood risk management investments and decisions to climate change are so-called 'no-regrets' measures that reduce the risk independently of the climate change scenario being realized (for example, measures that reduce current vulnerabilities to weather and climate, or other non-climatic drivers); options that incorporate flexibility into long-lived decisions; or options that have significant co-benefits with other areas, like ecosystems-based flood control (Ranger 2010). Figure 1.2 summarizes the key processes towards robust decision making in an era of climate change, while Case Study 1.8 focuses on the flexible and no regret measures that Mexico City is implementing under its climate change adaptation program.

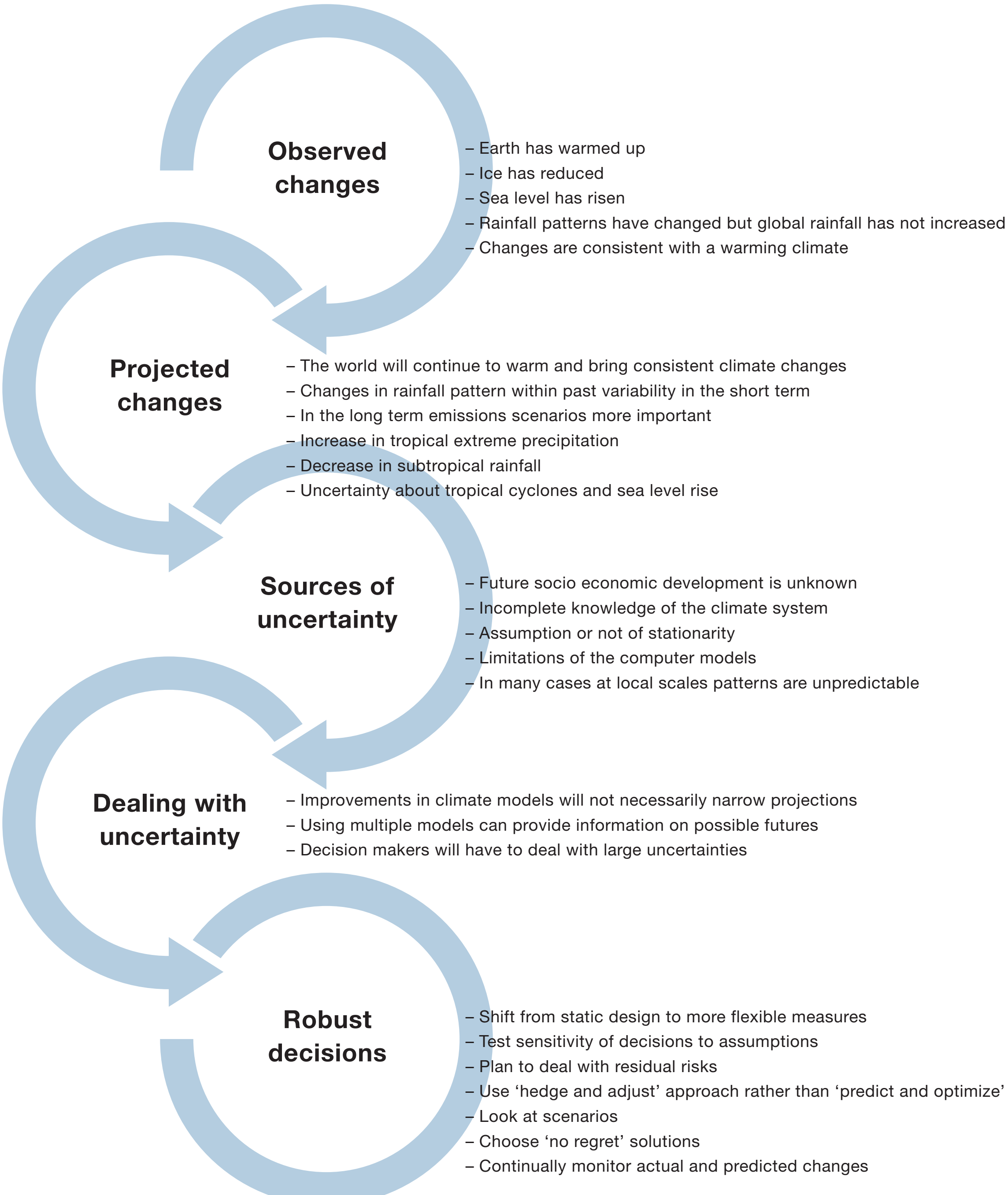

Figure 1.2 Making robust decisions in an era of climate change

Case Study 1.8: Mexico City's response to climate change and variability

Greater Mexico City, with a population of around 19.5 million, is one of the largest and most densely populated urban areas in the world. Over the past decades, the metropolitan area has experienced an increased incidence of flooding. Annual rainfall increased from 600 millimeters to over 900 millimeters through the 20th Century, while the annual incidence of flash flooding due to heavy rainfall increased from one to two annual flood events to six to seven flood events. It is expected that the incidence of flash flooding will continue to rise in the future due to the increased frequency of heavy precipitation associated with climate change and variability.

Flood impacts to Mexico City have also intensified mainly due to the way in which urban growth and spatial expansion are taking place. People living in informal settlements are particularly vulnerable, since they are often located in poorly or unplanned areas prone to flooding and landslides.

The municipal government of Mexico City recognized in recent years that climate change poses a serious threat to people and the economy and developed a 'Program of Climate Change Adaptation Measures' under a broader climate action program. This adaptation program, which is intended to become operational by 2012, identifies specific activities that are required in order to reduce the risks and the adverse effects of climate change and variability.

The first step of the program is the identification of primary threats to the city and a vulnerability analysis, followed by the integration of an adaptation perspective into existing government plans. The actual measures that will be then implemented have been categorized into two groups. The first group includes a hydro-meteorological monitoring and forecasting system and micro-basin management, such as the protection and restoration of urban ravines. The second group includes projects such as soil and water conservation projects and green roof schemes.

Both groups of measures selected include flexible and no regret measures, for example early warning systems and green infrastructure projects. Such measures are less sensitive to future flood risk and are relatively low in cost to set up. Although changes may be necessary in the future as risks change, flexible solutions allow for those changes without major reinvestment or the reversing of earlier actions.

Sources: Ibarrarán 2011; Martinez et al. 2008.

1.7. Technical Annexes

1.7.1. Types of flood models

Flood models can be categorized into several types depending upon their data requirement, level of complexity of the underlying equation, requirement of data for modeling, and the resolution.

Two important distinctions between models relate to the spatial aspects and input requirements. Models can be distinguished based on their spatial aspect of field characteristics:

– One dimensional (1D) models are simplified models which characterize the terrain through a series of cross sections and calculate the aspects like water depth and flow velocity towards the direction of flow. These models are well suited for areas where the direction of flow is well defined. Examples of such kind of model are the Beach profile model, HEC-RAS, LISS-FLOOD, and HYDROF.

– Two dimensional (2D) models calculate the flow non-parallel to the main flow i.e., they calculate the flow in both spatial dimensions with conditional uniformity. They are useful for modeling areas of complex topography such as wider floodplains or broad estuaries but require high quality data and long computation time. Examples of 2D model are TELEMAC 2D, SOBEK 1D2D, Delft 3D etc.

– Three dimension (3D) models are those where all the three components of velocity are considered. They are more complicated and thereby confined to modeling smaller areas. Some examples of 3D models are FINEL 3D, CFX, FLUENT, PHOENIX.

Based on inputs, flood models can be distributed into lumped models, distributed models and hydraulic models:

– Lumped models deal with the watershed as a single unit and the calculations are based on spatial average process. Semi-distributed models are also lumped models where the watershed is subdivided in order to model some of the physical parameters.

– Distributed models use distributed data like precipitation, infiltration, interception, interflow, infiltration, and base flow for forecasting purposes. This kind of model demands more data and knowledge than the lumped models.

– Hydraulic models use standard unsteady and non-uniform equations and are useful for measurement of flood wave travel time and attenuation.

Further classification of flood models is based on the implementation of techniques or methods; for example, linear models and non-linear models, finite element, finite difference and finite volume models, coupled models and nested models. The complexity of models is also reflected in their descriptions as first, second or third generation.

Additionally, there are two different approaches used in modeling flood events depending upon the user specific needs: probabilistic forecasts and runoff routing. In the probabilistic approach, statistical distribution is used to determine the uncertainty in model inputs. This method is gaining popularity because of its advantages of provision of probability of occurrence of flooding, including the level of uncertainty involved, thus aiding decision making. A rainfall–runoff approach provides complete hydrographs of the basin, by dividing it into sub-divisions and run offs routed from excess rainfall within each one. It is also advantageous for spatial distribution of rainfall over larger areas and, as a result, is helpful in prediction for larger basins.

For coastal flooding, erosion models are useful for estimating beach erosion to over wash and then breaching from the impact of waves. The most popular empirical model is that developed by Vellinga in the 1980s (FLOODsite 2008); this has been used in coasts of different morphology and characteristics and, although the original did not include this parameter, it has recently been modified to incorporate wave period (FLOODsite 2008). Other models include Komar et al. (1999, 2001), Kreibel and Dean (1993) and the Sheach Model (Larson et al. 2004), the latter having a wave propagation module to estimate cross shore transport in different zones. A detailed process based model to simulate breaching is TIMOR3 which was coupled with SWAN model to simulate sediment transport and bottom evolution (Witting et al. 2005). Attempts to develop a comprehensive erosion model are still ongoing.

Flood hazard simulation models are generally expensive to buy and require expert knowledge to use to get appropriate outputs. It is important for any flood manager to understand the importance of adopting an appropriate model based on the information needs for planned risk reduction and availability of resources. Table 1.2 earlier in this chapter describes the strengths and weaknesses of some common models. However, it should be kept in mind that not all developing countries can afford such expensive models for flood simulation. It is therefore important to have knowledge of the alternatives available in the form of freely available simulation software, which is discussed below in Section 1.7.3.

1.7.2. Flood hazard maps

Asia

An appraisal by the International Centre for Water Hazard and Risk Assessment reveals the present situation of flood hazard mapping in participant Asian countries (ICHARM 2010). It indicates that Bangladesh has large scale and medium scale inundation maps for the entire country up to district level and for the city of Dhaka. They have simulations up to 25-50 year return periods and are only used for flood forecasting and administrative purposes. These maps are not available to the public. Malaysia has flood hazard maps for the entire country up to a return period of 100 years for urban areas and 25 years for rural areas; updating of hazard maps of different catchments is in progress. Indonesia (for Jakarta) has flood maps for 1, 2, 5, 10, 25, 50 and 100 year return periods with inclusion of design structures, for example canals and rivers for the 100 year return period and ponds, macro and micro drains for 25, 10 and 5 year return period respectively.

Many countries have started involving the local people in community flood hazard assessment. In China, flood hazard has been simulated for 50-100 years for selected cities, reservoirs and embankment protection areas. The Philippines has flood hazard maps for the entire country and some of its most important cities for a return period of 25 years, while Thailand has them for 10, 20 and 50 years, taking into account the design structures for 500, 100, 50 and 25 year return periods. In India, flood hazard maps (known as 'Flood Atlas') are generated by the Central Water Commission (CWC); work is in progress on mapping flood-prone areas by organizations like the Building Materials and Technology Promotions Council (BMTPC) and the National Atlas and Thematic Mapping Organization (NATMO). The Indian Meteorological Department has also compiled statistics on values of probable maximum precipitation over the country, considering point rainfall data over a period of 24 hours, which is an important input for probability analysis and potential flood hazard assessment.

Europe

Flood hazard maps in Europe are generally available to the public, but their distribution and availability to the public domain varies by country. Flood maps in the UK are published by the Environment Agency, SEPA (for Scotland) and the Rivers Agency (for Northern Ireland); these illustrate flooding from rivers for a return period of 100 years, for coastal flooding 200 years and also provide an extent for an extreme 1000 year event. In Finland, flood maps are available from a scale of 1:20000 to 1:25000 for various return periods. In Germany, flood maps are produced separately depending on the end user, for example, for the general public the scale is 1:5000 with limited information but for research organizations and authorities the scale is much higher (information up to individual plot level can be obtained). In Hungary, flood maps have not been updated since 1972. In the Netherlands flood maps are available for different return periods to the public and are monitored and updated on a regular basis. In Bulgaria, maps of 1:50000 scales are available to the public; flood hazard maps are prepared on a hierarchical basis, from municipal level to the district level, then river basin level and finally at national level. Estonian flood hazard maps are available from the Meteorological and Hydrological Institute; and in Poland, they can be accessed at the Regional Board of Water Management and State Fire Service Head Quarters in scales of 1:25000 to 1:100000.

The Americas

In USA, the authority responsible for generation and distribution of flood maps is FEMA. Flood maps are available based on high, medium and low hazard zones and probability of occurrence (100 year, 500 year) for different locations at scales of 1:12,000, 1:6,000 and 1:24,000. There is also a provision of real time hazard mapping in some highly hazard prone areas. In Brazil the Agencia Nacional de Aguas is responsible for hazard mapping.

In the Caribbean region, flood hazard assessments are generally prepared by the national governments. In Belize, flood hazard assessments have been carried out since 1998-99, while the Government of Jamaica has undertaken a major flood hazard mapping program in the major river basins across the island. Mapping of inland flooding was completed by Antigua, Barbuda, St.Kitts and Nevis and they are available to the general public. The US Virgin Islands (USVI) developed a territorial flood hazard mitigation plan for remapping old archives. In Barbados, St. Vincent, Grenadines, Trinidad and Tobago, the Caribbean Disaster Emergency Management Agency (CDEMA) supported by the Japanese Government has undertaken pilot projects for mapping locational specific flood risks.

Africa

The hazard mapping situation in Africa appears to be the least advanced. There are few countries which have prepared hazard maps and those that exist are usually not available for public access. The Regional Centre for Mapping for

Resource Development in Nairobi, Kenya is responsible for mapping in the eastern part of Africa. Information is, however, available from the Dartmouth Flood Observatory in the US, which maintains a comprehensive database and archived maps of some of the major floods at different scales in different parts of the world including several countries in Africa (namely Zimbabwe, Mozambique, Malawi, Kenya, Uganda, Burkina Faso, Mali, Niger, Nigeria, Ivory Coast, Ghana, Togo, Benin and Guinea, Chad, Sudan, Ethiopia, Somalia, Tanzania, and Uganda). The observatory has a comprehensive archive of flood maps of different countries from other continents, which are freely available to the public. The list of maps available in the archive can be found here:

http://floodobservatory.colorado.edu/Archives/MapIndex.htm.

Data requirements for flood hazard mapping include:

- Discharge data for determination of peak discharge for probability assessment measures from different gauging stations
- Digital elevation model for estimation of elevation data
- Human-made structures and terrain, for example roads, buildings, bridges, embankments, dikes, other relevant structures to be incorporated within the DTM to generate digital surface model or incorporated separately to the model for analysis purpose
- Meteorological data: temperature, rainfall, snowmelt, wind speed
- Paleoflood and historical data obtained from geological, geomorphologic and botanical evidence of past flood events
- Topographic data for spatial estimation of hazard extent.

1.7.3. Tools for modeling and visualization

Most of the models and software used for flood hazard assessment are quite expensive to buy and are not freely available to public. Due to their high price they are an impractical consideration for many developing nations. High quality open source software, which will be able to serve the same purpose as these highly sophisticated models to does exist and can provide a general idea of the areas under threat.

Some of the open source software packages freely available for analysis and visualization purposes are as follows:

- A flow map designed by Utrecht University in the Netherlands is specifically designed to display flow data and works under Windows platform.
- GRASS is the most popular and well known open source software application which has raster and vector processing systems with data management and spatial modeling system. It works with Windows, Macintosh, Linux, Sun-Solaris, HO-Ux platforms.
- gvSIG is a GIS software application written in Java and works in Windows, Macintosh and Linux platforms.
- ILWIS is a multi-functionality GIS and remote sensing software which has the capacity of model building. Regular updates are available for this software.
- Quantum GIS is a GIS software which works with Windows, Macintosh, Linux and Unix
- SPRING is a GIS and remote sensing image processing software with an object oriented model facility. It has the capacity of working with Windows, Linux, Unix and Macintosh.
- uDig GIS is a desktop application which allows viewing of local shape files and also remote editing spatial database geometries.
- KOSMO is a desktop application which provides a graphic user interface with applications of spatial database editing and analysis functions.
- Interactive visualization tools:
- Showing sea level rise: http://globalfloodmap.org/South_Africa.
- Global Archive map of extreme flood events (1985-2002): http://floodobservatory.colorado.edu/Archives/GlobalArchiveMap.html.

Deltares, a leading research institute based in the Netherlands, has released specific modules of the Delft 3D model (FLOW, Morphology and Waves) as open source to bring experts all over the world together to share knowledge and expertise. It is a robust, stable, flexible and easy to use model which is internationally recognized; for more information see the following link: http://oss.deltares.nl/web/opendelft3d/home.

It must be borne in mind that uncertainty exists in every stage of hazard assessment, including data accumulation, model selection, input parameters, operational and manual handling of the model until the final output is obtained. Each element contributes to the uncertainty in accuracy of the final output, it is, therefore, necessary to consider the impact that uncertainty has on the output of a model and is essential to reduce this as much as possible.

1.7.4. Examples of flood forecasting and early warning systems

There are a several useful examples of such systems:

- DELFT-FEWS: one of the state of the art hydrological forecasting and warning systems developed by Deltares. This system is an integration of a number of sophisticated modules specialized in their individual capacities and the system is highly configurable and versatile. The system can be used as a standalone environment, or it can be used as a compliant client server application. Through its advanced modular system FEWS has managed to reduce the challenges like handling and integration of large datasets to a considerable extent. For further information see: http://www.deltares.nl/en/software/479962/delft-fews/479964?highlight=delft%20fews.

- Automated Local Evaluation in Real Time (ALERT) is the method used within the AUG member states to transmit data and information using remote sensors for warning against flash floods.http://www.sutron.com/project_solutions/Case_Studies_Individual.htm.

- Central America Flash Flood Guidance is an example of regional flash flood warning. The national Hydrologic Warning Council (NHWC) has member countries across North America and many parts around the world; it is also a major organization in data dissemination for early warning for flood events.

- The Mekong River Commission flood forecasting system, discussed above, has been operating since 1970. It is an integrated system which provides timely forecasting to its member countries. It consists of three main systems of data collection and transmission, forecast operation and information dissemination at both national and regional level. For more information see: http://www.mrcmekong.org/.

- The Southern African regional model for flood forecasting Stream Flow Model (SFM) has been applied after the Mozambique flood in 2000. The USGS along with Earth Resource Observation System (EROS) supports monitoring and modeling capacities of Southern African Countries.

- Regional Water Authority of Mozambique (ARA-Sul) is responsible for issuing flood warning and real time forecasting. The system is operational in Southern Africa with a mean area of 3,500 square kilometers. A simplified flood warning system, the Mozambique Flood Warning Project, is specially tailored to the needs of the local population. It also involves the local people and trains them to install, monitor and maintain the structures.

- Hydro Met Emergency Flood Recovery Project is used in Poland.

- Bhutan's Glacial Lake Outburst Flood (GLOFs) Iridium Satellite Communications is used as the telemetry back-bone for Bhutan's GLOF Early Warning Project.

- In the Toronto region of Canada, the Toronto and Region Conservation Authority (TRCA) flood forecasting and warning system is used; this is a scalable flood warning system including web-based data and video for nine watersheds.
- The Automatic Dam Data acquisition and alarm reporting system, is the Puerto Rican System to obtain, monitor and analyze, in real-time, critical safety parameters such as inflows, outflows, gate openings and lake elevations for 29 principal reservoirs
- Central Water Commission (CWC) in India provides the Turnkey Flood forecasting system across 14 states having 168 remote sites in six river basins. http://www.india-water.com/ffs/index.htm.

1.7.5. Downscaling Global Climate Model (GCM) information

Projections of climate change are generally obtained using GCMs whose spatial resolutions are typically of the order of a hundred kilometers. Different methods have been developed to generate climate change hazard information at spatial scales more relevant for adaptation planning. Following Wilby et al. (2009) a description of these follows, together with a summary of each approach's strengths and weaknesses.

1.7.5.1. Methods requiring limited resources

These approaches are modestly data dependent, place minimal demands on technical resources, and can be valuable for scoping assessments.

i) Sensitivity analysis: This requires a fully calibrated and validated model of the chosen system, for instance a model of coastal flood inundation in a given region. First the observed climate is fed into the model to establish the baseline conditions. Then, the observed climate is perturbed by fixed amounts to reflect arbitrary changes in precipitation for instance. A model simulation is performed for each change and any system response is measured against the baseline, providing a picture of the sensitivity to changes in the climate drivers.

Advantages: Easy to apply; requires no future climate change information; can indicate system thresholds.

Disadvantages: provides no insight into the likelihood or timing of different impacts; it cannot provide information about sequences of weather events that have not been recorded in the observations; perturbed time series might result not physically plausible; impacts model uncertainty is ignored.

ii) Change Factors: Provided that climate model information is available through GCM simulations, change factors between present and future climatology (typically long term averages for each calendar month) are calculated for the grid boxes overlying the region of interest. Change factors for temperature are computed as differences and for precipitation as proportional changes. These change factors are then added to the observed time series in the case of temperature (or multiplied by the observations in the case of precipitation) to generate perturbed climate time series.

Advantages: easy to apply (given availability of climate model data).

Disadvantages: perturbs only baseline mean and variance; ignores, for instance, changes in frequencies of rainfall and temporal sequencing of events; perturbed time series might result not be physically plausible or may lack consistency between different variables; it depends on the availability of GCM or Regional Climate Model (RCM) data for the location of interest.

iii) Climate analogues: analogue scenarios are constructed from paleo-data or more recent instrumental records that provide plausible representations of the climate of a region. Temporal analogues are taken from previous climate of the region; spatial analogues are taken from another region that has present conditions that could become the future climate of the Study site. The underlying assumption in constructing these analogues is that the geographic location between regions is similar and that the typical features of different latitudes (when using analogues from different zones) are not important.

Advantages: easy to apply; require no future climate change information; potentially reveals multi-sector impacts and vulnerability to past climate conditions or extreme events such as a flood or a drought.

Disadvantages: temporal analogues require that the climate forcing that led to extremes in the past is repeated in the future, however that is unlikely to happen if for instance human activities led to land use changes. Even if the same climate event recurs in the future, the impact will be different due to changing confounding factors such as changes in economy, infrastructure development or adaptation measures implemented during the interim.

iv) Trend extrapolation: extrapolating a trend over the next few years is an appealing option due to its simplicity. However, this assumes that recent trends will continue unchanged, and most importantly, that past records can provide robust information about trends. Even though this assumption might be correct for the slow changing components of the climate system (such as global sea level rise) at relatively short time scales, the trends are highly susceptible to false tendency due to data problems for instance, and their extrapolation ignores the possibility of abrupt changes in, for instance, climate circulation or rainfall patterns.

Advantages: easy to apply; uses recent patterns of climate variability and change.

Disadvantages: typically assume linear trend, trends are sensitive to the choice of records; it assumes that underlying climatology of a region is unchanged; needs high quality observational data; confounding factors can cause false trends.

1.7.5.2. Methods requiring modest resources

These methods are based on the use of different statistical approaches that in combination with climate model output generate projections of climate change.

i) Pattern scaling: this method is similar to the change factor approach; a spatial pattern of change for every grid box on the globe is derived using output from a GCM or RCM. These spatial patterns are then scaled using the global mean temperature change, simulated by a simple (and easy to run) climate model. This generates spatially resolved scenarios of climate change, for instance, different anthropogenic forcing, or different periods that have not been simulated by full GCMs. This approach relies on several major assumptions: that regional climate change patterns are constant between decades and only the magnitude of change varies; that the regional response depends linearly with global mean temperature change; and that the pattern of change can be scaled between different emission scenarios.

Advantages: modest computational resources only are required; allows analysis of GCM and emissions uncertainty; shows regional and transient patterns of climate change.

Disadvantages: relies on strong assumptions about the linearity of the climate response to different forcing; generated scenarios have coarse spatial resolution (same as GCM or RCM used to generate the patterns); fails to reproduce climate variability necessary to identify extremes.

ii) Weather generators: are models that replicate statistical attributes of meteorological station records (such as mean and variance) but do not reproduce actual sequences of observed events. In most cases a Markov model emulates transitions between wet and dry spells or dry-days, a probability distribution is used to optimally simulate daily rainfall totals, and secondary variables such as maximum and minimum temperatures, solar radiation and wind speed are obtained using multiple regression equations that link them to wet and dry-days. The use of weather generators to simulate projections of climate change assumes that statistical relationships valid under current climate will not be modified under climate change.

Advantages: modest computational demand provides daily or sub daily meteorological variables.

Disadvantages: needs high quality observational data for calibration and validation; assumes a climate change independent relationship between large-scale circulation patterns and local weather; scenarios are sensitive to choice of predictors and quality of GCM output; results are typically time slice rather than transient; it is limited to reproduce only time correlations for lags it has been trained to reproduce and can not simulate longer term temporal correlations.

iii) Empirical downscaling: in its simplest version consist of spatial interpolation of gridded GCM or RCM data to the required location (a particular place in a catchment for instance). More sophisticated approaches involve finding statistical relationships between large scale atmospheric variables (predictors) and local surface variables (predictands) at the location of interest. Different downscaling approaches can be distinguished by their predictor variables or by the form of the statistical model relating predictors to predictands.

Advantages: modest computational demand; provides transient daily variables, reflects local conditions; can provide scenarios for ‘exotic’ variables (such as urban heat island, or air quality).

Disadvantages: requires highly quality observational data for calibration and verification, assumes a constant relationship between large scale circulation patterns and local weather; projections are highly dependent on the choice of predictands and the GCM used to estimate the predictands in the future.

1.7.5.3. Methods requiring high intensity resources

These methods require a high degree of ongoing technical support and computing resource, but on the other hand they are the only methods that can produce in principle internally consistent climate simulations in response to different climate forcings. One is discussed below, as an example:

Dynamic downscaling: Regional Climate models (RCMs) are similar to GCMs but run at much higher resolution over a limited spatial domain (a continental region for instance). RCMs simulate climate variables dynamically at resolutions of 10-50km given that boundary conditions are provided at the limits of their spatial domain. Atmospheric fields such as surface pressure, wind temperature and vapor, simulated by the parent GCM are fed into the boundary of the RCM at every time step and different vertical and horizontal levels. The nesting of the RCM within the GCM is one way, so the behavior of the RCM does not influence the GCM. Therefore, the robustness of RCM simulations depends not only on the validity of the RCM physics, but also on the validity of the GCMs boundary information. For instance, gross errors in the RCM simulated precipitation can be caused by the parent GCM misplacing the storm track. The results are sensitive to the size of the RCM domain and grid spacing. In theory, the domain should be large enough to capture large scale atmospheric circulation, and the grid space small enough to resolve topographic, coastal and dynamical features such as tropical cyclones crucial to simulating local climate. In practice domain and grid spacing are limited by computational resources.

Advantages: maps regional climate scenarios at 20-50 kilometer resolution, reflects underlying land-surface controls and feedbacks at smaller scales; preserves relations between weather variables as simulated by the climate model; ensemble experiments are becoming available for uncertainty analysis.

Disadvantages: high computational and technical demand; the results are sensitive to the host GCM; requires high quality observational data for model verification; scenarios are typically time slice rather than transient; climate model uncertainties and sources of error are the same as for GCMs but compounded with the parent GCM uncertainties.

It is important to note that this approach cannot provide ‘magical fixes’ to possible limitations in the data being downscaled. If for instance GCM data is being downscaled using an RCM or a statistical downscaling technique to obtain information at the local catchment scale, the downscaled information will not be robust if the GCM data was not robust. In fact, the downscaling approach will only introduce one more source of uncertainty in the resulting output. In this case the generation of climate projections using downscaling techniques will almost certainly increase the level of uncertainty in the original GCM projections.

1.8. References

ActionAid. 2005 Floods in Mumbai and Maharashtra: *Report on Flood affected people in Mumbai*. Bangalore: Books for Change.

ADB (Asian Development Bank). 2005. *Climate Proofing: A Risk-based Approach to Adaptation*. Pacific Studies Series.

Bates, B. C., Kundzewicz, Z.W., Wu, S. and Palutikof, J.P., ed. 2008. "Climate change and water." Technical paper VI of the Intergovernmental Panel on Climate Change, Geneva, IPCC.

Benito, G. and Thorndycraft, V.R. 2005. "Paleoflood hydrology and its role in applied hydrological sciences." Journal of Hydrology 313, (1-2): 3-15.

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, 2007. "Regional Climate Projections." In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. Cambridge, UK and New York, NY, USA: Cambridge University Press.

CRED (Centre for Research on the Epidemiology of Disasters) n.d. http://www.cred.be/.

Dessai, S., Hulme, M., Lempert, R., and Pielke Jr. R. 2009. "Do We Need Better Predictions to Adapt to a Changing Climate?" *Eos, Transactions, American Geophysical Union* 90 (13): 112–3.

Defra. 2010. UK Climate Projections (UKCP09) index. Last updated April 30, 2010. http://ukclimateprojections.defra.gov.uk/content/view/601/690/.

Dinicola, K. 1996.. The "100-Year Flood - USGS fact sheet 229-96." US Geological Survey (USGS), Last Modified 22 August 2005. Accessed 11 March 2011. http://pubs.usgs.gov/fs/FS-229-96/pdf/FS_229-96.pdf.

EM-DAT (Emergency events database). n.d. http://www.emdat.be/.

Environment Agency 2009. *TE2100 Plan Consultation Document*. London: Environment Agency. http://www.environment-agency.gov.uk/static/documents/Leisure/TE2100_Chapter01-04.pdf.

EXCIMAP (European Exchange Circle on Flood Mapping) n.d. "Handbook on good practice in flood mapping in Europe." http://ec.europa.eu/environment/water/flood_risk/flood_atlas/pdf/handbook_goodpractice.pdf.

FEMA (Federal Emergency Management Agency). 2003. *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying, 57*. Washington, DC: FEMA. http://www.fema.gov/library/.

—— . 2005. *Final Draft guideline for coastal flood hazard analysis and mapping for Pacific coast of United States, Draft Guidelines*. Washington, DC: FEMA. http://www.fema.gov/plan/prevent/fhm/frm_cfham.shtm.

FLOODsite. 2008. "Review of Flood Hazard Mapping - Report no: T03-07-01.". Integrated Flood Risk Analysis and Management Methodologies-Integrated Project, Floodsite. http://www.floodsite.net/html/partner_area/project_docs/T03_07_01_Review_Hazard_Mapping_V4_3_P01.pdf.

Foster, S.S.D., Hirata, R., Gomes, D., D'Elia, M. and Paris, M. 2002. *Groundwater quality protection: a guide for water utilities, municipal authorities and environment agencies*. Washington, DC: World Bank.

Füssel, H-M. 2009. "An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report." *Climatic Change* 97 (3): 469-82.

Garrity, N.J., Battalio, R.P.E., Hawks, P.J. and Roupe. D. 2006. "Evaluation of event and response approaches to estimate the 100 year coastal flood for Pacific Coast sheltered waters" *Coastal Engineering 2006 Vol2 - Proceedings of the 30th International Conference*. San Diego, California, USA. 1651-63.

Germann, U., Berenguer, M., Sempere-Torres, D., and Salvadè, G. 2006a. "Ensemble radar precipitation estimation — a new topic on the radar horizon." *Proceedings of the 4th European Conference on Radar in Meteorology and Hydrology (ERAD*). Barcelona. September 18–22, 2006. 559–62.

Germann U., Galli, G., Boscacci, M, and Bolliger M. 2006b. "Radar precipitation measurement in a mountainous region." *Quarterly Journal Royal Meteorological Society* 132: 1669–92.

Germann, U., Berenguer, M., Sempere-Torres, D., and Zappa, M. 2009. "REAL — Ensemble radar precipitation estimation for hydrology in a mountainous region." *Quarterly Journal Royal Meteorological Society* 135: 445–56.

GLIDE (GLobal IDEntifier Number). n.d. “Disaster Data” (Africa; Senegal; Flood). http://www.glidenumber.net/glide/public/search/search.jsp.

Hall, J. W. and Solomatine, D. 2008. “A framework for uncertainty analysis in flood risk management decisions.” *International Journal of River Basin Management* 6(2): 85–98.

Hopson, T., and Webster, P. 2008. “Three-tier flood and precipitation forecasting scheme for Southeast Asia.” http://cfab2.eas.gatech.edu/.

—— . 2010. “A 1–10 day ensemble forecasting scheme for the major river basins of Bangladesh: Forecasting severe floods of 2003–2007.” *Journal of Hydrometeorology* 11: 618–41.

Ibarrarán, M.E., 2011 “Increased incidence of flash flooding in Mexico City.” In *Global Report on Human Settlements 2011 - Cities and Climate Change, United Nations Human Settlements Programme (UN-Habitat)*, ed. Naison D. Mutizwa-Mangiza; Ben C. Arimah; Inge Jensen; Edlam Abera Yemeru and Michael K. Kinyanjui, 68. http://www.unhabitat.org/grhs/2011.

ICHARM (The International Centre for Water Hazard and Risk Management). 2010. *Progress Report on Flood Hazard Mapping in Asian Countries*. Tsukuba-shi, Ibaraki-ken: PWRI. http://www.icharm.pwri.go.jp/publication/pdf/2010/4164_progress_report_on_fhm.pdf.

ICIMOD. 2011. “Glacial Lakes and Glacial Lake Outburst Floods in Nepal.” Kathmandu: ICIMOD.

IPCC (Intergovernmental Panel on Climate Change). 2000. “Summary for Policymakers - Emissions Scenarios – Special Report.” Geneva: IPCC. http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=0.

—— . 2007. “Summary for Policymakers.” In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, T., Tignor, M. and Miller, H.L. Cambridge, UK and New York, NY, USA: Cambridge University Press.

—— . 2011. “Summary for Policymakers. In: *Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, ed. Field, C. B., Barros, V., Stocker, T.F., Qin, D., Dokken, D., Ebi, K.L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S. K., Tignor, M. and P. M. Midgley. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

ISDR (International Strategy for Disaster Reduction). 2004. *Living with risk: A global review of disaster reduction initiatives*. Geneva: United Nations Publications.

Kates, R. W., Colten C. E., Laska S., Leatherman S. P. 2006. “Reconstruction of New Orleans after Hurricane Katrina: A Research Perspective.” *Proceedings of the National Academy of Sciences*. 103 (40): 14653-60.

Klemeš, V. 1989. “The improbable probabilities of extreme floods and droughts.” In *Hydrology of disasters*, ed. O. Starosolsky & O.M. Melder, 43-51. London: James and James.

—— . 1993. “Probability of extreme hydrometeorological events - a different approach.” In *Extreme Hydrological Events: Precipitation, Floods and Droughts (IAHS Publ. no. 213)*, ed. Z.W. Kundzewicz, D. Rosbjerg, S.P. Simonovic & K. Takeuchi. Yokohama: IAHS. 167–76.

—— . 2000. “Tall Tales about Tails of Hydrological Distributions I and II.” *Journal of Hydrologic Engineering* 5 (3): 227-39.

Komar, P.D., McDougal, W.G., Marra, J.J. and Ruggiero, P. 1999. “The Rational Analysis of Setback Distances: Applications to the Oregon Coast.” *Shore & Beach* 67 (1): 41-9.

Kriebel, D.L. and Dean, R.G. 1993. “Convolution Method for Time-Dependent Beach-Profile Response”. *J. Waterway, Port, Coastal and Ocean Engineering* 119 (2): 204-26,

Larson, L.W. 1993. “The Great Midwest Flood of 1993.” Natural Disaster Survey Report. Kansas City, MO: National Weather Service.

Larson, M., Erikson, L. and Hanson, H. 2004. “An analytical model to predict dune erosion due to wave impact.” *Coastal Engineering* 51 (8-9): 675– 96.

Lillycrop, W.J., Parson, L.E., and Irish, J.L. 1996. “Development and operation of the SHOALS airborne LIDAR hydrographic survey system”. *Proceedings of SPIE 2694 CIS Selected Papers: Laser Remote Sensing of Natural Waters: From Theory to Practice*, St Petersburg, November 01, 1996. 26 (1996): 26-37.

Manila Observatory. n.d. “Interactive Flood Map Post Ondoy.” http://www.observatory.ph/ondoy/index.php.

Martínez, O.V., del Valle Cárdenas, B., Álvarez. S.S., ed. 2008. “Mexico City Climate Action Program 2008-2012 Summary.” Translated by Carolina Clark

Sandoval. Mexico City: Secretaría del Medio Ambiente del Distrito Federal. http://www.sma.df.gob.mx/sma/links/download/archivos/paccm_summary.pdf.

Maskey, S., Guinot, V. and Price, R.K. 2004. "Treatment of precipitation uncertainty in rainfall-runoff modeling: a fuzzy set approach." *Advances in Water Resources* 27 (9): 889-98.

Matambo, S. and Shrestha, A. 2010. "World Resources Report Case Study. Nepal: Responding Proactively to Glacial Hazards." Washington, DC: World Resources Report. http://www.worldresourcesreport.org.

Mekong River Commission homepage. n.d. http://www.mrcmekong.org/.

Merz, B., Hall, J., Disse M. and Schumann, A. 2010. "Fluvial flood risk management in a changing world." *Natural Hazards and Earth System Sciences*. 10: 509-27.

Min, S.K., Zhang, X., Zwiers, F.W. and Hegerl, G.C. 2011. "Human contribution to more-intense precipitation extremes." Nature 470: 378-81.

MRC (Mekong River Commission). 2010. "8th Annual Mekong Flood Forum Flood Risk Management and Mitigation in the Mekong River Basin. Proceedings." Mekong River Commission Regional Flood Management and Mitigation Centre.

Munich Re. n.d. "NatCatSERVICE." http://www.munichre.com/en/reinsurance/business/non-life/georisks/natcatservice/default.aspx.

Néelz, S. and Pender, G. 2010. "Benchmarking of 2D Hydraulic Modelling Packages." Bristol: Environment Agency. http://publications.environment-agency.gov.uk/PDF/SCHO0510BSNO-E-E.pdf.

Nicholls, R.J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., Chateau, J. and Muir Wood, R. 2007a. "Ranking port cities with high exposure and vulnerabilty to climate extremes: Exposure estimates." OECD Environment Working Paper 1, ENV/WKP (2007) 1. Paris: OEDC.

Nicholls, R.J., Wong, P.P., Burkett, V., Codignotto, J., Hay, J., McLean, R., Ragoonaden, S, and Woodroffe, C.D. 2007b. "Coastal systems and low-lying areas." In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson. Cambridge: Cambridge University Press. 315-56.

Olsen, R. 2011. "Climate Change and Risk-Informed Decision Making." In *Scaling up World Bank's role in Disaster Risk Reduction – Urban Flood Risk Management:*

Workshop Session 3, Washington, DC, March 17. Washington, DC: World Bank.

http://siteresources.worldbank.org/INTEAPREGTOPHAZRISKMGMT/Resources/4077899-1228926673636/4-Rolf_Olsen.pdf

Oreskes, N., Stainforth, D.A. and Smith, L.A. 2010. "Adaptation to Global Warming: Do Climate Models Tell Us What We Need To Know?" *Philosophy of Science* 77 (5): 1012-28.

Oxford English Dictionary 1989 (2nd edition). Oxford: Clarendon Press

Pall, P., Aina, T., Stone, D.A., Stott, P.A., Nozawa, T., Hilberts, A.G.J., Lohmann, D. and Allen, M.R. 2011. "Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000." *Nature 470*: 382-85.

Pittock, J. and Xu, M. 2011. "World Resources Report Case Study. Controlling Yangtze River Floods: A new Approach." Washington, DC: World Resources Report. http://www.worldresourcesreport.org/files/wrr/ wrr_case_Study_controlling_yangtze_river_floods.pdf.

Ranger, N., Millner, A., Dietz, S., Fankhauser, S., Lopez, A. and Rura, G. 2010. "Adaptation in the UK: a decision-making process (Policy Brief)." London: Centre for Climate Change Economics and Policy. http://personal.lse.ac.uk/RANGERN/PB-adaptationUK-rangeretal.pdf.

Ranger, N., Lopez, A. 2011. "The role of climate change in urban flood risk management today." In *Scaling up World Bank's role in Disaster Risk Reduction – Urban Flood Risk Management: Workshop Session 3*, Washington, DC, March 17. Washington, DC: World Bank.

Rossa, A. M., Cenzon, G. and Monai, M. 2010. "Quantitative comparison of radar QPE to rain gauges for the 26 September 2007 Venice Mestre flood." *Natural Hazards and Earth System Science* 10 (2): 371–7.

Risbey, J.S, and O'Kane, T.J. (2011) "Sources of knowledge and ignorance in climate research." *Climatic Change* Online First, August 19, 2011.

Ruggiero, P., Komar, P.D., McDougal, W.G., Marra, J.J. and Beach, R.A. 2001. "Wave Runup, Extreme Water Levels and the Erosion of Properties Backing Beaches." *Journal of Coastal Research* 17 (2): 407-19.

Schaake, J., Franz, K., Bradley, A., and Buizza, R. 2006. "The Hydrological Ensemble Prediction Experiment (HEPEX)." *Hydrological and Earth System Sciences Discussions* 3: 3321–32.

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood and D. Wratt, (2007). "Climate Change 2007. The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge, UK and New York, USA. Cambridge University Press.

Stainforth, D. A., Allen, M.R., Tredger, E.R., and Smith, L.A. 2007. "Confidence, uncertainty and decision-support relevance in climate predictions." *Philosophical Transactions of the Royal Society A* 365 (1857): 2145-61.

Stone, D.A. 2008. "Predicted climate changes for the years to come and implications for disease impact studies." *Revue Scientifique et Technique – Office international des epizooties* 27(2): 319-30.

Stott, P. A., Stone, D. A. & Allen, M. R. 2004. "Human contribution to the European heatwave of 2003." *Nature* 432: 610–4.

Thielen, J., Schaake, J., Hartman, R. and Buizza, R. 2008. "Aims, challenges and progress of the hydrological ensemble prediction experiment (HEPEX) following the third HEPEX workshop held in Stres 27-29 June 2007." *Atmospheric Science Letters* 9: 29-35.

Thorndycraft, V.R., Benito, G., Barriendos, M. and Llasat, M.C., ed. 2003. "Palaeofloods, Historical Floods and Climatic Variability: Applications in Flood Risk Assessment." *Proceedings of the PHEFRA Workshop*, Barcelona, October 16-19, 2002.

Thorndycraft V.R., Benito G., Walling D.E., Sopeña A., Sánchez-Moya Y., Rico M. and Casas A. 2005. "Caesium-137 dating applied to slackwater flood deposits of the Llobregat River, N.E. Spain". *Catena* 59: 305-18.

Trenberth, K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Soden and P. Zhai. 2007. "Observations: Surface and Atmospheric Climate Change." In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller. Cambridge, UK and New York, NY, USA. Cambridge University Press, UNISDR (United Nations International Strategy for Disaster Reduction). 2004. "Guidelines for Reducing Flood Losses." Geneva: UNISDR. http://www.unisdr.org/files/5353_PR200402WWD.pdf.

UNOCHA (United Nations Office for Coordination of Humanitarian Affairs). n.d. http://www.unocha.org/.

Vellinga, P. 1982. "Beach and dune erosion during storm surges." Delft Hydraulics Communication No 372. Delft: Waterloopkundig Laboratorium (Delft Hydraulics Laboratory).

Wang, H.G., Montoliu-Munoz,. M., GeoVille, G. and Gueye, N.F.D. 2009. "Preparing to Manage Natural Hazards and Climate Change Risks in Dakar, Senegal: A Spatial and Institutional Approach." Washington, DC: World Bank.

WHO (World Health Organisation). n.d.http://www.who.int.

Wilby, R.L., Troni, J, Biot, Y. Tedd, L., Hewitson, B.C., Smith, D.M. and Sutton, R.T. 2009 "A review of climate risk information for adaptation and development planning." *International Journal of Climatology* 29 (9): 1193-215.

Witting, M., Mewis, P. and Zanke, U. 2005. "Modeling of storm induced island breaching at the Baltic Sea coast." *Coastal Dynamics* Barcelona: ASCE.

WMO (World Meteorological Organisation). 1999. "Comprehensive Risk Assessment for Natural Hazards. WMO/TD No. 955." Geneva: WMO.

—— . 2009 "Statement on the status of the global climate in 2009". World Meteorological Organization Report no 1055. Geneva WMO. 14

World Bank. 2011. "Vulnerability of Kolkata Metropolitan Area to Increased Precipitation in a Changing Climate." Sector Note: 53282-IN. Environment, Climate Change and Water Resources Department. South Asia Region.

Zappa, M., Rotach, M.W., Arpagaus, M., Dorninger, M., Hegg, C., Montani, A., Ranzi, R., Ament, F., Germann, U., Grossi, G., Jaun, S., Rossa, A., Vogt, S., Walser, A., Wehrhan, J., and Wunram, C. 2008. "MAP D-PHASE: Real-time demonstration of hydrological ensemble prediction systems." *Atmospheric Science Letters* 2: 80–7.

Graham Leith and his son Kieran outside the flooded house of his mother Doreen Leith in Toll Bar village outside Doncaster, UK (2007). Source: Gideon Mendel

Chapter 2

Understanding Flood Impacts

Chapter 2. Understanding Flood Impacts

2.1. Introduction

Chapter Summary

This chapter translates the concept of flood hazard into flood risk. The following questions are addressed in order to assess the urgency and necessity of tackling flood risk before an event and to help in dealing with an actual flood:

What impact does flooding have on urban areas? Who and what are affected and for how long? What effect does urbanization have on flood risk? How can resources be targeted to protect those most vulnerable?

Key messages from this chapter are:

– Rapid urbanization severely challenges existing flood management infrastructure but also presents an opportunity to develop new settlements that incorporate integrated flood management at the outset.

– Direct impacts from major events represent the biggest risk to life and property, but indirect and long term effects and regular more minor flooding can erode other development goals.

– The poor and disadvantaged suffer the most from flood risk. Mapping risk and vulnerability assists in directing resources to protect them.

Flooding is one of the major natural hazards which disrupt the prosperity, safety and amenity of human settlements. The term flood refers to a flow of water over areas which are habitually dry. It covers a range of types of event, many of which can also include other sources of damage such as wind. Sources of floodwater can arise from the sea (in the forms of storm surge or coastal degradation), from glacial melt, snowmelt or rainfall (which can develop into riverine or flash flooding as the volume of water exceeds the capacity of watercourses), and from ground infiltration. Flooding can also occur as the result of failure of man-made water containment systems such as dams, reservoirs and pumping systems.

Excess water in and of itself is not a problem; rather, the impacts of flooding are felt when this water interacts with natural and human-made environments in a negative sense, causing damage, death and disruption. The experience of flooding for a rural agriculturalist and an urban slum dweller will be very different:

to the farmer the flood is a natural force to be harnessed or endured for the long-term benefits it may bring, but for the urban dweller flooding is, at best, a nuisance and at worst a disaster which destroys all possessions.

This chapter is concerned with the impacts of flooding in urban environments.

First, in Section 2.2, it describes the challenges posed by rapid urbanization and urban expansion, stressing the situation of informal settlement or slum areas, both in central city and peripheral locations, which are known to be particularly vulnerable to flood impacts. Case studies are used to throw light on the actual situation in the field.

Section 2.3 explains the direct impacts of flooding on primary receptors including people, the urban built environment, infrastructure, and family assets. Risks to life and health caused directly or indirectly by flood water are discussed, with flood-related injuries described in the pre-onset, onset and post-onset phases.

Damage to buildings and infrastructure is then examined, again detailing both direct and indirect damage. The characteristics of a flood are seen to be an important factor in determining the extent and nature of damage caused. Methods of construction, the use of construction materials and different forms of building are also shown to have implications for the severity of damage. Damage to infrastructure is shown to be a significant challenge to and inhibitor of post-event recovery.

The section goes on to provide an example of how to perform a damage assessment which makes uses of the Damage and Loss Assessment (DALA) methodology.

Section 2.4 provides a discussion of the other effects of flooding, including the impacts on the natural environment (such as erosion and landslides) and longer-term human and social impacts (including effects on demography and economic, and political and institutional impacts). The psychological and mental effects of flooding on people are also discussed.

The approach taken in this chapter is based on a commonly-accepted definition of flood risk: as a function of the flood hazard, of exposure to the flood hazard, and of the vulnerability of receptors to the flood hazard. It should be noted that exposed receptors may be vulnerable to the hazard or alternatively may be resilient to it. The final Section 2.5 describes the various options for assessment of risk and vulnerability, together with approaches to mapping, and includes discussion of the types and sources of data required. Categories of vulnerability are explained and the factors affecting their rate of exposure presented. The chapter ends with a detailed explanation of how to undertake a vulnerability assessment.

2.2. Urbanization, urban expansion and urban poverty

In the short-term, and for urban settlements in developing countries in particular, the factors affecting exposure and vulnerability to flooding are increasing rapidly, as urbanization – broadly defined as the transition from rural to largely urban societies – puts more people and more assets at risk. Rapidly growing informal settlement areas, often termed slums, in central city and peripheral suburban or peri-urban locations, are particularly vulnerable to flood impacts.

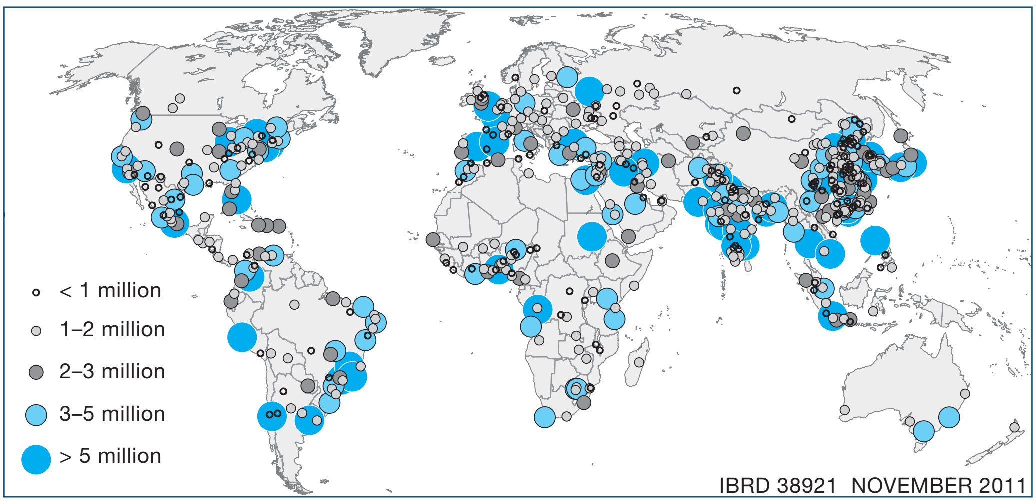

Figure 2.1: Urban agglomerations with more than 750,000 inhabitants in 2010. Source: Based on Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision and World Urbanization Prospects: The 2009 Revision.

2.2.1. Urbanization trends

In 2008 for the first time in human history, half of the world's population lived in urban areas, as illustrated in Figure 2.1 (UN-HABITAT 2008). It is estimated that by 2030 some 60 percent of the world's population will live in urban areas and by 2050 this will have risen to 70 percent (UN-HABITAT 2008; WDR 2010). In the developing world, some 95 percent of urban population growth takes place in low-quality, overcrowded housing or in informal settlements, with urbanization rates typically higher in small and medium-sized cities, although this varies from continent to continent (WDR 2010; WGCCD 2009; Parnell et al. 2007).

In East Asia, for example, most of the increase in urban population over the next 15 years is expected to be in towns and cities with fewer than one million inhabitants (Jha and Brecht 2011). In addition, a significant percentage of urban growth will be in peripheral areas adjoining existing major cities. However, it is important to understand that urban areas are not necessarily cities: Satterthwaite (2011: 1764-65) points out:

"Although it is common to see the comment that more than half the world's population lives in cities, this is not correct: they live in urban centers, a high proportion of which are small market towns or service centers that would not be considered to be cities."

2.2.2. Defining the 'urban'

Although the world is becoming more urban in nature, there is no commonly accepted definition of what is meant by the term 'urban'. Often, places with paved streets, street lighting, piped water, drainage and sanitation infrastructure, hospitals, schools, and other public institutions, are considered as urban areas. Urban centers, however, vary in size from a few thousand inhabitants to megacities with more than 10 million inhabitants. In addition, urban areas vary with regard to their spatial form, economic base, local resource availability, and local institutional structure. Typically, the conception of urban is now seen within the perspective of a rural-urban continuum spanning, in any given society, villages, small towns, secondary (or medium-sized) cities, metropolitan areas, and megacities. In addition, significant urbanized agglomerations are emerging, covering entire urban regions or urban corridors which encompass a range of urban centers of different sizes.

There are also significant regional differences: a town of a few thousand people in Africa is often considered to be an urban center, whilst in Asia urban areas tend to be agglomerations with far larger populations. There is even greater variation in the level and speed with which individual countries and individual cities within regions are expanding (Cohen 2004). For example, Latin America is more urbanized than Africa or Asia, and matches Europe or North America with current urbanization levels of around 70 percent. However, urbanization trends in Latin America are lower than in Asia and Africa, which are expected to experience relatively faster rates of urbanization over the coming decades. By 2030, Sub-Saharan Africa, which is the fastest-urbanizing world region, will have crossed the threshold to be a principally urban region. In the 20 years that follow, Africa's urban population will rise to 1.3 billion people.

2.2.3. Implications of urbanization and urban expansion for local environments and the flood hazard

Urban centers concentrate people, enterprises, infrastructures and public institutions, while at the same time relying for food, freshwater and other resources from areas outside of their boundaries (Satterthwaite 2011). Furthermore, urban areas are often located in hazard-prone locations such as low-elevation coastal zones, which are at risk from sea-level rise, or in other areas at risk from flooding and extreme weather events (OECD 2009; WDR 2010).

Urbanization is accompanied by increasingly larger-scale urban spatial expansion as cities and towns swell and grow outwards in order to accommodate population increases. Urban expansion alters the natural landscape, land uses and land cover, for example by changing water flows and increasing impermeable areas, thereby adding to the flood hazard problem (Satterthwaite 2011). High levels of urbanization in river flood plains and other areas of catchments might also change the frequency of occurrence of flooding. In the mid-1970s, when urbanization was just starting to accelerate, a study by Hollis (1975) showed that the occurrence of small floods might increase up to 10 times with rapid urbanization, whilst more severe floods, with return periods 100 years or over, might double in size if 30 percent of roads were paved. The changes in land use associated with urbanization affect soil conditions and the nature of run-off in an area. Increased development of impermeable surfaces leads to enhanced overland flow and reduced infiltration. It also affects the natural storage of water and causes modification of run–off streams (Wheater and Evans 2009).

Urban centers also change the local environment by reducing rainfall and increasing night-time temperatures. Urban micro-climates, especially urban heat islands caused by lack of vegetation, can modify the hydrology of an area. Heat islands create higher temperatures over cities: for example, during the summer heat wave of 2003 in the UK, differences of up to 10°C between city and rural temperatures were measured in the London area.

The ways in which the effects of urbanization combine with limited urban planning and inadequate maintenance of waterways to lead to increased vulnerability to flooding is illustrated in Case Study 2.1.

Case Study 2.1: Changing rainfall patterns and poor urban planning expose Lusaka to floods

Floods caused major disruption to Lusaka, Zambia in March 2010. As one account put it:

"Water rose above the window levels of many houses, strong currents carried away pieces of market stalls and boys hoisted fishing nets to catch whatever they could from the gullies where, not long before, they had walked to school."

March usually marks the end of the country's rainy season. But in 2010 the rains were more intense and longer than usual. Population pressures and the need for improved urban planning in Lusaka have increased people's vulnerability to floods: according to the country's Central Statistics Office, Lusaka's population has increased by 400,000 people since 2004, reaching at least 1.5 million currently. This trend, caused by in-place growth and rural-urban migration, is expected to continue. Population densities have also increased, particularly in peri-urban areas on the city's periphery, where they reach up to 1,450 persons per hectare according to the Lusaka City Council. Some 70 percent of inhabitants are under 30.

As 60 percent of Lusaka's residents live in dense, informal, unplanned settlements, the local population is particularly vulnerable to floods. Specifically, many houses have been built in areas not suitable for construction or which are highly vulnerable to flooding, particularly as drainage channels are often blocked by buildings or filled with waste.

It is also important to highlight the effect that floods have on human health. According to the Ministry of Health, in March 2010 564 cases of cholera were recorded in Zambia, with 30 deaths in Lusaka. This also had much to do with poor wastewater management and potable water boreholes being inappropriately designed or built.

The Ministry of Finance estimates that upgrading Lusaka's drainage system - not to mention improving wastewater management, treatment and disposal and improving access to safe and reliable drinking water - would be very costly.

However, in the 2011 national budget only US$33.2 million was allocated for water and sanitation projects in Zambia. As a result, Lusaka's problems are likely to continue to grow unless further investment is secured. Furthermore, given the level of ongoing urbanization, such investment needs to be allied with improved urban planning and management.

Source: Kambandu-Nkhoma (no date).

2.2.4. The urban poor

The concentration of people in urban areas increases their vulnerability to natural hazards and climate change impacts. Vulnerability to flooding is particularly increased where inappropriate, or inadequately maintained infrastructure, low-quality shelters, and lower resilience of the urban poor intertwine (World Bank 2008). The fact that rapid urban expansion typically takes place without following structured or agreed land use development plans and regulations makes conditions even more problematic. In addition, as the urban poor are often excluded from the formal economy, they lack access to adequate basic services and because they cannot afford housing through the market they are located in densely populated informal slum areas which may be vulnerable to flooding.

The houses of poor people in these most vulnerable informal settlement areas are typically constructed with materials and techniques that cannot resist extreme weather or natural disasters (Parry et al. 2009). Rapid urbanization in low-income and middle-income nations tends to take place in such relatively high-risk areas, thereby placing an increasing proportion of the economies and populations of those countries at risk (Bicknell et al. 2009).

Case study 2.2 presents an example of the complexity of the impacts of urban flooding on the urban poor.

Case Study 2.2: The dilemma of poverty and safety: The case of urban flooding in the Aboabo River Basin in Kumasi, Ghana

In the Kumasi Metropolitan Area (KMA), which is the second largest city in Ghana with a population of approximately 1.6 million, the Aboabo River Basin is home to various communities, namely the Anloga, Dichemso, Aboabo and Amakom. Flooding in the river basin affects life and property in many ways. In particular, urban flooding affects the built environment considerably, as many structures are impacted by the floods. In some instances, both completed and uncompleted buildings are abandoned as a result of what is now an annual phenomenon.

An interesting insight into the causes of flooding was provided by residents who live in the area in a recent survey conducted by academics from the city's Kwame Nkrumah University of Science and Technology (KNUST). According to survey respondents, the most important cause of flooding is improper garbage or refuse disposal. A large percentage of the residents indicated that the method for refuse disposal was an issue. They believed that it was a major cause of the flooding problem since drains and the river bed itself were both choked with refuse. The next important cause of flooding incidence is the lack of drains in the area.

According to the survey, 61 percent of all respondents continued to live in the area, despite enduring the phenomenon of flooding each year, because they could not afford the cost of moving to another place. Some 10 percent continued to stay on because of proximity to their places of work, or because they had businesses at the flood risk areas where they also lived. Another 19 percent remained for other reasons, such as having lived there all their lives, or because the land belonged to them or was their family home.

The above evidence validates the assumption that it is socio-economic factors which affect the motivation of urban populations to stay in flood-prone areas. Residents remain in these at risk locations because of a variety of reasons but seemingly it is the cost of moving which prevents them from relocating. The case highlights some of the social issues that have to be considered in developing robust flood risk management plans and strategies.

Source: Personal communication: Divine Odame Appiah, Lecturer, Environmental Resources Management, KNUST, Kumasi, Ghana

2.2.5. Urban challenges

The economies of urban centers vary from simple, small market towns to more complex, large cities and metropolitan regions serving local, regional, national and global markets. Cities are usually major economic centers hosting enterprises and industries that create most of the Gross World Product (GWP) (Kamal-Chaoui and Robert 2009; Bicknell et al. 2009). However, the benefits associated with urban centers are not unalloyed. This is mainly because of the existence of negative externalities, including environmental costs such as high carbon-intensities, as well as the high vulnerability to climate change and natural disasters such as floods (Corfee-Morlot et al. 2009).

In addition, urbanization is to an extent responsible for higher concentration of greenhouse gases (GHGs) in urban areas and cities, causing greater capital costs and environmental damage (Corfee-Morlot et al. 2009). Rapid urbanization also means that urban centers will need to invest in infrastructure services given the increase in the demand for these (Jha and Brecht 2011).

Urbanization and consequent increases in urban populations, accompanied by urban expansion, can result in declines in average densities, as built-up areas spread outwards. This can compound flood risk and weaken urban resilience to flooding. Even though some of this increase is the natural consequence of urban population growth, urban expansion, which is often referred to pejoratively as urban sprawl, can also be associated with inefficient land use and planning policies (World Bank 2008). However, the need for accommodating expanding urban populations does require the consumption of more land. Similarly, higher densities are not always or necessarily a panacea for alleviating urban flood risk, as they often are coupled to increases in non-permeable surfaces, the occupation of vulnerable terrains, and levels of congestion which can compromise or even overwhelm the operation of infrastructure services such as solid waste. Photo 2.1 illustrates the impact of flooding on an informal settlement.

Photo 2.1: Informal Settlement in Mexico City, Copyright: UN-HABITAT.

2.2.6. Opportunities

The unprecedented rate of global urbanization in cities and other urban areas implies that exposure and vulnerability is increasing, which will cause loss of life and property unless proactive measures are mainstreamed into urban planning processes (Jha and Brecht 2011). Cities themselves are often blamed for social inequalities, the inadequacy of city governments, authorities and institutions, and environmental degradation (UN-HABITAT 1996; Dodman 2009). Nevertheless it should be recognized that cities can contribute towards more sustainable development, if they are adequately planned, governed and managed. Rapid urbanization presents the opportunity to do things right first time, by integrating flood risk management concerns into new settlements as they develop. As Dodman (2009: 186) argues, many of the processes implicit in urbanization may have a beneficial effect on global environmental change, as economies of scale and proximity can provide cheaper infrastructure and services. In order for cities to take advantage of their potentials, however, good governance and urban planning are prerequisites.

The Working Group on Climate Change and Development (WGCCD 2009) suggests that urban authorities in developing countries need to deal with both outdated infrastructure and urban expansion if they want to increase resilience in the face of climate change. Moreover urbanization shifts the balance of prevention from individual measures to collective action (World Bank and United Nations 2010). As a consequence, to address the flood risk that cities and urban areas in low- and middle-income countries face, a coherent, locally-specific and integrated response to this environmental hazard and risk is needed.

2.3. Direct impacts on primary receptors

This section outlines the direct impacts of flooding on primary receptors including people, the urban built environment, infrastructure, and family assets. Risks to life and health caused directly or indirectly by flood water are discussed, with flood-related injuries described in the pre-onset, onset and post-onset phases.

2.3.1. People

Floods worldwide pose a range of threats to human life, health and well-being. In 2010, reported flood disasters killed over 8,000 people directly. While economic losses rise, direct deaths from flooding may be declining over time as measures to prevent flooding are employed, particularly in developed countries.

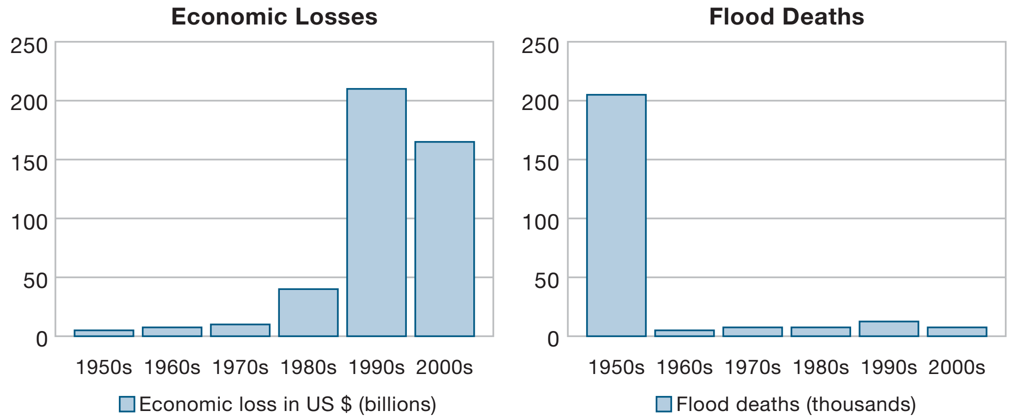

Figure 2.2: Reported economic losses and deaths. Source: based on EM-DAT/CRED

Two-thirds of direct deaths from flood events are caused by drowning and one-third by physical trauma, heart attack, electrocution, carbon monoxide poisoning or fire (Jonkman and Kelman 2005). Most deaths occur during a flash flooding event as against the slower riverine events (Du et al. 2010).

In developing countries such as Bangladesh, the majority of flood deaths have been found to be caused by diarrhea and other water-borne diseases, or from drowning and snake bites. In Vietnam, electrocution is the biggest cause of death in the immediate aftermath of flooding, followed by respiratory diseases, pneumonia and exposure to cold. Diarrhea-related deaths are primarily caused by a lack of pure drinking water, improper storage and handling of drinking water, poor hygiene practices and the often total deterioration of sewage and sanitation facilities which lead to the contamination of drinking water in flood affected areas (Kunii et al 2002; Ahern et al. 2005). These deaths can occur during the period following the reported flood and, therefore, are not necessarily recorded in disaster databases.

According to the Emergency Events Database (EM-DAT), on average over the past three decades more than one hundred million people each year have been affected by floods. This is reason enough for governments to take action towards reducing these statistics. The numbers affected have grown from around four million a year in 1950, to the present level, which represents more than one percent of the global population. The amount and seriousness of the impact on the affected population will vary and can involve physical injury or other health effects.

The most commonly reported flood-related injuries are sprains and strains, lacerations, contusions and abrasions. People may injure themselves as they attempt to escape, either by objects being carried by fast-flowing water or by buildings or other structures collapsing (Du et al. 2010). Flood-related injuries can also happen in the pre-onset phase, as individuals attempt to remove themselves, their family or valued possessions from the approaching waters (Ahern et al. 2005). Post-onset injuries are likely to occur when residents return to their homes and businesses to start the recovery and reconstruction process (WHO 2002, Few et al. 2004; Ahern and Kovats 2006). As these injuries are not monitored adequately, it is difficult to quantify the true burden of ill health due to flood events (Few et al. 2004).

The mental trauma of flooding, caused by witnessing deaths, injuries and destruction of the home, can result in severe psychological effects in some individuals. Grief and material losses, as well as physical health problems, can lead to depression or anxiety. Three types of mental health issue have been noted: common mental health disorders; post traumatic stress disorders (PTSD); and suicide (Ahern and Kovats 2006).

In the slums of Nairobi, coping responses to flooding include bailing out of houses to prevent damage to belongings; placing children on tables and later removing them to nearby unaffected dwellings; digging trenches around houses before and during floods; constructing temporary dykes or trenches to divert water away from the house; securing structures with waterproof recycled materials; relocating to the highest parts of the dwelling; or using sandbags to prevent the ingress of water.

The most vulnerable members of the community can also be those worse affected: the poor, the elderly and the youngest members of the community will often require special help and assistance. Research has found that children and the elderly are more likely to die, particularly from drowning, than are adults (Bartlett 2008).

2.3.2. Buildings and contents

Buildings and their contents can be directly and indirectly affected by flooding in a range of ways. In cities and towns, flooding in underground spaces, including subways, basement floors and utility facilities under the ground, is also typical. Direct impacts are the physical damage caused to buildings and their contents, whereas indirect effects include the loss of industrial or business processes.

The impact of flooding on housing and households can be devastating. Fast-flowing floodwaters are capable of washing away entire buildings and communities. Depending on their form of construction and characteristics of the flooding, many buildings may survive the flood but will be damaged quite extensively by the corrosive effect of salinity and damping, and be in need of substantial repairs and refurbishment.

Case study 2.3 describes the effect of flash flooding in Brazil.

Case Study 2.3: Flash floods and landslides in Brazil

Flooding in Brazil poses serious risks to people, infrastructure and businesses. River and flash floods combined with landslides is not something new for the country. It is important to highlight here that floods and landslides in Brazil, as elsewhere, not only directly affect people, buildings, infrastructure and the natural environment, but also have indirect effects, such as losses from business interruption as well as increased burdens on public and household budgets. Business interruption (e.g. caused by damage to business premises and buildings), increased travel time and costs and loss of income are indirect impacts that are often more difficult to quantify, and yet represent a significant proportion of the overall flood damage to communities.

In January 2011, floods in South-Eastern Brazil, including Rio de Janeiro and São Paulo, killed over 800 people. Over 100,000 people were left homeless and key infrastructure was destroyed. Increases in the frequency and severity of flood events are making flood risk prevention a top priority. In response to this, Brazil's major infrastructure program 'Programa de Aceleração do Crescimento' (PAC) plans investments in flood risk prevention, and President Dilma Rousseff requested World Bank support to modernize Brazil's disaster risk management systems.

Implementation of the projects is to be carried out jointly by the states and the municipalities, while the federal government provides funding. An example of flood risk prevention investment is an urban drainage project in the Baixada Fluminense region, which aims to control flooding in urban areas and will reach in total around 500,000 households. The case demonstrates the imperative for governments to attempt to help mitigate future flooding through investment in flood risk prevention measures.

Sources: Swiss Re 2011; IUCN 2011; PAC 2: http://www.brasil.gov.br/pac

Flood events can have a variety of impacts on businesses, ranging from direct physical impacts to indirect effects (to supply chains, for example). Damage to premises, equipment and fittings; loss of stock; reduced customer visits and sales as well as disruption to business activities are among the common effects experienced by UK businesses (Ingirige and Wedawatta 2011).

The characteristics of a flood, including flood depth, duration and contaminants, will influence the extent of damage caused to a building. The speed of flooding can also determine the extent of the damage: flash flooding, for example, can completely destroy properties or cause irreparable structural damage. In a slow rise flood, on the other hand, static floodwater can damage buildings in the following ways:

- Water soaks into the fabric of the building elements causing them to deteriorate. Water can soak upwards through building materials through capillary action and in hot conditions can also cause damage through excess humidity in enclosed spaces.
- Water pressure of standing water causes building elements to fail or structures to collapse
- Water can travel underneath buildings and their foundations, thus lifting or partially lifting them causing them to float away or to crack. Water can also lift building contents and they may be damaged or cause damage within a building.
- Chemicals or contaminants in the water can react with building elements or contaminate them.
- Water can cause failure of electrical systems resulting in secondary damage.

In a fast flood or coastal flood, water which flows around buildings may damage them in the following additional ways:

– Water that is moving exerts a greater lateral pressure on building elements than static water. Changing pressure can increase the stress on building elements.

– Moving water will tend to cause scour or erosion, potentially undermining buildings and causing collapse.

– Debris is carried at higher velocity and can cause severe damage due to collision.

– Fires can be caused by the collision of fuel containers with buildings.

Generally speaking, the faster the velocity of the water the greater the damage, but the depth of floodwater is clearly another important factor in determining the scale of damage. It has been found that flood depths greater than 600 millimeters are more likely to result in structural damage to buildings (USACE 1988). This relationship is normally demonstrated by a depth damage curve such as the example in Figure 2.3.

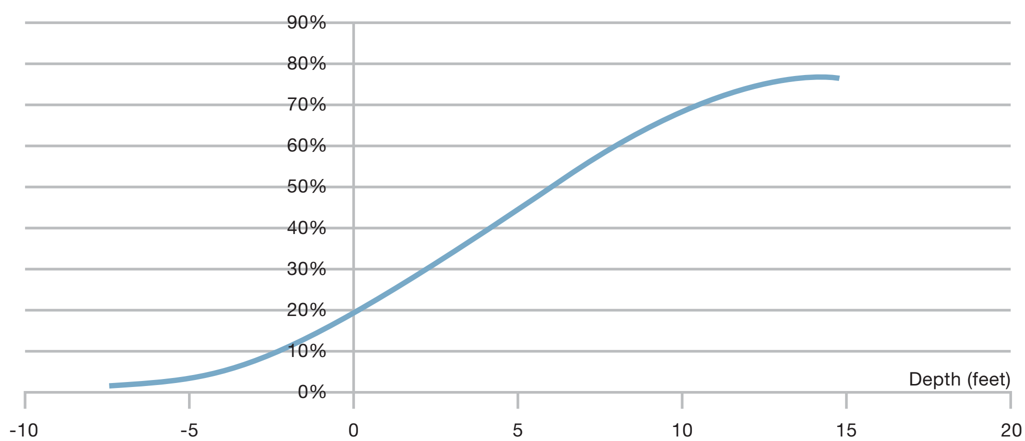

Figure 2.3: Example of a depth damage curve for one story residence with basement. Source: USACE National Economic Development Manuals

Anticipated flood depth will tend to be a deciding point for the method of flood protection. Hydrostatic head – the pressure caused by the weight of water being held above the pressure point – will place stresses on walls and any other vertical elements and will also drive floodwater through walls. If the flood depth is predicted to be greater than 900 millimeters, flood proofing is unlikely to be feasible unless specially constructed methods are used. The consensus of opinion is that the cut-off depth for wet-proof construction should be 600 millimeters (USACE 1988).

Flow velocity is presumed to be an important factor in the causation of flood damage, although hazard models rarely quantify its impact and its influence is therefore rarely taken into account. Some recent studies which have examined both water depth and flow velocity have concluded that the latter has a significant influence on structural damage, for example on roads, but only a minor influence on monetary losses and business interruption (Kreibich et al. 2009). However, it has also been recommended that if the other impact factor, water depth, is less than two meters then flow velocity alone is not a suitable consideration for estimating monetary loss in flood damage modeling and assessment.

The materials used for buildings, their drying characteristics and the condition of the building can also influence the extent of damage caused. Masonry construction, for example, is able to withstand the impact of flood waters up to a point but, being a porous material, it will absorb a large volume of water and take considerable time to dry out. Timber construction can be relatively waterproof but is often less robust. Adobe and soil based construction are more vulnerable to scour and erosion.

Building quality also has an impact on a structure's ability to withstand flooding. Flash floods within an urban environment present particularly high risks with respect to damage to buildings. As previously noted, many of the larger cities in the world which are at risk of flooding are characterized by high levels of density and congestion. For example, the city of Mumbai is extremely overcrowded which constantly threatens the city management system, leading to overburdens in sewage and wastewater, the dumping of household and commercial garbage disposals in open landfills and direct discharges to water bodies. Safety standards are also overlooked to fulfil the demand for space and development of property. As a result of the already existing difficulties in management, a flood in such cities causes havoc. Flood waters carry with them the debris of waste but also the treasured belongings of a dense and overcrowded city. The materials from buildings damaged by floodwater are also swept along. In an overcrowded space this may lead to an avalanche of further damage.

Existing buildings located in flood zones, therefore, represent a particular risk; in the light of climate change predictions, the adaptation of such buildings to future flood risk poses a considerable challenge for many countries. Regulations should also be designed to restrict or prevent new development, although it is possible that new buildings can be designed to withstand the affects of flooding by appropriate use of materials and flood resilient measures (Satterthwaite et al. 2007).

Damage caused to public buildings such as hospitals, clinics, educational buildings, and significant cultural sites such as churches can lead to further indirect impacts: for example, the disruption to education, which over a long term period can lead to children suffering academically; similarly, there is likely to be a reduction in the capacity for providing both immediate and longer term health care and support.

Release of contaminants poses serious public health risks for survivors of floods. Flood waters can mix with raw sewage and thus dramatically increase the incidence of water-borne diseases. Although the release of toxic chemicals is diluted by flood water (causing toxicity levels to decline) the uncontrolled release of various chemicals – some of which may interact with each other – poses a considerable risk to public health. Infrastructure

The UK-based Centre for the Protection of National Infrastructure (CPNI) defines national infrastructure as “those facilities, systems, sites and networks necessary for the functioning of the country and the delivery of the essential services upon which daily life … depends” (CPNI 2010). These sectors include finance, food, government, emergency services and health. Particularly at risk from flooding, are: communications; transport (roads and bridges, rail, waterborne navigation, both inland and sea, air), telecommunications; energy (power generation and distribution, petrol, gas, diesel and firewood storage and distribution); water supplies, and waste water collection networks and treatment facilities.

Case study 2.4 describes the impacts of flooding in Lomé on the city’s infrastructure, and specifically the damage caused to its road systems.

Case Study 2.4: Flooding in Lomé, Togo

Lomé, the capital of Togo in West Africa, is part of a submerging coast and lagoon system within coastal dunes. The city has two wet seasons due to its location which places it between the deep rain forests of the Amazonia type as well as the Congo Basin type. The practice of illegal sand mining is becoming a serious problem as the demand for sand is rising with increasing population and the exploding construction activities currently ongoing in Lomé. The increased sand-winning activities are causing coastal erosion and subsidence, and invariably causing huge harm for the ecological balance of the coastal flora and fauna in that area of the Gulf of Guinea coast.

The coastal lowlands within Lomé are the most populous neighborhoods and suffer from excessive pressure of formal and informal settlements, poor planning in urban areas, lack of proper drainage infrastructure and maintenance, and low levels of education and social awareness among people. The Lomé city master plan that is currently in use was crafted in 1983. While its provisions and management systems configuration may have been appropriate for the time it was drafted and the population was not as high as it is today, the plan needs immediate updating. The city in 1983 had about 120 km^2 of area but today, the estimated area of Lomé is 160 km^2. The problems are made worse by a continuous influx of people to the city in search of employment and a better standard of living. In Lomé and its surroundings, called "Great Lomé", over 250,000 people live in informal settlements most of which have been built in spaces previously assigned as waterways or natural water collection points. Most of the lands occupied by the very poor people happen to also be located in mostly low-lying parts of the city thus rendering the very poor vulnerable to floods. Flooding is a constant concern and poses a severe problem because floodwater sometimes takes several months to recede; pumping techniques are not appropriate because of the saturated water table in the low-lying coastal plain.

As a result of the country's decade-long creeping political crisis leading to social and political instability there persisted a complete (a) lack of maintenance and new investments which had considerably hampered the delivery of basic municipal services, and (b) a dramatic increase in urbanization, largely compounded by crisis-led population displacement contributing to increased pressure on existing infrastructure and services in most urban centers, especially, Lomé. Over 54% of Togo's population lives in Lomé city alone (Amankwah-Ayeh and Caputo 2011).

Lomé suffered from a flood event in June 2010 in which about 200,000 people were directly affected. The estimated costs and losses were: social sector $15.5 million and infrastructure $19 million. The impacts of flooding in Lomé and Togo in general have more far reaching implications and cascading impacts. Lomé is a major communications center and port, not only for Togo but also for neighboring landlocked countries such as Burkina Faso: the main roads, therefore, carry a great deal of traffic. In 2008, due to flooding disrupting the main roads and destroying rail infrastructure, heavy traffic was diverted on to minor routes. These minor roads became unusable, turning into rivers of mud. The damage to the road system is illustrated in Photos 2.2 and 2.3.

Photos 2.2 and 2.3: Roads destroyed in Togo, 2008. Source: Ayeva 2011

Due to lack of funds, only a few interspersed stretches of the major trunk road linking the port of Lomé to the landlocked capitals Ouagadougou, Niamey and Bamako have been reconstructed since the 2008 floods. This was worsened by the 2010 major floods. One of the consequences of the persistent flooding in the country has been a huge exodus of people, mostly out of rural areas in the north of the country to urban centers in the south, in search of stability and economic opportunities. As a result, urban poverty and overcrowding has dramatically increased in Lomé.

Recent government initiatives have resulted in many planned preventative measures of which a minority is in place with many more in process. Achievements to date have included refurbishment of pumping stations, dredging and cleaning activities, and roadside drain construction.

The study reveals how the actions in response to flooding can lead to other indirect impacts – in this case the damage caused to minor roads by traffic diverted from main roads due to flood disruption. Again the complex relationships of direct and indirect impacts and socio-technical challenges of flooding come to the fore.

Sources: Amankwah-Ayaeh and Caputo, 2011; Ayeva 2011.

Critical infrastructure is also defined by the CPNI as those elements of national infrastructure, of which “The loss or compromise ... would have a major impact on the availability or integrity of essential services leading to severe economic or social consequences or to loss of life.” Flood damage to infrastructure represents a considerable concern as it affects the ability of communities to respond during a flood and to recover after an event. Damage to critical infrastructure can represent a danger to life: damage to the road network, for instance, can prevent temporary flood defenses from being erected, as well as leading to major disruptions in the lives of people and businesses. Flooding of airports and railways can similarly create chaos for major national and international transportation hubs.

Impacts on power generation can lead to temporary and permanent power losses leading to loss of electricity, heating and lighting in some locations. Table 2.1 shows the damage to the electricity sector in Yemen by flooding in 2008.

	Hadramout-Wadi		Hadramout-Sahel		Mahara		Total Damage
Damage items	urban	rural	urban	rural	urban	rural	
a) Power plants							
Diesel power generators	0	50	200	90	220	40	600
others	10		10		4		24
b) transmission and distribution systems							
Transmission lines	880	300	220	40	140	20	1600
Distribution lines	300	150	200	20	120	20	810
transformers	120	30	70	100	40	40	400
c) transmission and distribution grids	150	50	100	20	20	10	350
others	40	10	150	20	10	2	232
total	1500	590	950	290	554	132	4016

Table 2.1: Damages to electricity services in flood-affected areas of Yemen (million YR). Source: GOY 2009

Water supplies can become disrupted and contaminated leading to health concerns. Waste water collection and treatment facilities can become overwhelmed leading to pollution and contamination of drinking water supplies. Damage to urban water systems can be much more severe than in the rural areas as shown in Table 2.2 from the earlier 2008 floods in Yemen. Urban damages again exceed rural ones.

Table 2.2: Damages and Losses in the water supply and sanitation sector

Sector	Damage	Loss	Total	Total
	Riyal Millions			US$m
Rural	1,059	66	1125	5.63
Urban water	3559	612	4171	20.86
Urban wastewater	1414	43	1457	7.29
Total	6032	721	6753	33.78

Source GOY 2009

Drainage systems can also become overwhelmed as a consequence of intense rainfall; they may also have inadequate capacity to cope with the rate of rain water runoff, leading to surface water flooding.

Box 2.1

Specific guidance on the social, economic and environmental impacts of disruption to essential services is limited. The UK's Water Services Regulation Authority, known as Ofwat, provides a framework listing the following as potential consequences of flooding-related disruption of water infrastructure:

- Loss of state revenues due to non-functioning of the private sector
- Costs associated with state support for provision of emergency supplies if interruption is substantial
- Inconvenience of interruptions due to service loss
- Health risk due to contamination of water supply and the environment
- Extra clean-up costs due to wastewater mixing with flood water and entering property
- Environmental pollution due to wastewater mixing with flood water.

Source: Ofwat 2009

The interconnected nature of modern infrastructure systems often means that failure of one system caused by floodwater can have a cascading impact on other systems which may or may not have been damaged by the flood. Loss of power, for example, may have impacts on many other systems such as water supply and communications. In particular the high dependence of most modern systems on information and communications technologies makes them extremely vulnerable to loss of connectivity.

2.3.3. Animals and crops

Within urban and peri-urban environments the impact of floods are likely to be on domestic pets and individual animals kept for personal food supply, such as poultry. Such animals can be regarded as part of the family and their rescue, or concern for their whereabouts, can delay or prevent evacuation. Floods also cause deaths and injuries to livestock and fish stocks and damages crops, although for urban populations this may represent an indirect impact, as they are less likely to be involved in agriculture than the rural population. Loss of agricultural production will, however, affect the food supply chain on which the population of urban areas are highly dependent (Weir 2009). Large-scale disasters like flooding can reduce food availability in cities, but such urban food insecurity is, for the most part, considered to be a food access problem, rather than a food availability problem. Food shortages lead to rising prices, so that the poor cannot afford to buy it as incomes decrease due to lack of work; this results in economic and financial hardship (IFRC 2010).

2.3.4. Cascading impacts

Flood events can be a catalyst for other disasters both natural and human-made, or can be part of a chain of cascading events mentioned above. A dramatic recent example of this phenomenon is the damage to the Fukushima nuclear power generator in Japan after the 2011 tsunami: a massive-scale disaster arose at the end of a chain initiated by an earthquake, as described in Case study 2.5 below.

A common secondary effect of flooding is large mudflows and landslides, as was observed in Korea in 2011. Catastrophic failure of interconnected infrastructure can also cause a man-made disaster if, for example, dam controls fail due to loss of power or flood damage. Chemical or sewage related pollution of water supply can result from damage to factories or treatment plants. In considering the impact of floods, and the benefits of prevention, the potential for cascading impacts should not be overlooked.

Case Study 2.5: 2011 Tsunami in Japan

On March 11 2011, a magnitude 9.0 earthquake, with its epicenter approximately 70 kilometers off the coast of Japan, triggered tsunami waves of up to 30 meters in height which struck Japan's coastline. More than 28,000 people died and some 490,000 people were affected. The earthquake and tsunami caused enormous damage to Japan's infrastructure including roads, railways and nuclear power plants. Preliminary estimates of the cost of the earthquake and tsunami are around US$309 billion, making it the world's most expensive natural disaster on record.

The case of Japan verifies that disasters can sometimes overwhelm even the best prepared countries and cities. Although concrete seawalls, breakwaters and other structures had been constructed along more than 40 percent of Japan's coastline, the tsunami overtopped these walls.

The result was even more devastating for the Fukushima nuclear power plant: the impact of the tsunami disabled the diesel generators that were vital to maintain power for the reactors' cooling system. The consequent malfunctions caused overheating which led to nuclear meltdown in reactors, and became Japan's worst nuclear accident.

The unprecedented crisis in the Fukushima nuclear plant highlights the risk of dependence on seawalls in particular, and other structural measures in general. Yoshiaki Kawata, a disaster management expert in Kansai University in Osaka and director of the Disaster Reduction and Human Renovation Institution in Kobe, commented in The New York Times:

"… this [disaster] is going to force us to rethink our strategy ... This kind of hardware just isn't effective."

Sources: Onishi 2011; EM-DAT (no date); UNEP 2011.

2.3.5. Post-disaster damage assessment

In the aftermath of major disasters such as floods, governments with the help of organizations such as the World Bank and the United Nations, undertake damage, loss and needs assessment, widely known as Post Disaster Needs Assessment (PDNA), in order to better plan recovery actions. Many use the Damage and Loss Assessment (DaLa) methodology, which was developed by the UN Economic Commission for Latin America and the Caribbean (UN-ECLAC) in the early 1970s. In the 2010 Pakistan floods, which have been described as the worst in the last 80 years, the assessed damage and loss estimated by the PDNA was PKR 855 billion or US $10.1 billion, which is equivalent to 5.8 percent of GDP (GFDRR, 2010).

Flood loss assessment can be carried out at various points within the event cycle: during the flood itself (thus informing the emergency response and relief coordination); in the immediate aftermath of a flood event (around one to three weeks after the flood peak); or three to six months after the event (to provide a more in-depth assessment of the full economic impact). Often the best time to conduct an in-depth assessment of flood losses is after six months, as most losses, including indirect and intangible losses, can then be assessed with sufficient reliability.

There needs to be a standard approach to loss assessments, primarily to ensure that works undertaken to provide mitigation or warning systems produce a sound return on the investment; to have a common measuring tool for assessing alternative mitigation plans; and to assist with post-disaster recovery planning and management.

Loss assessments should be transparent, so assessment procedures can be easily followed; consistent and standardized, to allow meaningful comparisons; replicable, to enable the assessments to be checked; and based on economic principles, so that assessed losses accurately represent the real losses to the economy.

2.3.6. How to conduct a flood damage assessment

It is important to perform damage assessment after any major disaster including flooding to enable a full and accurate assessment of the type and extent of damage. This damage may be a consequence of the economic, social and environmental impacts of flooding. Damage assessments might be undertaken most effectively sometime after the flooding, for example to help inform the development of flood risk management strategy at governmental level. At this time, it is more likely that the full impact of the flooding, including the indirect and intangible losses, will be known. The indirect impacts include those caused by disruption of physical, social and economic linkages of the economy and are more difficult to quantify in the immediate aftermath of the event. Typical examples are the loss of economic production due to destroyed facilities; lack of energy and telecommunication supplies; and the interruption of supply with intermediary goods. Results of damage assessments can also be used to evaluate cost-benefit appraisals when considering different flood mitigation measures and investments in specific flood defence schemes. At a more local scale, damage assessments can help inform the emergency response and relief coordination efforts in deciding how best to allocate resources and prioritize the response. It is equally important that damage assessments are undertaken in a reliable, consistent and transparent manner. Inaccuracies may lead to poor or improper investments and responses and so lead to a misuse of resources. A consistent approach provides for an evaluation of damage trends over a period of time and allows for a reliable evaluation of the benefits of flood mitigation measures.

Method

The following damage assessment methodology provides guidance towards undertaking a localised assessment of the tangible flood damage and is broadly based on that used by Jha et al (2010). The information obtained through this process will help to plan for the eventual re-occupancy of homes and businesses and provide useful information for plans for the design of new buildings including the adaptation of existing properties. Technical information on the type and nature of damage will be captured that will help inform the methods of repair and reinstatement and the resources (equipment, manpower and time) needed. The methodology involves a systematic approach which can be planned and rehearsed in advance of future flooding which will help with prompt implementation in the event of a flood.

1. Initial reconnaissance survey

2. Habitat mapping

3. Village transect
4. Property-level survey
5. Photographic documentation
6. Classification of buildings

1. Initial reconnaissance survey

An initial survey involves walking around the affected area to develop a general understanding of the extent and nature of the flood damage. This is best undertaken after the flood waters have receded and appropriate measures should be taken to ensure this is conducted safely. Personal protection equipment such as gloves, strong boots or wellingtons and a safety helmet would be suitable precautions. The information gathered at this stage will help develop a broader understanding of damage and help plan for subsequent more detailed surveys of individual properties. This will also enable plans for prioritizing next steps in the recovery process to be developed and provide information for the emergency services and others involved in the reinstatement process. The initial survey may be carried out by a team or individually by trained community workers, engineers and local officials.

2. Habitat mapping

Habitat mapping is a process of creating an aerial overview of the flood damage based on local information towards developing a visual representation of the location of damaged buildings and public spaces. Damaged property and infrastructure are identified geographically and categorized based on their damage (i.e. extent, type, severity). The map helps to provide a local understanding of the extent of damage to property and their proximities to other buildings, public areas and roads etc. Mapping can be undertaken using basic manual hand-drawn recordings or using high resolution GIS data. Information from the habitat map should be transformed into a list that is cross-referenced with public records / databases. The mapping is best undertaken by trained assessors including local officials and community members.

3. Village transect

A transect is a line following a route along which a survey is conducted or observations made and is used to analyze changes in physical characteristics from one place to another. A village transect will follow one or more streets and will show changes in the damage to buildings and infrastructure. This will help to identify emerging patterns in the type of damage to buildings and relate this damage to settlement patterns, the local geography, environmental features and other land uses. Drawings and sketches can be used to capture the extent and nature of flood damage as it relates to these features. This information is used to make decisions about environmental management, as well as relocation, resettlement and the planning and organization of the recovery process. The product of this process is flood event specific information in the context of local environmental characteristics and land uses.

4. Property level survey

Individual property surveys must be undertaken to provide detailed information for record / administrative purposes (tenure of property, owner characteristics and damage category) and for technical purposes (type of construction and materials, details of damage, reinstatement steps). This information is best recorded on a standardized survey form developed for this purpose. Checklists and prompts can be designed into the survey form to ensure consistency and completeness of the information collected. In carrying out the survey, attention should be paid to the depth of flooding as this will influence the extent of the damage and the likelihood for repair. Deep flooding can often cause structural damage to buildings which might require specialist works and in some cases the entire demolition of the building. Masonry built structures are normally able to withstand the effects of floods below say 400mm in depth but will typically absorb water and require drying out before repair works commence. Electrical services should be disconnected and checked by an approved electrician before they are used. Floodwater will usually leave a deposit of debris and sediment and this will need to be removed before repair works can proceed. These surveys are best undertaken by experienced surveyors or engineers with knowledge of buildings and materials.

5. Photographic documentation

A photographic record of each individual property serves a variety of useful purposes and can be undertaken as part of the property level survey. Insurers will find these photographs particularly useful in providing a clear record of damage to buildings and contents. This record can be used to validate other sources and will provide a basis for monitoring the reconstruction process. Local trained photographers with an understanding of the documentation process are needed to carry out the process.

6. Classification of buildings

Where no existing numbering system is in place, it is useful to create a temporary numbering system to help with the recording of information and management of the recovery and repair processes. This should follow a logical and simple format and is best designed by local community officials. Alongside this, it is useful to design a simple process of categorizing the levels of damage to buildings. This will need to be designed by qualified surveyors or engineers and some training will need to be provided to ensure consistency in its application. This combined process will serve to provide a comprehensive numbering and classification of property damage.

2.4. Indirect and other effects of flooding

In addition to the direct impacts of floods outlined above, there are indirect impacts caused by the complex interactions within the natural environment and the human use of resources in cities and towns. Such indirect impacts can be hard to immediately identify and harder still to quantify and value. Indeed, some will not become fully apparent until well after the flooding subsides. These indirect impacts can be subdivided into four major groups and are outlined below.

2.4.1. Natural environment

High rainfall can cause erosion and landslides, often on a large scale in areas of steep topography. These in turn can damage infrastructure, especially roads, which are often the only way of accessing communities affected by flooding. The erosion causes high concentrations of sediment and debris which are then deposited when the flooding subsides. Removal of the sediment and debris is costly and time-consuming. In some extreme cases, buildings and whole parts of towns may well have to be abandoned. Relocation may be the only solution, which will involve revised land use zoning.

The smothering of agricultural land by sediment can also be a problem for high value vegetable production in peri-urban zones, as a lot of such sediment is low in organic matter. Yields may never return to their previous level with resulting impacts on human livelihoods and nutrition.

Heavy rainfall can also cause damage to vegetation (whether natural or planted), and results in the reduction in the ability of vegetation to dissipate the energy of heavy rain. Primary forest cover with a high closed canopy is very efficient at dissipating rainfall energy whereas secondary regrowth or trees planted for economic reasons are less likely to have closed canopies and are less efficient in diffusing rainfall energy. This can result in less infiltration to the soil and higher levels of rainfall runoff which also further increases the risk of soil erosion and gullying (the latter being illustrated in Photo 2.4).

Photo 2.4: A gully caused by soil erosion. Source: Alan Bird

Coastal flooding in tropical areas as a result of tsunamis triggered by seismic action, or cyclones, causes damage or destruction to coral reefs which then reduces their ability to dissipate wave energy. When coupled with the fact that sea level rise in many such locations is now faster than the rate of coral growth, the risk of more severe flood events is increased. The damage to coral often increases the risk of coastal erosion.

The flooding of coastal areas with saline sea water as a result of cyclones and tsunamis renders farmland unfit for many crops, including high value vegetables that are often grown in peri-urban areas. It can take a long time and careful management to reduce the level of salinity. In many cases this may never happen. In some coastal areas such saline flooded land is converted to aquaculture with a whole set of complex issues over land ownership, land use planning, water quality and water management. After the 1991 cyclone in Chittagong, Bangladesh, for instance, such issues were further complicated by the spread of disease in saltwater shrimps which created pressure from aquaculture producers to change the water management system to supply them with non-saline rainfall runoff (Aftabuddin and Akte 2011).

2.4.2. Human and social impacts

The survivors of floods have a range of immediate needs, including safe drinking water, food and shelter. Such survivors are likely to be traumatized and vulnerable. It is a harsh truth that in cases where flood warnings, evacuations and safe havens have been successful this increases the demands after the flood in dealing with the larger number of displaced people than if these people had not survived. Lives saved during the emergency may result in increased hardship and deaths in the aftermath. This illustrates the need for flood warning and preparedness measures to be backed up by the stockpiling of immediate requirements – and also by a workable flood recovery plan.

2.4.2.1. Demographic changes

Demographic impacts of loss of life as a result of flooding can be significant, causing the age structure of communities to become unbalanced. A rapid epidemiological assessment in two cyclone devastated areas in the aftermath of the 1991 Bangladesh cyclone showed that mortality was greatest in children below the age of 10 and lowest (approximately four percent) for males greater than age 10. Further, for females, mortality increased with age and was greatest (approximately 40 percent) for women over the age of 60 (Bern et al. 1993).

The affected communities had very few elderly people left alive; similarly they had lost children who were too old to be carried, but not old enough to run inland to the main road which became the main refuge. More women than men were killed, partly because they were less physically able to run, but also as they had tried to save their children, putting their own lives at risk. It was also apparent that more girls and young women were killed than boys: the boys were often able to climb trees, whereas the girls did not, partly because of social taboos. Some years later, there was an increase in the birth rate, which was seen to be a response to 'replace' children who had perished. This created a very unbalanced age structure and, in particular, put a greater burden on women, which is often exacerbated by rising levels of post-flood gender-based violence and the negative impact of floods on women's assets, such as dowries, which often do not feature in post-disaster impact assessments.

In the case of Bangladesh, as elsewhere, these changes in demography varied greatly across the affected area, reflecting highly localized flood risk situations.

2.4.2.2. Health impacts

The impacts on human health as a result of flooding can be very serious indeed, and there is evidence that in some flood events more fatalities have occurred due to waterborne and water-related disease or injuries, rather than by drowning. During the 2007 monsoon floods in Bangladesh, snake bites were estimated to be the second most significant cause of death after drawing and contributed to more deaths than even diarrheal and respiratory diseases (Alirol et al. 2010)

Post-disaster human health is also closely associated with changes in the balance of the natural environment. For example, flooding caused by overflow of river banks, or by storm surges, alters the balance of the natural environment and ecology, allowing vectors of disease and bacteria to flourish. Outbreaks of cholera and a higher incidence of malaria can result from such alterations. Noji (2005) maintains that an increase in disease transmission and the risk of epidemics in the post-flood period depends on population density and displacement, and the extent to which the natural environment has been altered or disrupted. In 2009, weeks after back-to-back cyclones left nearly 1,000 people dead, the Philippines was grappling with an outbreak of Leptospirosis (a fatal flood-borne disease); this infected survivors from areas where dirty water had yet to subside. In a report to emergency relief agencies, Health Secretary Francisco Duque said that as of 26 October that year, there were 2,158 confirmed cases of this particular infection, with 167 deaths reported by the National Epidemiology Center (IRIN 2009).

The provision of adequate non-contaminated water supplies during and after a flood event is critical. There are often problems due to a lack of fuel to boil water for drinking. The range of measures that can be used to address this problem are outlined in Chapter 4. The main risks are diarrheal diseases including cholera, dysentery and typhoid along with malaria, dengue (although mosquito carriers require relatively clean water habitats), Leischmeniasis (also known as kala-azar) and the above-mentioned Leptospirosis, spread by contact with water contaminated by infected animal urine.

Another significant issue is the psychological impact on survivors, including delayed trauma. Many survivors, including children, will be severely traumatized. Great care is needed when dealing with this. A number of studies have shown a range of symptoms resulting from exposure to natural disasters such as flooding. Among these consequences, individuals may experience symptoms of post-traumatic stress disorder (PTSD), depression, and anxiety (Mason et al, 2010). Fischer (2005) and Miller (2005) suggest that alcohol consumption, substance abuse, and antisocial behavior increased among men in the aftermath of the 2004 Indian Ocean Tsunami in India and Sri Lanka.

Given the range and severity of health implications following disasters, the health profession has developed new approaches and new mechanisms referred to as 'disaster medicine' or 'disaster health management' (Andjelkovic 2001).

2.4.2.3. Human development impacts

The impact on long-term health and development of populations may be difficult to quantify but some research shows that severe floods can affect nutrition to the extent that children affected never catch up and are permanently disadvantaged (Bartlett 2008). Births in the immediate aftermath of disasters are likely to result in higher mortality and birth defects. After a major event, displacement or break up of families due to the death of one or both parents can have disastrous long-term effects on the families themselves and the wider community. Education can also suffer due to malnutrition effects, displacement or schools being closed. Although in wealthy areas a flood event is usually a temporary interruption which can be coped with, in poorer areas floods typically worsen poverty..

2.4.3. Economic and financial impacts

The direct impacts of flooding identified in Section 2.3 will have knock-on economic implications aside from the cost of replacing damaged or destroyed items. For example, a recent report stated that flooding is one of the major factors that prevents Africa's growing population of city dwellers from escaping poverty, thereby standing in the way of the UN 2020 goal of achieving 'significant improvement' in the lives of urban slum dwellers (ActionAid 2006).

Case study 2.6 describes how heavy rains caused extensive landslides and floods in many parts of Colombia, affecting millions of people and having a significant effect on the economy.

Case Study 2.6: Colombia's 2011 floods

Continuous heavy rains caused mudslides and floods in 28 of Colombia's 32 provinces (Departamentos). In total, more than three million people, which represents nearly seven percent of the country's total population, were displaced or suffered significant damages to their homes and livelihoods. It was probably the worst disaster caused by a natural event in the country's history: according to the national government, this flood disaster could reduce Colombia's 2011 GDP by over two percent.

The La Niña/El Niño weather phenomenon along with Colombia's geography were the major triggers responsible for the unprecedented disaster. The average amount of precipitation in some parts of Colombia in the middle of 2010 was five to six times above the average. In addition, rain-saturated mountain soil crumbled away, causing daily landslides as well as sedimentation, which raised water levels in rivers.

However as Manuel Rodriguez Becerra, former Colombian Minister of the Environment noted, flood risk had been considerably increased by human-induced activities. Deforestation and the destruction of both high-mountain and savanna wetlands has altered the water cycle in the country and have led to the more flood events, which have in turn created favorable conditions for landslides. Moreover, development has often been allowed in flood plains; poorly-designed drainage systems mean even modest rain showers can cause flash flooding. "These are natural catastrophes but, essentially, they are man-made," Bruno Moro, the UN Humanitarian Coordinator in Colombia, commented. Colombia's recent floods demonstrate the impact of human activity towards increasing flood risk – in this case a combination of deforestation, destruction of wetlands, improper development and poorly designed infrastructure – and the necessity of accounting for this impact in designing flood risk management measures.

Sources: Otis 2011; Morales 2011.

2.4.3.1. Impact on long-term economic growth

In assessing the economic impacts of flooding, care must be taken to adopt both local and national perspectives. Disasters have a large impact on those directly affected but a much smaller effect on the national economy. Some local impacts, such as the effect on the tourist trade, may be balanced by growth in trade elsewhere in the country. Typically, small to medium scale disasters may have no impact on the national balance sheet.

At a national level, studies have found a variety of relationships between disasters and economic growth. There is some evidence to suggest that frequent natural disasters can have a positive impact on national economies (Kim 2010). The process has been labeled 'creative destruction', based on the assumption that reconstruction activities result in increased employment and renewal of facilities. An article by Skidmore and Toya (2002) into natural disasters in 89 countries concluded that the frequency of climatic disasters is positively correlated with human capital accumulation, growth in total factor productivity and per capita gross domestic product (GDP) growth. Noy (2009) found that a nation's ability to mobilize resources for reconstruction influences the relationship between disasters and economics. Developing countries are therefore unlikely to benefit in the long term from disasters.

Other studies have contradicted these findings, but Kim (2010) found a difference between climate-related and geological disasters, in that the former had a positive effect on the long run economy. Loayza et al (2009) found that median level flood events had a significantly positive impact on economic growth, while larger scale floods had little effect.

2.4.3.2. Impact on development goals

As a result of the lack of insurance cover, most low income countries divert funds from other development goals to flood recovery operations after the fact. Governments may face liquidity problems in the face of massive natural disasters and have to rely on international aid, development funds or insurance to reinforce national tax revenue. Gurenko and Lester (2004) estimate that, on average, the direct cumulative costs of natural disasters in India account for up to 12 percent of central government revenues. This can have a significant impact on the national economy, resulting in important infrastructure spending being delayed or cancelled.

In addition, there will be a need to arrange a system of financing for replacement infrastructure provision, both private and public. It is likely that funding for this will be at the expense of existing ongoing development work. Economic priorities have to be set against a background of widespread need and the economic implications will, therefore, spread through a much wider part of the society than those directly impacted by flooding. The challenge is for governments and the private sector to work together to set the priorities for reconstruction.

Another post-flood impact, which directly or indirectly affects already suffering people, is the burden of debt for restoration of the economy. This puts extra pressure on people and reduces their financial ability to cope with the changed situation, making them in turn more vulnerable.

2.4.3.3. Impact on livelihoods

At the household level, livelihoods are likely to be severely undermined. The severity of this is a function of the impact of the flood on employment availability, specifically whether any members of the household have been killed or injured and the degree to which they contributed to the social and economic functioning of the household. Single-headed households, notably by women, are particularly vulnerable to the loss of livelihoods.

At the wider community level, skills which will suddenly be in demand (for instance, those needed for building replacement infrastructure) could well be beyond those available within the surviving population.

2.4.3.4. Business interruption

Businesses often fail in the aftermath of disasters due to direct damage, or to indirect impacts such as business interruption. Business may be closed down due to lack of access or failure of basic services, such as water supply, waste water collection and treatment, electricity, roads and telecommunications. This, in turn, is likely to have significant economic implications for areas much wider than the immediate flooded area. The replacement of such services can be complex (for example, starting up a damaged power station when you need power in order to do so), will take time and money, and will cause serious economic losses. The 2011 tsunami in Japan put a serious strain on the national economy and also had global impacts: as an example, the supply of

Japanese-made vehicle parts to automobile assembly plants around the world was severely disrupted.

Businesses which can continue to operate may take months to recover and to return to normal trading. The recovery process may be hampered by the loss of documentation in the flooding, leading to delays in tracing orders, completing insurance claims and issuing invoices. Other indirect effects may include increased expenses; lack of demand; the short term loss of market share; loss of key personnel; lack of availability of staff due to injury, travel difficulties or involvement in recovery operations; loss of production efficiency; loss of supplies; withdrawal of licenses; and loss of quality accreditation or approved standards. For many businesses these impacts can be catastrophic: one report suggests that 43 percent of companies experiencing a disaster never reopen and 29 percent of the remainder close within two years (Wenk 2004).

2.4.4. Political and institutional issues

A severe flooding occurrence is likely to place a serious strain on the institutional structures and capabilities that, in less developed countries, may already be weak. There will be a pressing need to clearly identify the roles and remits of both government and non-government organizations. The lack of or poor performance by government organizations can seriously undermine faith in government institutions; this happened after Hurricane Katrina in New Orleans in 2005. In some cases, political bias in allocation of funds is detectable, which may result in donors reducing the level of future disaster aid.

Another major factor can be maintaining the security of assets that displaced people have been forced to leave behind. The less well-off sections of society will be those least able to help themselves, but conversely they have fewer assets to lose. This may also have ethnic or gender dimensions, which can divide communities and lead to political instability.

2.5. Vulnerability and risk mapping

Given the seriousness and implications of the flood impacts detailed above, techniques are required for the estimation and assessment of risk. According to the United Nations Department of Humanitarian Affairs (UNDHA) the concept of risk assessment involves the survey of a real or potential disaster in order to estimate the actual or expected damage for making recommendations for prevention, preparedness and response (UNDHA 1992). This essentially consists of evaluation of risk in terms of expected loss of lives, people injured, property damaged and businesses disrupted. Based on the existing definitions, risk is the product of hazard and vulnerability and can be mathematically expressed for a given event in a particular area and reference time period.

Hazard assessment is explained in detail in the previous chapter. The associated factor for risk assessment, vulnerability, will be dealt in the following section. Assessments are mainly based on the depth of flood water and they are further used for risk analysis and evaluating the cost of damage. The main philosophy behind evaluation of risk is to provide a sound basis for the planning and allocation of funds and other resources. The framework of risk assessment illustrated by WMO (1999) indicates that evaluation of hazards and vulnerability assessment should proceed as parallel activities, in a consistent manner, so that results may be combined and comparable. For example, two cities may be equally vulnerable, but could have very different exposure to the hazard, depending on their elevation. The main problem in doing so is the availability of organized data, especially in developing countries – and the cost and effort needed to acquire data.

The basic steps involved in a risk assessment process are:

- Hazard estimation with reference to location, level of severity and the frequency of event occurrence
- Estimation of exposure of elements at risk
- Estimation of vulnerability
- Estimation of risk by integrating hazard, exposure and vulnerability.

As indicated earlier, in most cases risk assessments are performed based on direct damages. Indirect damages, also known as 'second order' effects, are often ignored leading to underestimation of the total cost of flood damage. It can be difficult to get appropriate data for indirect damage assessment, the main problems being measuring accurately the ripple effects on the economy and impacts on infrastructure and communication disruption. In addition, historical data do not disaggregate the total loss into direct and indirect losses; discrepancies in data can arise when gathered on a survey basis and there may be non-cooperation in disclosure of financial losses by affected people and companies. The assessment of second order risks is, however, achievable if appropriate data is available. In order to perform a comprehensive risk assessment, thus reducing the difference between actual and estimated damage assessment, integration of primary and secondary sources of damage assessment and risk evaluation is necessary.

In areas of multiple hazards the risk is sometimes cascading in nature. It might not be generated by natural sources, but accompanies an event or follows immediately afterwards. Flooding leaves a large amount of debris in its way, disrupting normal drainage and transportation systems. It may also cause fires and electrical short circuits, leading to more damage and destruction. Salt water contamination in coastal regions can also affects water supply lines, as well as contributing to the rate of deterioration of property and other assets.

In addition to raw sewage spills and debris, flood water may also contain toxic materials, leading to pollution of the local environment. There are occasions when a landslide or earthquake causes flooding: this is particularly true in multihazard areas where one disaster leads to another, resulting in a much greater incidence of damage and destruction.

Case study 2.7 discusses risk assessment issues within the context of the most significant international flood events in recent times in Pakistan.

Case Study 2.7: The 2010 Pakistan flood and the challenges of risk assessment

In July and August 2010, Pakistan was hit by extreme rainfall leading to devastating flooding that killed more than 2,000 people and affected more than 20 million. The areas most affected by the overflow of the Indus River coincided with the districts with the highest population density. This is because population in this semi-arid area has concentrated near to sources of water.

The onset of the flood event was intense monsoon rainfall on the last three days of July and the first days of August. In the northern part of the catchment, this led to a sharp peak in the river level. Continuous heavy rains then further enforced the flood wave as it moved downstream.

More deaths were reported in the upper catchment where the river gradient and flow velocities were highest. The flood event in the upper catchment area was significantly higher than previous maxima in the 66 years of records. Extrapolation from the gauging station data indicated that for the upper catchment this corresponded to a 1000-year return period, and in the mid-catchment to an 86-year return period. Downstream, the semi-arid areas were more accustomed to deal with water shortages, rather than flood disasters.

Flood monitoring and prediction along the River Indus during such events is problematic. While flood arrival times along the river are relatively easy to predict (the lead times were as much as 10 to 15 days in the southern parts of the country), the propagation of the water in the floodplains is not. There are strong interactions between the main channel of the river and its wide irrigated floodplain, which extends to as much as 20 kilometers across at peak discharges. The unpredictability is exacerbated by the uncertain state of repair of embankments: where these fail, the water immediately and unpredictably inundates the areas behind them. This case reveals how previous flood events may not be a reliable source in predicting future flooding. The complexities involved in predicting propagation of the water are considerable, and uncertainty in the state of embankment repair can lead to further unpredictability.

Source: Straatsma et al. 2010; NDMA Pakistan: http://www.ndma.gov.pk

As discussed above, the impact of floods on the urban environment is caused by the action of hazard on exposed and vulnerable receptors. Changes in impacts from flooding can, therefore, result from changes in the hazard; changes in the exposure of populations and their assets; or changes in the vulnerability of the exposed populations and assets. To understand the potential impact on a community and the appropriate response, flood risk maps are an invaluable tool: they provide the foundation upon which a well-planned risk management strategy can be built. They assist decision makers to make cost benefit assessments, to prioritize spending, to direct emergency assistance and to design and implement mitigation activities of all kinds. Risk maps are also necessary for financial planning and insurance purposes.

Flood risk maps are built upon the flood hazard maps which were discussed in Chapter 1 and on the understanding of the impact of different flood events on the exposed population and assets. In this chapter the impacts which lead to damage and loss have already been outlined. In order to quantify flood risk completely, it is necessary to estimate the expected losses from potential future flood events, based on the best understanding of impacts. Most risk assessments will start with an assessment of losses due to physical direct damage using a stage damage function and asset database.

Extension of risk analysis to incorporate indirect and intangible losses is rarer. Such damage calculations include other sources of uncertainty such as the valuation of non-market goods and affected services (like ecosystems and biodiversity) and the choice of discount rate or any other means of dealing with time preference (Hall 2008; Merz 2010).

2.5.1. Assessing vulnerability

Vulnerability is the degree to which a system (in this case, people or assets) is susceptible to or unable to cope with the adverse effects of natural disasters. It is a function of the character, magnitude and rate of hazard to which a system is exposed, its sensitivity (the degree to which a system is affected, adversely or beneficially) and its adaptive capacity (the ability of a system to adjust to changes, moderate potential damages, take advantage of opportunities or cope with the consequences). The different types of vulnerability and the factors affecting their rate of exposure are shown in Table 2.3.

Types of Vulnerability	Exposure factors
Individual or household vulnerability	Education, age, gender, race, income, past disaster experience
Social vulnerability	Poverty, race, isolation, lack of social security services
Institutional Vulnerability	Ineffective policies, unorganized and non-committed public and private institutions
Economic Vulnerability	Financial insecurity, GDP, sources of national income and funds for disaster prevention and mitigation
Physical Vulnerability	Location of settlement, material of building, maintenance, forecasting and warning system
Environmental Vulnerability	Poor environmental practices, unprecedented population growth and migration
System vulnerability	Utility service for the community, health services, resilient system
Place Vulnerability	Mitigation and social fabric

Table 2.3: Different types of vulnerability and the factors affecting their rate of exposure

To measure vulnerability at different scales, hazard researchers have used numerous strongly correlated variables, such as the physical, social, economic, and political condition of the area of occurrence. Some of the major factors which increase vulnerability to urban flooding, especially in developing countries, are: poverty; poor housing and living conditions; lack of preparedness and management of flood defenses; increasing population; development of squatter settlements in hazard prone regions; poor maintenance of drainage structures; lack of awareness among the general population; and limitations in early warning systems.

Vulnerability assessment is carried out in order to identify the most vulnerable sections of the society and thus prioritize the assistance by channeling resources. Undertaking a vulnerability assessment therefore requires consideration of: the location of the area; resources under threat (both population and physical elements); level of technology available; lead time for warning; and the perceptions of residents regarding hazard awareness (ADPC 2005). Mapping vulnerability can help the policy makers and managers to identify the areas of highest susceptibility and impact, in order to reduce vulnerability and enhance capacity building, by concentrating efforts in those locations.

Case study 2.8 describes a comprehensive vulnerability study of a city in western India.

Case Study 2.8: Surat vulnerability analysis, India

Surat is a coastal city located in the state of Gujarat along the tidally-influenced Tapti River in western India, approximately 250 kilometers north of Mumbai. In the last four decades, the city recorded one of the highest growth rates in the country and a 10-fold population rise. About 20 percent of the city's population lives in 420 slums.

Many of these slums are located along the tidal creeks and the riverside, and are therefore highly exposed to flood risk. Flooding, coastal storms and cyclones, as well as sea level rise, are among the current climatic threats Surat must cope with.

A city wide vulnerability assessment was recently carried out using a GIS-assisted vulnerability assessment technique. The UK's Department for International Development's (DFID) livelihood framework, adjusted for the urban context, was employed for the vulnerability analysis. With regards to disasters, the vulnerability analysis found that:

- A low educational capacity among lower income groups and slum dwellers is one of the main constraints to raising awareness and implementing effective resilience strategies
- Surat has one of the highest per capita incomes in India. However, about one-third of its households experience income instability, as more than 75 percent of the lower income groups and slum dwellers work in semi-skilled or unskilled jobs, and approximately half of the middle class population relies on informal trade. As a result, these population groups are highly vulnerable to changes in the city's economy, disasters or other external shocks
- The data also suggest that lower income groups, slum dwellers as well as migrants, have weak social networks while NGOs and micro-finance coverage is limited, meaning that other ways to increase social capital have to be explored
- Among the poorer socio-economic groups, insurance coverage is low. As a result, they suffer considerably during disasters and need more time to recover
- Lower income groups and slum dwellers as well as upper socio-economic groups both live in locations exposed to floods, resulting in increased physical vulnerability independent of socio-economic factors.

The Surat vulnerability study reveals the implication of low educational capacity, income, social networks, insurance and location for vulnerability. All of these factors have to be considered in prioritizing investment and other social interventions in the cause of flood risk management.

Sources: ACCCRN 2009; SMC n.d.; Bhat 2011.

2.5.2. Vulnerability maps

Vulnerability maps are based on two major factors: the location of the elements at risks (buildings, roads, bridges, settlements critical infrastructure and utilities); and the vulnerability of those elements to different aspects of flooding (flood height, duration, sediment concentration, velocity of water, impulse and level of pollution). Development of vulnerability curves, or stage-damage curves, can be plotted based on different classes of land use, to specify their values in relation to the magnitude of flooding (Smith 1994).

Vulnerability can be expressed as the degree of loss resulting from occurrence of a natural phenomenon on a scale of 0 to 1, where 0 indicates no vulnerability and 1 is the highest level of vulnerability. This helps in prioritization of mitigation activities. The stage damage curves can be developed in two different ways: either from the actual damage survey from an event, or based upon a hypothetical scenario of an event. The data for the stage damage function are normally obtained from existing inventories, such as cadastral maps, land use maps and information from land valuation or registration offices. Information on the materials used to construct buildings is required, as well as an indication of the condition (whether in a good state of repair, for example). Obtaining such detailed data on an individual level is quite difficult in many cases, especially in countries with weak asset data systems. The survey is conducted based on the value of different classes and a potential valuation curve or stage damage curve is prepared; based on these, a flood vulnerability map can be prepared using GIS software to assign values per pixel for the entire affected area. The map will then indicate the level of vulnerability that each land use type is exposed to, based on their indicative values from the depth-damage curves.

Flood management in an area can be made highly effective by means of vulnerability zoning, in which areas classified from higher to lower levels of vulnerability. This further helps in the proposition of flood defense mechanisms, effective flood control measures, evacuation planning and flood warning. Figure 2.4 illustrates how factors like the velocity of water and water depth (the main impact factors) help in developing flood hazard maps, and in turn, in identification of the areas of highest vulnerability based on a land use map. This gives an indication of which areas need to be evacuated most rapidly, as well as showing areas suitable for temporary refuge. Table 2.4 summarizes the methods that can be used for vulnerability at different scales of interest, from national down to local.

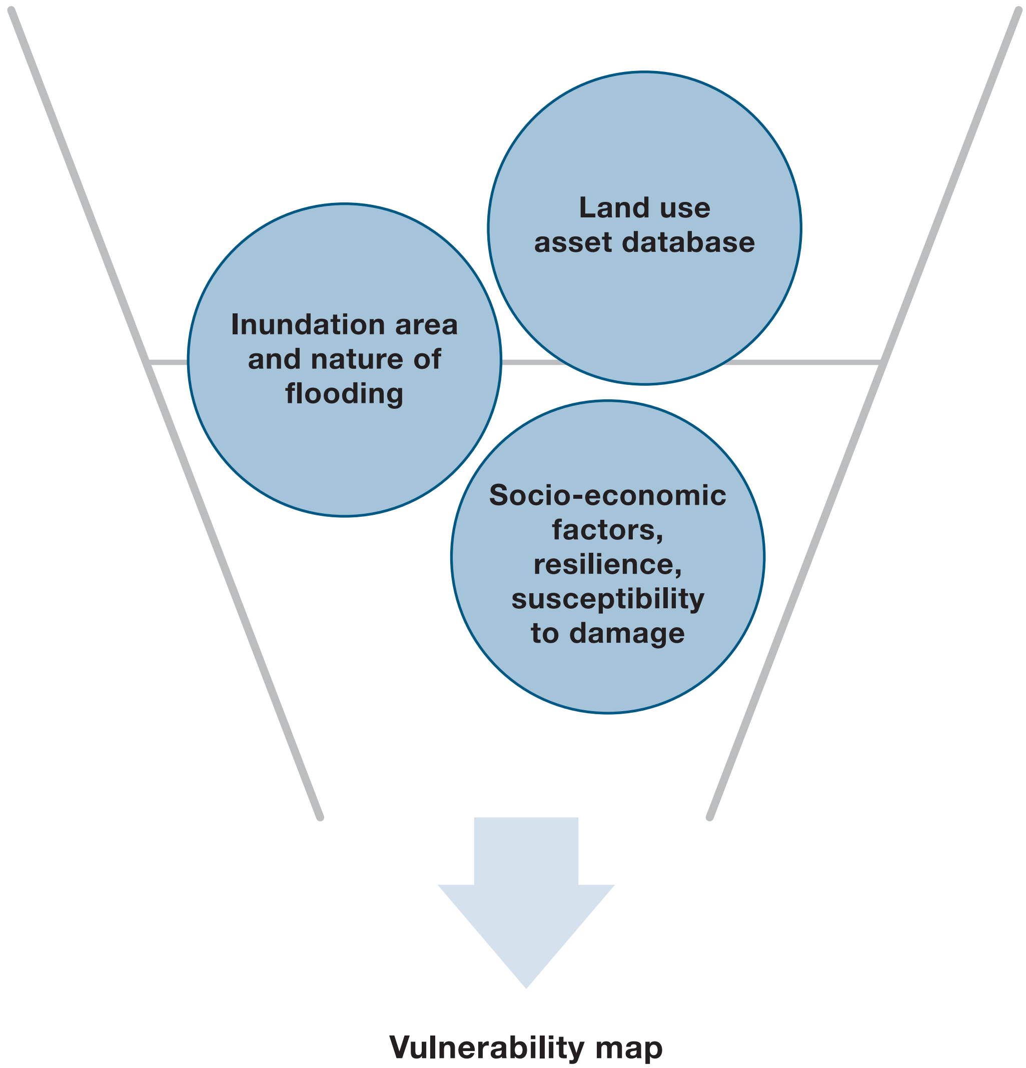

Figure 2.4: Flood Vulnerability assessment in urban areas

Table 2.4 Vulnerability assessment methods at different scales:

Serial number	Methods	Remarks
A	National Level	
1	Disaster Risk index by BCPR-UNDP	Based on historical vulnerability, for example mortality and level of damage; simple and straightforward
2.	Hot spot model by World Bank	Calculated to get vulnerability coefficients; based on disaster related mortality and losses
3	Composite vulnerability index for small island states	This method is event specific.
4	Small island states: natural disaster vulnerability indicator	Uses five specific indicators of vulnerability; representation via scale of 1-4, (1 being of highest vulnerability and 4 the lowest)
B	Megacity level	
1	Mega city level vulnerability assessment by Munich Re	It is important for understanding the level of vulnerability of the existing infrastructures and population; does not take into account historical disasters
C	Local Scale	
1	Vulnerability assessment at local level	Data acquired from local offices at municipal level, questionnaires and national archives, where available; several factors are used to assess vulnerability
2	Household sector approach	Effective for high magnitude event; surveys individual households to gather data about their level of vulnerability
3	Vulnerability at community level	This approach provides a comparative vulnerability analysis between communities in an area; data is primarily collected through questionnaire surveying and interviews
4	Normalizing vulnerability and risk community comparison	Vulnerability is accessed at town and city level by integrating data from aggregation of parameters at this level
5	Holistic approach	Method combines the approach as represented by exposure rate, social fragility and lack of resilience measures; easy to apply in cities but needs specific survey to gather information

Source: Adapted from Villagran de Leon 2006

2.5.3. Flood risk maps

Areas at risk of flooding can be dynamic in nature. With a changing level of development, the nature and degree of risk also changes. Flood risk increases mainly because of an increased level of exposure of the elements under threat. For example, there are occasions when infrastructure or other buildings are constructed in areas already at risk, thereby automatically falling within a risk zone. There are also instances when, at the time of construction, the assets and infrastructures are thought to be outside the risk region, but there are newer effects arising from changing land uses as urban development proceeds. These can include increased rates of runoff, lack of drainage systems, lack of storage systems, overwhelming amounts of rainfall leading to overflow, and the channelization of rivers which may reduce the amount of discharge they can accommodate. All these factors can increase the number of elements at risk of flooding in an area. Continuous updating and monitoring of risk maps is, therefore, most important for proper flood risk management: decision-makers need up-to-date information in order to allocate resources appropriately.

Flood risk maps represent a spatial integration of the hazard, exposure and the level of vulnerability. They effectively combine vulnerability maps with flood hazard maps to give an overall view of risk, as illustrated in Figure 2.4.

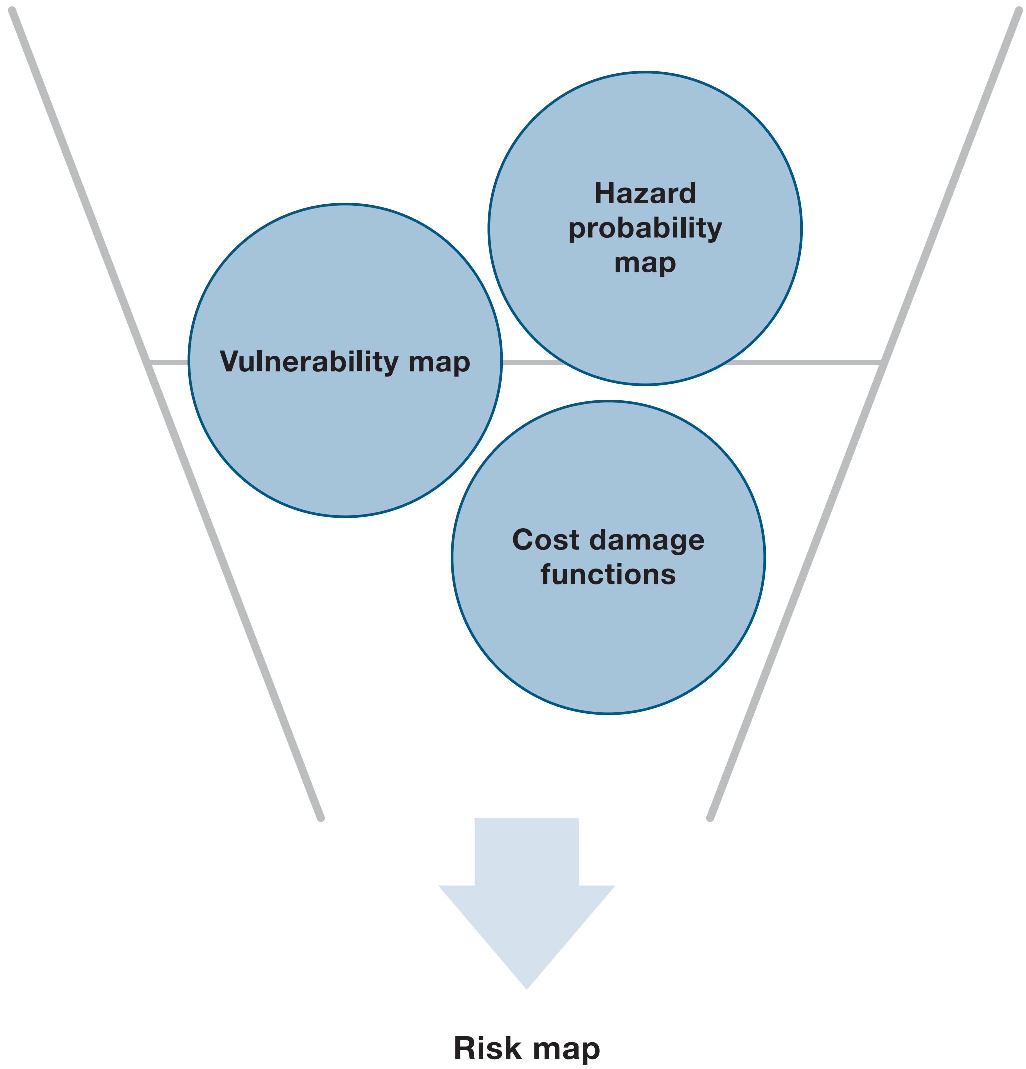

Figure 2.4 Generation of risk map.

The hazard maps provide information on the probability of flooding for different return periods, as well as the depth and extent of the flood water in the affected area. It has been argued that, even without an increase in flood hazard over time, the impact of flooding has risen (and will continue to rise) because of the increased exposure of primary and secondary receptors (Changnon 2003). There are other factors that are potentially quite significant, but may be difficult to quantify: changing risk due to societal factors, (such as development in and near floodplains), land surface alteration, the dynamic nature of social systems in general and societal vulnerability to flooding in particular (Moors 2005).

Numerous sources of uncertainty are present in the formal calculation of risk, as discussed in Section 1.3.2; flood damage prediction depends on approximations in hydrological and hydraulic models, including the neglected contributions to flooding such as debris, structure failures, and local storm water drainage.

There may be differences of opinion when it comes to the decision-making process in assessing the areas of highest risks. It is, therefore, a prerequisite to appraise these areas to an appropriate level, in order to identify the best strategies for risk reduction. This requires special attention to the magnitude of flooding (from the flood hazard maps) and the identification of the vulnerable elements (from the vulnerability assessment criteria). The spatial distribution of the vulnerable elements shown by the flood risk map will then identify clearly the areas of concern and their level of risk. The decision-making process also depends upon other factors, such as perception of risk in relation to cost-benefit analysis, measures taken for risk reduction strategies or alternatives available for risk mitigation. The risk map is, however, the core component of the flood risk management strategy.

2.5.4. Considerations for flood risk mapping

Risk evaluation is the basis for the design of methods to prevent, mitigate and reduce damages from natural disasters. Although there are several available methods for assessment of risk, it has been observed that in many cases societies prefer to set arbitrary standards as the basis for risk mitigation.

Without a clear and detailed evaluation of risk, those with responsibility for planning will have inadequate information for allocation of resources for mitigation purposes. This makes it more important to have a standard method for preparation of flood maps as a utility tool for the decision makers. Table 2.5 below presents key issues for flood risk mapping.

Actions	Considerations/ operations	Outputs / benefits
Data Collection and Integration	Actual event data, historical data, socio-economic and physical data Sources: local municipalities, regional or national data archives, international organizations like WMO, EM-DAT, existing vulnerability curves for different countries Field Surveying Hypothetical scenario generation for modeling vulnerability	Output in the form of database Important for integration of data from different sources and for future vulnerability analysis of the elements at risk
Generation of stage damage functions or vulnerability curves	Depth of flood water for different return periods Value of the elements at risk depending on their location, condition, material of construction, number of floors, and existence of cellars Extracting data by graphically representing the percentage of damage of the elements at risk to depth of flood water due to lack of resilience and adaptive capacity	Vulnerability curves are important for identifying the level of damage that has been (or can be caused by) different water depths
Conversion of depth-damage-curves to vulnerability maps	Importing data to GIS software (Arc GIS (ESRI), ILWIS (Integrated Land And Water Information System; open source), GRASS (Geographic Resource Analysis Support System; open source) Map classifications based on high, medium and low vulnerability	Conversion of results to an accessible, visual format as maps Essential for illustration of zones of high, medium and low vulnerability for action prioritization
Using vulnerability maps for risk assessment	Integration of hazard maps and vulnerability maps to produce risk maps	Output is in the form of maps showing high, medium and low risk areas Utility tool for decision making to local, regional, national and global authorities

Table 2.5 considerations for flood risk mapping

2.5.5. Further reading

UN Economic Commission for Latin America and the Caribbean (ECLAC). 2003 "Handbook for Estimating the Socio-Economic and Environmental Impact of Disasters." ECLAC.

Planitz, A. 1999. "A Guide To Successful Damage And Needs Assessment." South Pacific Disaster Reduction Program (SPDRP).

World Bank. 2010. "Damage, Loss and Needs Assessment. Guidance Notes." Washington DC: World Bank.

WMO. 2007. "Associated Program on Flood Management - Conducting Flood Loss Assessments." Geneva: WMO/GWP.

2.6. References

ActionAid. 2006. "Climate change, urban flooding and the rights of the urban poor in Africa." ActionAid International.

ADPC and UNDP (Asian Disaster Preparedness Center and United Nations Development Programme). (2005). Integrated flood risk management in Asia. Bangkok: ADPC and UNDP. http://www.adpc.net/maininforesource/udrm/floodprimer.pdf.

Aftabuddin S. and Akte N. 2011. "Swollen hindgut syndrome (SHG) of tiger shrimp Penaeus monodon (Crustacea, Malacostraca, Penaeidae) post larvae: Identification of causing pathogenic bacteria and their sensitivity to some antibiotics." *AACL Bioflux* 4(1).

Ahern, M. and Kovats, S. 2006. "The Health Impact of Floods." In *Flood Hazards and Health: Responding to Present and Future Risks*, ed. Few, R. and Matthies, F. London: Earthscan.

Ahern, M., Kovats, R.M., Wilkinson, P., Few, R. and Matthies, F. 2005. "Global Health Impacts of Floods: Epidemiologic Evidence." *Epidemiological Review* 27(1): 36-46.

Alirol E, Sharma SK, Bawaskar HS, Kuch U, Chappuis F (2010) Snake Bite in South Asia: A Review. PLoS Negl Trop Dis 4(1): e603. doi:10.1371/journal.pntd.0000603

Amankwah-Ayeh, K. and Caputo, P. 2010. "Cities in Disaster

Management - the Case of 2 West African Cities" Presentation to World Bank. http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1296405826983/KwabenaCaputo.pdf.

Andjelkovic, I. 2001. "Guidelines on Non-Structural Measures in Urban Flood Management." UNESCO, IHP-V | Technical Documents in Hydrology, No. 50, UNESCO, Paris.

Asian Cities Climate Change Resilience Network (ACCCRN). 2009. *Responding to the Urban Climate Challenge*. ed. ISET (Institute for Social and Environmental Transition). Boulder, CO: ISET.

Ayeva, K. 2011. "The case of the capital Lomé and peri-urban (adjoining) areas." Presentation at consultative workshop, Accra, Ghana (nd).

Bartlett, S. 2008 "Climate change and urban children: impacts and implications for adaptation in low and middle-income countries." *Environment and Urbanization* 20 (2): 501-19.

Bern, C., Sniezek, J., G.M. Mathbor, Siddiqi, M.S., Ronsmans, C., A.M.R. Chowdhury, A.E. Choudhury, K. Islam, Bennish, M., Noji, E., and Glass, R.I. 1993. "Risk factors for mortality in the Bangladesh cyclone of 1991." ***Bulletin of the World Health Organization***, 71 (1): 73-7.

Bhat, G. K. 2011. "Coping to resilience - Indore and Surat, India." Presentation to 2nd World Congress on Cities and Adaptation to Climate Change, Bonn, June 3-5.

Bicknell J., Dodman D. and Satterthwaite D. 2009. *Adapting Cities to Climate Change: Understanding and Addressing the Development Challenges*. London and Sterling, VA: Earthscan.

Cohen, B. 2004, *Urban Growth in Developing Countries: A Review of Current Trends and a Caution Regarding Existing Forecasts*. Washington, DC: National Research Council.

Corfee-Morlot, J., Kamal-Chaoui, L., Donovan, M.G., Cochran, I., Robert, A. and Teasdale, P-J. 2009. "Cities, Climate Change and Multilevel Governance." OECD Environmental Working Papers N° 14, OECD.

CPNI (Centre for the Protection of National Infrastructure). 2010. "Glossary of terms." London: CPNI.

Dodman, D. 2009. "Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories."*Environment and Urbanization* 21 (1): 185-201.

Du, W., Fitzgerald, G., Clark, M. and Hou, X. 2010. Health impacts of floods. *Prehospital and Disaster Medicine* 25: 265-72.

EM-DAT (Emergency Events Database). n.d. http://www.emdat.be/search-details-disaster-list. Accessed August 16, 2011.

Few R, Ahern M, Matthies F and Kovats S 2004 "Floods, health and climatic change, a strategic review." Tyndall Centre for Climate Change Research Working Paper 63, Tyndall Centre for Climate Change, Norwich.

Fischer, S. 2005. "Gender Based Violence in Sri Lanka." http://www.gdnonline.org. Accessed March 1, 2008.

GFDRR. 2010. "Pakistan 2010 PDNA estimated flood impacts at $10 Billion." PDNA at a glance. http://www.gfdrr.org/gfdrr/node/325.

GOY (Government of Yemen). 2009. "Damage, Losses and Need Assessment: October 2008 Tropical Storm and Floods, Hadramout and Al-Mahara, Republic of Yemen." GOY.

Gurenko, E. and Lester, R. 2004. "Rapid Onset Natural Disasters: The role of financing in effective risk management." World Bank Policy Research Working Paper 3278, World Bank, Washington, DC.

Hall, J. W. and Solomatine, D. 2008. "A framework for uncertainty analysis in flood risk management decisions." *International Journal of River Basin Management* 6 (2): 85–98.

Hallegatte, S., Henriet, F., Patwardhan, A., Narayanan, K., Ghosh, S., Karmakar, S., Patnaik, U., Abhayankar, A., Pohit, S., Corfee-Morlot, J., Herweijer, C., Ranger, N., Bhattacharya, S., Bachu, M., Priya, S., Dhore, K., Rafique, F., Mathur, P. and Navill, N. 2010. "Flood Risks, Climate Change Impacts and Adaptation Benefits in Mumbai: An Initial Assessment of Socio-Economic Consequences of Present and Climate Change Induced Flood Risks and of Possible Adaptation Options", OECD Environment Working Papers, No. 27, OECD. http://www.oecd-ilibrary.org/environment/flood-risks-climate-change-impacts-and-adaptation-benefits-in-mumbai_5km4hv6wb434-en.

Hollis, G. E. 1975. "The effect of urbanization on floods of different recurrence interval." *Water Resour. Res.*, 11: 431-5.

Ibarrarán, M. E. 2011. "Increased incidence of flash flooding in Mexico City." In *Global Report on Human Settlements 2011 - Cities and Climate Change, United Nations Human Settlements Programme (UN-Habitat)*, ed. Naison D. Mutizwa-Mangiza; Ben C. Arimah; Inge Jensen; Edlam Abera Yemeru and Michael K. Kinyanjui, 68. http://www.unhabitat.org/grhs/2011.

Ingirige, B. and Wedawatta, G. 2011. Impacts of flood hazards on small and medium sized companies. In *Flood Hazards: Impacts and Responses for the Built Environment*, ed Lamond, J., Booth, C., Hammond, F. and Proverbs, Florida: CRC Press.

IFRC (International Federation of Red Cross and Red Crescent Societies). 2010 "World disasters report: focus on urban risk." IFRC.

IRIN. 2009. "Philippines: Flood victims grapple with Leptospirosis." UNOCHA news service: October 28, 2009. http://www.irinnews.org/report.aspx?reportid=86779.

IUCN (International Union for Conservation of Nature). 2011. "Floods in Brazil." http://www.iucn.org/?uNewsID=6787.

Jha, A. K. 2010. Safer homes, stronger communities: A handbook for reconstructing after natural disasters. Washington, DC: World Bank, GFDRR. http://www.housingreconstruction.org/files/saferHomesStrongerCommunities.

Jha, A. K. and Brecht, H. 2011. "Building Urban Resilience in East Asia. An Eye on East Asia and Pacific. East Asia and Pacific. Economic Management and Poverty Reduction. No 8." Washington, DC: World Bank.

Jonkman, S.N. and Kelman, I. 2005. "An Analysis of the Causes and Circumstances of Flood Disaster Deaths." Disasters 29 (1): 75-97.

Kamal-Chaoui L. and Robert A. ed. 2009. *Competitive Cities and Climate Change*. OECD Regional Development Working Papers No. 2, OECD publishing.

Kambandu-Nkhoma, M. n.d. "CDKN AlertNet." http://www.cdkn.org/.

Kim, C.-K. 2010. "The Effects of Natural Disasters on Long-Run Economic Growth." *The Michigan Journal Of Business* 41: 15-49.

Kreibich, H., Piroth, K., Seifert, I., Maiwald, H., Kunert, U., Schwarz, J., Merz, B., and Thieken, A. H. 2009. "Is flow velocity a significant parameter in flood damage modeling?" *Nat. Hazards Earth Syst. Sci.*, 9: 1679-1692.

Kunii, O., S. Nakamura, R. Abdur and S. Wakai, 2002. "The impact on health and risk factors of the diarrhoea epidemics in the 1998 Bangladesh floods."

Public Health 116: 68-74.

Loayza, N., Olaberria, E., Rigolini, J. and Christensen, L. 2009. “Natural disasters and growth: going beyond the averages.” Policy Research Working Paper 4980, World Bank. Washington, DC.

Morales, L. 2011. “Colombia’s Flooded Economy.” Pulitzer Center on Crisis Reporting, May 27, 2011. http://pulitzercenter.org/articles/colombia-bogota-rain-flood-wetlands-ecosystem?format=print.

Mason V, Andrews H and Upton D. 2010 ‘The psychological impact of exposure to floods’, article in ‘Psychology, Health & Medicine’, 15: 1, 61-73.

Merz, B., Kreibich, H., Schwarze, R. and Thieken, A. 2010. “Assessment of economic Flood Damage” *Nat. Hazards Earth Syst. Sci* 10: 1697–1724.

Miller, G. 2005. “The tsunami’s psychological aftermath.” Science 309: 1030.

Moore, K.M., Bertelsen, M., Cisse, S. and Kodio, A. 2005. “Conflict and agro-pastoral development.” In *Conflict, social capital and managing natural resources: a West African case study*, ed. Moore, K.M., 1–23. Wallingford: CAB International.

Moreda, Y. 2007. “2D approach to urban flood modeling” EuroAquae, Floodsite GOCE-CT-2004-505420. Grenoble: Sogreah Consultants.

Noji, E.K. 2005. “Indian Ocean tsunami. Public health issues in disasters.” Crit Care Med. 33 (1 Suppl): S29–33.

Noy, I. 2009 .“The macroeconomic consequences of disasters.” *Journal of development economics* 88: 221-31.

Ofwat (Water Services Regulation Authority for England and Wales). 2009. *Asset Resilience to Flood Hazards: Development of an Analytical Framework*. Birmingham: Ofwat.

OECD (Organisation for Economic Cooperation and Development). 2009. “Integrating Climate Change Adaptation into Development Co-operation: Policy Guidance.” OECD.

Onishi, N. 2011 “Seawalls Offered Little Protection Against Tsunami’s Crushing Waves.” *The New York Times*, March 13. http://www.nytimes.com/2011/03/14/world/asia/14seawalls.html?pagewanted=all.

Otis, J. 2011. “After 11 Months Colombia Asks, Who’ll Stop the Rain?” *TIME Magazine*, May 10.

http://www.time.com/time/world/article/0,8599,2069653,00.html.

Parnell S., Simon D., and Vogel C. 2007. "Global environmental change: conceptualizing the growing challenge for cities in poor countries." *Area* 39 (3): 357-69.

Parry M., Arnell N., Berry P., Dodman D., Fankhauser S., Hope C., Kovats S., Nicholls R., Satterthwaite D., Tiffin R., Wheeler T. 2009. *Assessing the costs of adaptation to climate change*. A review of the UNFCCC and other recent estimates. London: IIED (International Institute for Environment and Development and Grantham Institute for Climate Change).

Satterthwaite D. 2011. "How urban societies can adapt to resource shortage and climate change." *Phil Trans R Soc* A 369: 1762-83.

Satterthwaite, D., Huq, S., Pelling, M., Reid, H. and Romero Lankao, P. 2007. "Adapting to Climate Change in Urban Areas. The possibilities and constraints in low- and middle-income nations." IIED Human Settlements Discussion Paper Series, IIED (International Institute for Environment and Development), London.

Skidmore, M., and Toya, H. 2002. " Do natural disasters promote long run growth." *Economic Enquiry* 40 (4): 664-87.

SMC (Surat Municipal Corporation). n.d. "Surat City Resilience Strategy – Draft document (under ACCCRN Phase II)." SMC. http://www.suratclimatechange.org/page/19/surat-city-resilience-strategy-%E%80 %93-draft-document.html.

Smith, D. I. 1994. "Flood damage estimation – A review of urban stage damage curves and loss functions." *Water SA* 20 (3): 231–8.

Straatsma, M., Ettema, J. and Krol, B. 2010. "Flooding and Pakistan causes, impact and risk assessment." ESA, ITC, University of Twente. http://www.itc.nl/flooding-and-pakistan.

Swiss Re. 2011. "Flood risk in Brazil." Swiss Re Ltd. http://www.swissre.com/rethinking/natcat/Flood_risk_on_the_rise_in_Brazil.html.

UNEP (United Nations Environment Programme). 2011. "The Japan Earthquake and Tsunami Disaster - Update - 11 April 2011." http://www.unep.org/tsunami/.

UN-HABITAT. 1996. *An Urbanizing World: Global Report on Human Settlements 1996*. Oxford: Oxford University Press.

------. 2008. *State of the World's Cities 2008/2009: Harmonious Cities*. London and Sterling, VA: Earthscan, UNDHA (United Nations Department of Humanitarian Affairs). 1992. *Internationally Agreed Glossary of Basic Terms Related to Disaster Management*. Geneva: UNDHA.

USACE (U.S. Army Corps of Engineers). 1988. *Tests of Materials and Systems for Flood Proofing Structures*. Washington, DC: Army Corps of Engineers.

USACE NED manuals. n.d. http://www.corpsnedmanuals.us/Toolkit/toolkit.asp.

Villagran de Leon, J. C. 2006. "Vulnerability: A conceptual and methodological review." Studies of the University: Research Council, Education publication series no 4/2006, United Nations University (UNU_EHS).

WDR (World Development Report). 2010. *Development and Climate Change*. Washington, DC: World Bank.

Weir, R. 2009. *Mapping and Analysis of the Resilience of the Food Supply chain in Scotland*. Glengarnock: AEA Technologies for the Scottish Government.

Wenk, D. 2004. "Is 'good enough' storage good enough for compliance?" *Disaster Recovery Journal* 17 (1): 1-3.

WGCCD (Working Group on Climate Change and Development). 2009. "Other worlds are possible: Human progress in an age of climate change. The sixth report from the Working Group on Climate Change and Development." NEF (New Economics Foundation).

Wheater, H. and Evans, E. 2009. "Land use, water management and future flood risk." *Land Use Policy*, 26: S251-S264.

WHO (World Health Organization). 2002. "Reducing Risks Promoting Healthy life". World Health Report, WHO, Geneva.

World Bank and The United Nations. 2010. *Natural Hazards, Unnatural Disasters: the economics of effective prevention*. Washington, DC: World Bank.

World Bank. 2008. *Climate Resilient Cities: 2008 Primer Reducing Vulnerabilities to Climate Change Impacts and Strengthening Disaster Risk Management in East Asian Cities*. Washington, DC: World Bank, FGDRR and UNISDR.

World Meteorological Organization (WMO). 1999. *Comprehensive Risk Assessment For Natural Hazards - WMO/TD no 955*. Geneva: WMO.

Part of the six kilometer long levee which locals had built to protect the small town of Warracknabiel from a 'once in 200 years' flood in Victoria, Australia (2011). Source: Gideon Mendel

Chapter 3

Integrated Flood Risk Management: Structural Measures

Chapter 3. Integrated Flood Risk Management: Structural Measures

3.1. Introduction

Chapter Summary

This chapter is focused on structural measures that are used to control the flow of water both outside and within urban settlements, within the context of an integrated approach to urban flood risk management. The measures described include what are traditionally viewed as structural hard-engineered solutions, such as drainage channels, as well as more natural and sustainable complementary or alternative measures, such as wetlands and natural buffers. The chapter starts with a discussion of the integrated approach to flood risk management. The focus then turns to structural measures themselves.

Questions answered include:

What is an integrated approach? What structural measures may policy-makers consider for mitigating flood risk in urban environments? In which cases are structural measures effective?

The key messages from this chapter are:

- An integrated strategy usually requires the use of both structural and non-structural measures.
- Structural measures range from heavily-engineered interventions, such as floodways and reservoirs, to more natural approaches like wetlands and greening measures. They cover water management at the catchment and urban level.
- Heavily-engineered structural measures can be highly effective when used appropriately, but they share one characteristic: that they tend to transfer flood risk from one location only to increase it in another. In some circumstances this is acceptable and appropriate, while in others it may not be.

Human settlements have been protected by flood risk management measures for as long as they have existed. The success of traditional methods in limiting flood damage coupled, somewhat contradictorily, with the experience of continued flooding despite such measures, have resulted in guiding principles and lessons for flood risk management. The modern approach which has emerged is often referred to as integrated or holistic. In 21st Century urban environments, which are much more complex and often much larger than their historic counterparts, action is required at a much larger scale. Integrated flood risk management, which usually includes both hard-engineered structural and non-structural management measures, is required to reduce flood risk.

Within this perspective, risk managers for urban areas should consider the catchment as a whole, as the most effective risk reduction measure may be an upstream or offshore approach. However, as it is unrealistic to expect to keep all flooding away from towns and cities, flood risk managers face the additional issues of the increasingly complex behavior of flood waters once they reach the urban built environment. The interaction of floodwater with concentrated population centers, buildings and urban infrastructure is characteristic to urban flooding and requires a specific set of solutions.

Section 3.2 defines integrated urban flood risk management and gives an overview of flood risk management options, both structural and non-structural. The chapter goes on to examine structural measures in detail. Non-structural measures, aimed at keeping people safe from flooding by the planning and management of urban environments, are then covered in Chapter 4.

Section 3.3 describes the purpose of conveyance, which is the provision of a route to take potential floodwater away from areas at risk.

Flood storage measures aimed at reducing the peak of flood flows are discussed in Section 3.4.

Section 3.5 deals with urban drainage systems, while 3.6 focuses on infiltration in urban areas.

Section 3.7 is concerned with groundwater management, which is necessary to prevent land subsidence which can lead to greater problems in low-lying areas.

The following section, 3.8, outlines a set of measures that can be considered for reducing the amount and speed of rainwater runoff in urban areas by utilizing wetlands and creating environmental buffers.

Section 3.9 pays attention on the design of buildings that can reduce their vulnerability to flood impact and can therefore reduce the residual risk of flooding and enable occupation of floodplain areas.

Flood defense measures that aim at reducing the risk from flooding of people and the developed and natural environment are discussed in Section 3.10.

Finally, Section 3.11 considers defenses against estuary and coastal flooding, stemming from tides, storm surges and tsunamis.

3.2. An Integrated Approach to Flood Risk Management

Flood risk management requires the holistic development of a long-term strategy balancing current needs with future sustainability. An integrated strategy usually requires the use of both structural and non-structural solutions. It is important to recognize the level and characteristics of existing risk and likely future changes in risk. This has been discussed in Chapters 1 and 2. Reducing that risk then involves a set of measures which individually contribute to risk reduction. After measures have been adopted there will remain a residual risk.

This Chapter covers measures which are designed to control flood water, usually by physical construction or by environmental management. Chapter 4 covers measures which are designed to keep people safe from flooding by the planning and management of urban environments. These are often referred to as "non-structural" or "soft" measures. The two types of measures are complementary to each other and both form part of the integrated approach.

Integrated flood risk management also includes the recognition that flood risk can never be entirely eliminated and that resilience to flood risk can include enhancing the capacity of people and communities to adapt to and cope with flooding. Four capacities for reduced vulnerability and increased resilience are illustrated below in Figure 3.1.

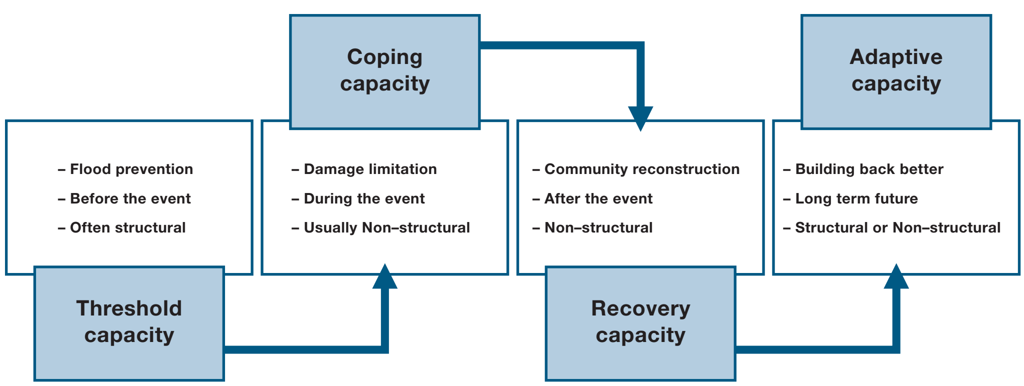

Figure 3.1: The four capacities towards increased resilience.

Flood risk reduction, for urban areas as political or economic units, must be considered at a range of scales, including the river and water catchment as a whole. This is because the source of flooding may be at some distance from the affected receptor (in this case a town or city). The best option, therefore, may be to tackle the flooding problem before it reaches the urban environment. The following figures illustrate the types of flood risk reduction measures that may need to be considered at a range of different spatial scales to create an integrated flood risk solution.

The selection of possible solutions will involve identifying technically feasible sets of measures designed to address the particular flooding scenario and should be carried out in consultation with experienced technical specialists. The development of the final strategy should be carried out through a participatory process involving all those people and institutions that have a vested interest in flood management, including people at risk or directly impacted by flooding. The established methodologies for such a planning approach are given in Chapter 6.

Figure 3.2 illustrates multiple risk management techniques in their appropriate catchment locations surrounding an urban settlement.

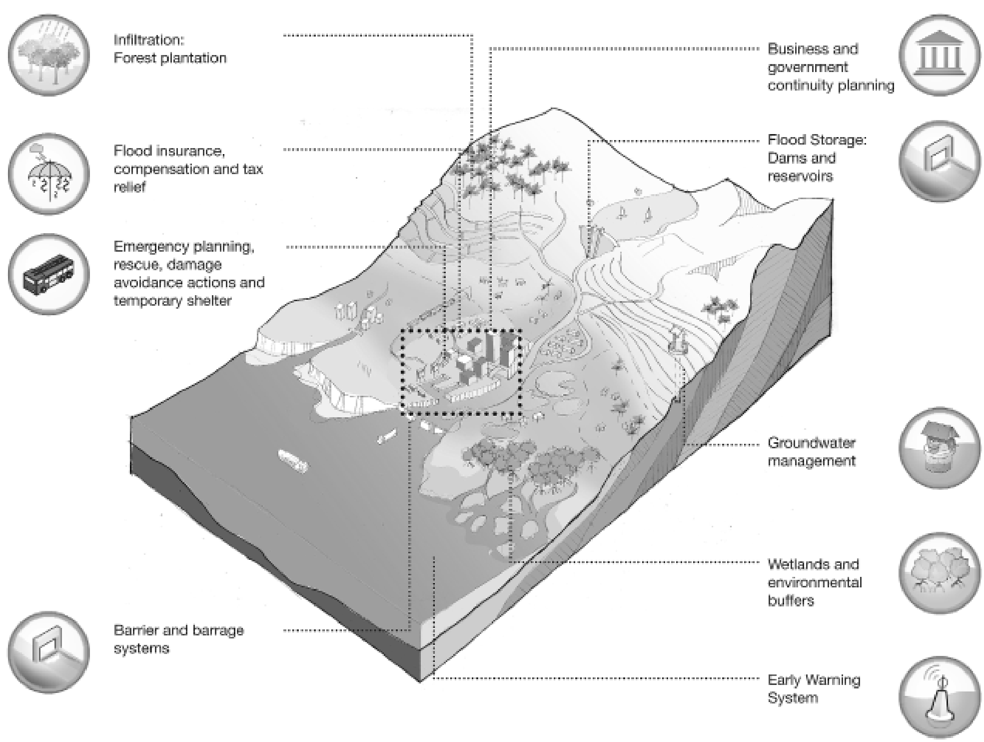

Figure 3.2: Overview of flood risk management options, catchment scale, Source: Baca Architects

Figure 3.3 illustrates measures that may need to be considered at a town or city scale, with emphasis on city defenses, land use planning and other planning level measures.

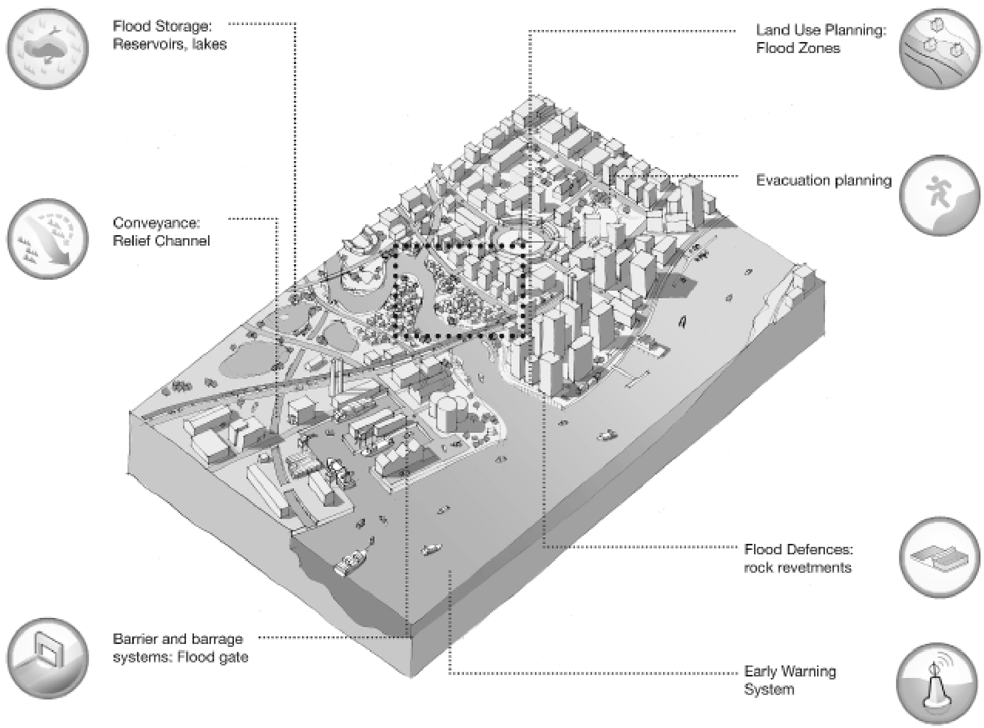

Figure 3.3: Overview of flood risk management measures, city scale, Source: Baca Architects

Figure 3.4 below illustrates measures that may need to be considered at a neighborhood or community scale, including structural and non-structural.

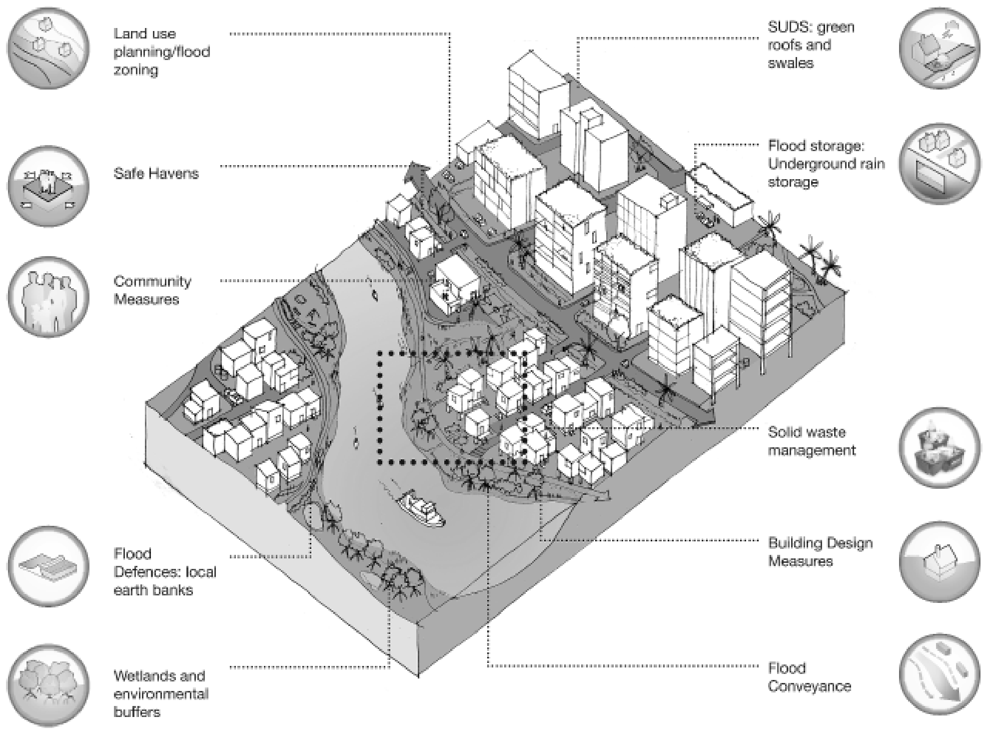

Figure 3.4: Overview of neighborhood flood risk management measures, Source: Baca Architects

Figure 3.5 illustrates building level measures and the responsibility of individuals in flood risk reduction.

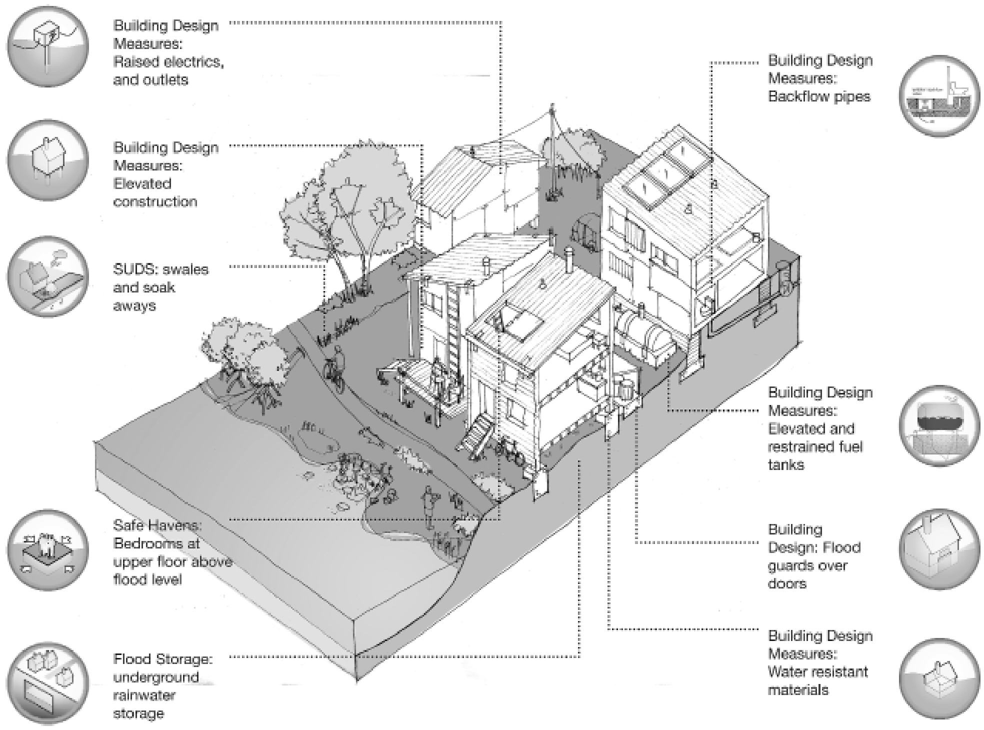

Figure 3.5: Overview of flood risk management measures, building scale, Source: Baca Architects

Both temporal and spatial issues should be taken into account when determining strategy. Structural solutions such as flood defenses and conveyance systems can form a long-term solution to flood risk, rendering floodplains habitable by protecting existing settlements. However, particularly in the developing world, they may be seen only as longer-term goals requiring large investments which will not always be available. Non-structural solutions such as flood warning systems, evacuation planning and coordinated recovery procedures are also necessary for the protection of the populations of cities and towns already at risk of flood, whether protected by defenses or not. Measures which can be implemented more quickly (such as operations and maintenance, greening of urban areas, improved drainage, building design and retrofitted protection measures) can also enable occupation of flood risk areas while minimizing the expected damage from flooding.

At the same time, one of the major tools for heightened resilience against the increasing risks caused by growth of urban population, and the expansion of urban settlements, is the redirection of such settlements away from areas at high flood risk. The use of urban land use planning can reduce both exposure to flood hazard and the run-off into urban areas. In the urbanizing developing world, the opportunity to better plan the formation of new settlements and new buildings is central to preventing the predicted increases in future flood impacts from being realized. It is realistic to recognize that floodplain development is likely to continue, due to pressure on land and other political and economic considerations. However, where new settlements are planned – rather than just occur – within areas at risk from flooding, flood-adapted design can be employed at a lower cost during the building phase than would be the case if retrofitted.

Non-structural measures need to be seen as potentially applicable to all types of urban settlements. However, given the differences in the future challenges faced by urban settlements worldwide and their development goals and resource constraints it is not possible to be prescriptive in the application of management strategies. The specific solution, or set of solutions, which is optimal in a particular location can only be arrived at after extensive evaluation, cost benefit analysis and consultation with multiple stakeholders. The measures selected will need to be negotiated with the relevant stakeholders, and will need to be adaptable to natural, social and economic conditions which can be expected to change over time.

3.3. Conveyance

In the context of flood risk management, the purpose of conveyance is to provide a route to take potential flood water away from areas at risk. Traditionally this has been seen as a way to remove the problem of flooding from the urban environment. Such systems often form part of a much broader water management approach including, for example, hydro-electric schemes in which control of excess flows forms a part.

3.3.1. Means of conveyance

Conveyance may be given effect either via natural or artificial channels. In remote areas, rivers may be in a completely natural state; in many parts of the world, rivers have been heavily modified; and in particular contexts, flood conveyance may be achieved by purpose-built artificial channels.

When water flows in any channel it must have sufficient energy to overcome the frictional resistance to flow created by the contact with the channel bed and sides. This energy is effectively provided by the slope of the channel. The capacity of a river or channel is a function of three main factors: the transverse cross-sectional area, the slope, and the frictional resistance. In a long channel with a constant area, it is possible to visualize 'uniform flow' in which the depth does not vary with distance; in this case there is equilibrium between the energy provided by the slope and the energy needed to overcome frictional resistance.

It should be noted that in addition to the general meaning of transferring flow, 'conveyance' has a specific definition in hydraulics: it is a combination of all the properties, apart from slope, that determine the capacity. Thus, if one channel construction is to be replaced by another for a particular length, assuming the overall slope cannot be changed, the conveyance of the new construction should not be less than the old, if a reduction in capacity is to be avoided.

The relationship between the physical properties of the river channel, the flow-rate and the water depth can be simulated for both steady (time-constant) and unsteady (time-varying) conditions using well-established software modeling packages. This can be linked to rainfall-runoff generation to represent flood conditions, and potentially be used to predict the development of a flood event in real time.

3.3.2. Conveyance and storage

The concepts of conveyance and storage (the latter is examined in Section 3.4) are closely linked. Any storage has the effect of attenuating (reducing the peak) of flood flows. As depths increase in a length of channel with no additional inflows from tributaries, storage within the channel itself is utilized, and so there is attenuation as the flood flow moves downstream. Attenuation also occurs when the storage volume offered by the floodplain is utilized. Figure 3.6 illustrates the functions of storage and conveyance on the attenuation of flows within a catchment.

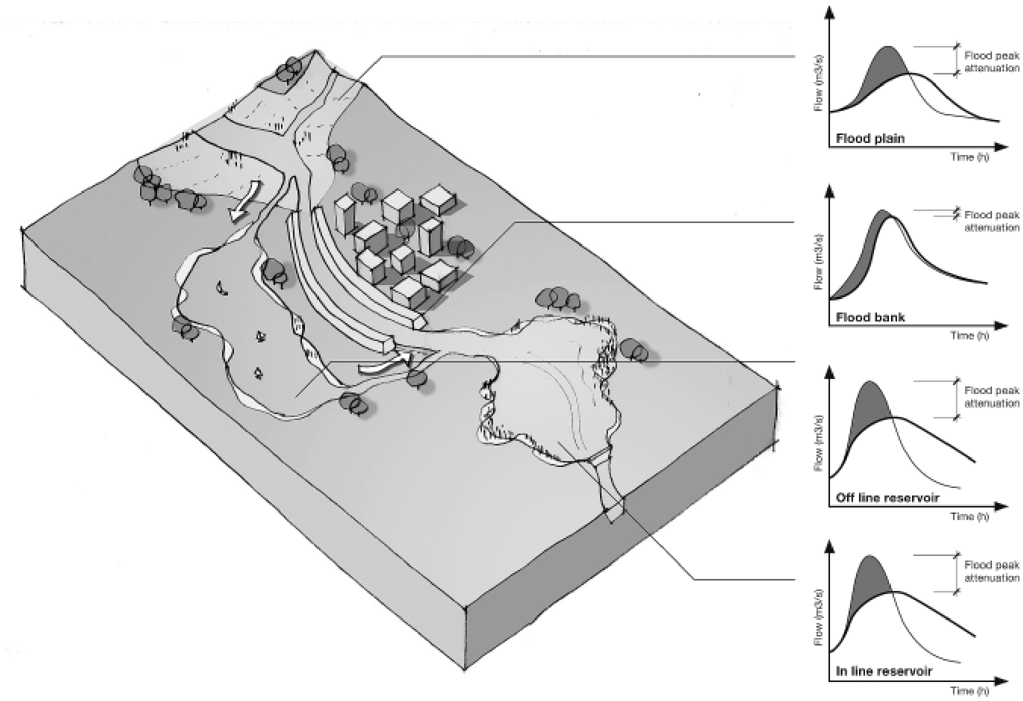

Figure 3.6 Attenuation of conveyance and storage devices within a catchment, Source: Baca Architects

Traditional schemes that have increased the flow-carrying capacity of a river (by decreasing roughness or straightening the course and therefore speeding up the flow) have the opposite effect, in that they reduce attenuation. They may, therefore, decrease flood risk at a particular location, but increase it further downstream. Any scheme that reduces the flooded area at a particular location will, in effect, reduce storage and therefore increases flood risk downstream. A dramatic instance of this was seen in the Mississippi river floods of 2011, as seen in Case study 3.1.

Case Study 3.1: The Mississippi River Floods of 2011

In 2011, for the first time since 1973, the U.S. Army Corps of Engineers, as the US Federal Agency providing flood risk management on the Mississippi River and Tributaries, opened up the Morganza Floodway to relieve flood pressure. Up to 17,000 cubic meters per second can be released from the 125 gates into the floodway, which diverts water from the Mississippi River to reduce flows passing the levees protecting the cities of Baton Rouge and New Orleans. To control the high flows, USACE was forced to breach some upstream levees which resulted in the inundation of farmland and smaller settlements as a means of protecting more densely populated areas (see Photo 3.1). These inundations provided water storage that attenuated (reduced the peak) flows in the main channel..

Photo 3.1: The Morganza Spillway opens to divert water from the Mississippi River, May 19, 2011. Source: FEMA, photo by Daniel Llargues

Flooding is not something new in the region, with the greatest reported flood event occurring as far back as 1927. Large floods also occurred in 1937, 1973, 1993 and 2008. In the spring of 2011, increased water levels in the Mississippi River were caused by the combination of rainfall levels up to four times the normal and unusually high snowfalls in some regions. In addition to these factors, flood risk has also been increased due to urban development in areas that were once farmland. As a result, the hydrolic profile has been altered, causing water to flow quickly into rivers rather than being absorbed by the ground. Professor Nicholas Pinter, who works on flood hydrology at Southern Illinois University, calls this 'hydro-amnesia'. It causes people to build in locations that were flooded in the past and will always have flood risk.

The Morganza Floodway illustrates the successful use of conveyance and storage upstream to divert flooding away from urban areas. It also demonstrates that, even when structural solutions function as planned, there may be downstream consequences which are unpalatable. This is particularly true of systems that are not used very often, and which allow collective amnesia to erode the awareness of risk in the sacrificial areas (in this case, the farmland and homes that were inundated when the levees were breached).

Sources: Lovett 2011; Wynne 2011.

3.3.3. Modification of rivers

Modification of existing rivers may involve engineering procedures which:

- Increase the flow area or alter the line
- Protect the banks from erosion
- Increase the height of banks

The motivation for modification may be to manage flood risk, but it may also be to maintain navigability, reduce bank erosion or facilitate urban development.

Rivers are also modified by maintenance procedures, such as dredging or clearing of vegetation, debris or silt. The main objective here is to preserve the capacity of the channel to carry flood flows, by restoring cross-sectional area or reducing roughness.

3.3.3.1 Increasing the flow area or altering the line

Traditionally, interventions in river channels have been carried out to reduce flood risk at a particular location. This approach has produced artificial river geometries which have often been found, for a variety of reasons, to be unsustainable. A core principle of modern river engineering is that, in general terms, rivers tend to return to their natural 'regime' state, in which the main channel has the capacity for a particular flow and no more. While major rivers, especially in developing countries, must be treated as being unique, current thinking is that this flow-rate corresponds roughly to the mean annual flood (Pepper and Rickard, 2009). Greater flow-rates, therefore, are not necessarily contained in the main channel. Artificial deepening of a river channel increases cross-sectional area but may reduce slope; the result can be reduced velocity and increased deposition of silt, tending to a reversal of the initial deepening. Artificial widening may cause deposition close to the river banks. Cutting off a meander will shorten the channel between two points and therefore increase the bed slope; this will increase flow-carrying capacity but will also increase velocities. The result may be erosion of the banks or the bed (termed 'scouring') together with deposition further downstream; this will also tend to reverse the initial steepening.

In some circumstances, decreasing roughness or straightening the course may solve local flooding problems, by increasing the capacity of the channel, but a reduction in both storage and attenuation is inevitable. In contrast, where channel naturalization or river restoration includes returning a watercourse to a more natural condition (for example, by reinstating meanders) this can increase storage, enhance the amount of attenuation and thereby reduce flood risk downstream. Photos 3.2 and 3.3 illustrates the contrast in course regimes.

Photos 3.2: Highly channelized red Rouge River Dearbon for flood control purposes source USACE; Photo 3.3 Riverine Wetlands in Northwest Iowa, Source Lynn Betts.

3.3.3.1 Protecting the banks from erosion

Around the world there are many systems of erosion protection, many involving local natural materials and traditional techniques. Bank protection forms part of the local environment and must be appropriate environmentally as well as structurally. Design also involves understanding the scouring potential of the flow. Protection using natural materials may involve establishing vegetation, for example, grasses or shrubs; close to the waterline, reeds or structures made from natural materials, sometimes combined with established vegetation may be used. Wire mesh or open geotextile may be used as erosion protection whilst allowing the establishment of vegetation. Artificial systems include use of gabions, (a basket-like container of mesh or wicker, filled with rocks) stone, concrete blocks, and sheet piling. A revetment is a protective structure with a covering of loose rocks (termed ‘riprap’), gabions or concrete blocks, and an under-layer which provides drainage and protects the base soil from being washed out. However, an alternative approach is to avoid the need for bank protection by re-profiling the bank to a flatter slope, thereby achieving a reduction in velocities (Pepper and Rickard 2009).

3.3.3.1 Increasing the height of banks

Here we consider the physical characteristics of flood walls and flood embankments. Their role, beyond river modification, is further considered in Section 3.10.

Flood walls can be constructed of brick, masonry, concrete or sheet piling. Flood embankments, (also known as levees or dykes) are generally earthen embankments that may have a clay core to reduce seepage; they must be protected from scour where necessary. The height of the wall or embankment must be sufficient to provide the degree of flood protection intended; the strength and stability of the structure must be sufficient to withstand long-lasting pressure of water (for example, if the defense is overtopped). The distance between embankments on opposite sides of a channel has a significant impact on the storage available as water levels rise.

The crest level to which the flood wall or embankment is constructed relates to the probability of the flooding against which defense is being provided. 'Freeboard' is additional height provided to allow for uncertainties and wave effects. Flood walls may form part of the river frontage, such as retaining walls or quays, or can be relatively remote from the river and are solely flood protection structures. The latter may be disguised as landscaped features.

Flood embankments require protection from erosion and scour just as river banks do, as considered above. The typical shape is a trapezium with a flat crest and sloping sides (typically at slopes of between 1:2 and 1:3, vertical to horizontal ratio). Embankments are normally set back from the river edge, both to reduce the risk of erosion and provide storage within the flow area at times of flood. Temporary or demountable flood defenses are covered in 3.10.

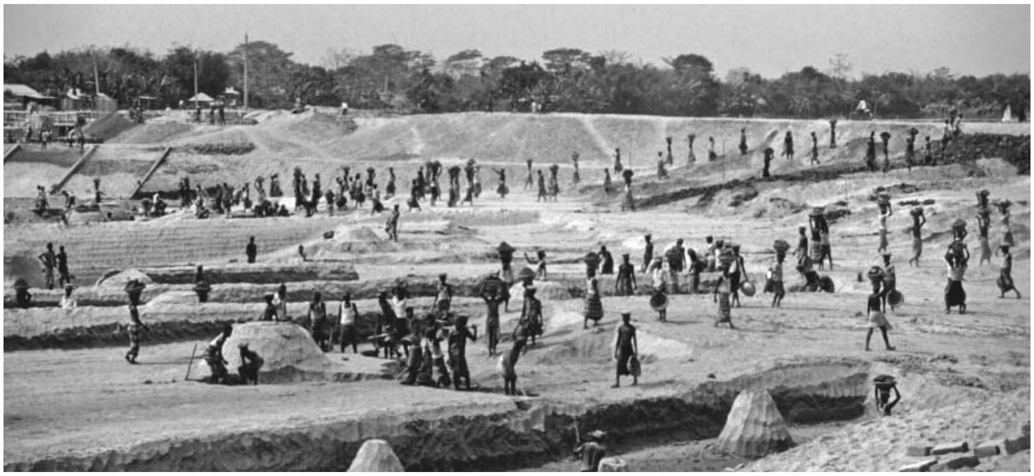

Photo 3.4: Labor intensive construction of river flood protection embankments in Bangladesh. Source: Alan Bird

3.3.4. Relief channels

Relief channels are designed to re-direct some of the flow at peak river levels by using an off-take structure (normally a side weir) and a canal to an area where water can be safely discharged without adverse impacts. A 'normally dry' relief channel is at a higher level than the main channel and only carries flow in flood conditions. There may, therefore, be safety issues during sudden flooding as people in the area will have become accustomed to using the area for other purposes (see also Section 3.5.2). A 'normally wet' channel carries some flow at all times, but in both cases there will be a downstream impact of the diverted flow.

In an urban context, floodways act as relief channels and may be a significant component in the 'major' drainage system, as discussed in Case Study 3.2 below and in Section 3.5.

Case Study 3.2: Modernization of the Wroclaw floodway system

Construction of the first components of the Wroclaw floodway system in Poland, one of the largest flood protection systems in Europe started in 2011. The project includes large scale improvements to the system of river channels and flood defenses which provide protection from the floodwaters of the River Odra that flows through Wroclaw. The goal of the project is to reduce the city's flood risk to a probability of less than a 1000-year event.

The city's present floodway system dates to 1923 and has a capacity of approximately 2,400 cubic meters per second, corresponding to a 200-year return period. In 1997, the largest flood event ever recorded in Wroclaw flooded about 35 percent of the city, causing major damage and widespread disruption along the valley of the Odra, this flood was variously estimated as a 1 in 200 to in 1000 year event.

The estimated total flow upstream of the city in this event was over 3,500 cubic meters per second, almost 50 percent greater than the capacity of the city's existing floodway system. Widespread flooding was caused by the breaching and overtopping of the flood defense embankments; in addition a diversion structure to the River Widawa was destroyed, together with the training embankments..

After the floods of 1997, a range of responses to the problem of flooding in Wroclaw, and along the River Odra valley were investigated. Changes in responsibility for flood protection came in 1999 so that the governors of large strong provinces have no reason to wait for central directives. The feasibility study identified a need for the following complementary and interdependent projects mounting to an estimated cost of over $400 million:

- The Bukow Polder completed in 2002 at a cost of $51million
- A 185 million cubic meter on-line flood storage polder (the Raciborz Polder) to be constructed 200 kilometers upstream of the city, this to be extended to 320 million cubic meters once gravel extraction is completed in the area.
- The capacity of the diversion structure and channel to the River Widawa to be increased to 300 cubic meters per second, in combination with improvements to embankments along the River Odra. This will by increasing the conveyance of the channel rather than raising defenses and will require the removal of large amounts of material and bridge widening and strengthening
- Improved forecasting and warning systems

In order to assess the highly complex impacts of each of the proposed improvements, their interaction with each other and with other components of the flood protection scheme, a hydrodynamic computer model of the floodway system has been developed to:

- Test the effect of each component of the project
- Enable 'fine tuning' of the design where necessary
- Understand and allow for the effect of uncertainties in key design parameters.

The models have concluded that the combination of the three measures will be sufficient to manage a 1 in 1000 year flood and protect 2.5 million inhabitants of towns and villages as well as the city of Wroclaw.

The construction of the Raciborz polder would pose a risk of occasional flooding of inhabitants that are concentrated primarily in two villages (240 families). Under Polish regulations, this risk is unacceptable and therefore, the inhabitants are to be moved and the land/property within the polder acquired by the State. This resettlement plan has delayed the completion of the polder.

This example Illustrates the complexity of negotiating a new integrated system of flood control. The defenses have been designed at a catchment level and involve an international water body (the river Oder). A full range of evaluation reports such as EIA and safeguarding reports were required. Structures downstream of Wroclaw have also had to be altered to accommodate extra flow, but areas downstream will also benefit from the increased attenuation in the polders.

Sources: IWPDC 2011; Halcrow n.d.; Faganello and Attewill 2005.

3.3.5. Floodplain restoration

The nature of the development of human settlement in the floodplain of rivers has been identified in Chapter 2 as a major constraint to flood management. Towns and cities have grown and expanded into floodplain areas without consideration of the flood risks involved. Land use zoning and its effective enforcement is a key management tool in trying to prevent such development. Where pressure on land is too great for this, then there is a need to design and construct buildings so that they are able to cope with flooding risks. Also required is an overall management program for floodplain areas, looking at how their former roles as regulators of peak floods can be restored: measures can include remodeling of river banks and the reconnection of former channels that have been built over or blocked.

3.3.6. Reopening culverts

Culverts typically carry flow in a natural stream or urban drainage channel under a road or railway. In some urban areas, the practice of culverting long lengths of a natural watercourse to gain space for urban development has traditionally been widespread. The practice is now generally recognized as having a negative impact on amenity and biodiversity.

Culverts tend to increase flood risk, especially if they are either too narrow in diameter or become blocked by debris. An urban structure or development that has been facilitated by the routing of a natural stream within a culvert may be at risk of flooding from that same culvert. Compared with an open stream, access for maintenance of culverted watercourses is also limited. Reopening culverts (sometimes termed 'daylighting') can be part of the integration and enhancement of watercourses in urban areas, with benefits in terms of biodiversity, water quality and amenity as well as flood risk reduction.

An example of this approach is the elevated freeway constructed above the Cheonggyecheon River in Seoul, South Korea, in the early 1970s. At the time, it was considered a symbol of progress, but by the early 2000s, the Cheonggyecheon area was the most congested and noisy part of Seoul. A river restoration project was therefore initiated to remove the freeway and restore the stream. This was completed in 2005 and is considered a major success.

3.4. Flood storage

As stated in Section 3.3.2 above, storage has the effect of attenuating (reducing the peak) of flood flows. This is especially true when there is a significant volume of storage available and the outflow is controlled. There is storage in all parts of the natural water cycle, which can be enhanced by creating additional opportunities for storage within a catchment. Storage, preferably semi-natural storage, is also a key to modern urban drainage design (see Section 3.5). Storage is likely to be one component in an overall strategy for flood risk reduction.

Storage occurs naturally in a catchment, for example within the floodplain or, more locally, in ponds. Artificially created storage facilities include flood storage reservoirs, retention ponds and detention ponds; deliberate flooding of farmland, or urban areas like playing fields or car parks, may also be utilized. This aspect is covered in more detail in Sections 3.4.2 and 3.5.2 and is also illustrated in Case Study 3.3, with an example of a retarding basin in Japan.

Some major reservoirs on river systems, while providing attenuation that is relevant to flood risk, may have additional functions such as water supply or hydroelectric power generation. Traditional approaches to managing reservoir operations, based on purely hydraulic considerations relating to the main function of the reservoir, may need to be widened within a context of integrated water resources management to achieve environmentally sensitive reservoir operation.

Another important consideration concerns sediment flows, as there is a risk that reservoirs can lose capacity as a result of long term deposition.

Where several flood storage reservoirs are provided in a catchment, the overall effect must be considered: reservoirs on separate tributaries may cause attenuation individually, but if the downstream attenuated peak flows are allowed to join the main river at the same time, the benefit may be lost.

3.4.1. On-line and off-line

On-line storage forms part of the line of the main channel and all flow passes through it. Typically located in the upper catchment of a river, on-line storage normally consists of an impounding structure, a flow control arrangement at the outlet and a spillway or overflow, to bypass the controlled outlet in extreme events.

Off-line storage, by contrast, is filled by water diverted from the main channel and subsequently released back to it. It is usually associated with larger rivers with wide floodplains, and typically consists of an intake structure (most often a weir) to divert water from the main channel; the storage area itself (frequently a reservoir formed from low or excavated ground, or by means of retaining structures); outlet flow-control returning water to the river (by gravity or pumping); and a spillway or overflow.

In both cases, controlled emptying soon after a flood event is necessary, in order to make storage available for subsequent events. Outlet flow control devices include orifices, throttle pipes and devices that induce vortex motion to control flow (making flow control less dependent on varying water heads). The greatest effect of storage on reducing flood risk can be realized through the control of inflow and outflow to ensure that the storage is not filled too early or too late in a storm, but this requires a complex system of real-time control.

Case Study 3.3: A multi-purpose retarding basin in Japan

The Tsurumi River Basin spreads from Machida City through to Tokyo Bay. The area has always been prone to river flooding. In the 1980s a comprehensive flood control plan was implemented with a protective level of a 150-year flood event. Part of the plan was the construction of a multi-purpose retarding basin which stores flood water from the river, releasing it via controlled outflows (as illustrated in Figures 3.7). At other times, this area is used for leisure purposes and includes an international sports stadium, as shown in the aerial photograph in Figure 3.7.

Figure 3.7: An outflow control facility and Tsurumi multi-purpose retaining basin. Source: Ministry of Land, Infrastructure and Transport, Japan; Tanaka 2011.

The height of the levee between the river and the retarding basin is set to allow water flow over the levee as it reaches flood height, thus preventing overtopping on the other side. The stadium itself is raised on piles which ensure that the sports venue and the main roadways could still be used during a flood event. The total water storage capacity of the basin is 3,900,000m3. After a flood event, the water is drained away through a spillway into the Tsurumi River.

An information center as well as notice boards in the retarding basin serve as a communication mechanism for the general public and provide early warning information. Other measures that were carried out on the Tsurumi River included dredging, the construction of levees, regulating reservoirs and greenery reservoirs.

The most important lesson learnt, therefore, is that measures must effectively utilize the limited land available in what is a very densely populated city, and be integrated within land use plans and procedures.

Source: PWRI 2009; Tanaka 2011.

3.4.2. How to utilize temporary storage in an urban area

There significant scope for providing temporary storage for stormwater in urban areas by making use of areas with other primary functions, for example, parkland, playing fields or car parks. Water can be diverted from rivers or channels to this storage, typically via a weir; alternatively urban runoff may enter the storage as ‘exceedence flow’ when the capacity of the urban drainage system (the ‘minor system’) has been exceeded

Method

The method given below covers the main aspects of identifying suitable locations for temporary storage and planning their use. Detailed design considerations are not included here.

1. Identify suitable locations for temporary storage

2. Determine maximum flood depth for each location

3. Estimate volume of storage provided and include in a hydraulic model if appropriate

4. Specify outlet arrangements

5. Consider health and safety issues.

1. Identify suitable locations for temporary storage

Typical urban features used as temporary storage are given in Table 3.1. It should be borne in mind that the location:

- Will be used relatively infrequently for storage of flood water
- Will normally have a different primary use (car park, playing field etc)
- Will probably not have the primary use available while the location is being used for storing stormwater.

2. Determine maximum flood depth for each location

Recommended maximum flood depths are given on Table 3.1.

Table 3.1: Types of temporary storage in urban areas.

Storage type	Description	Maximum water depth
Car parks	Used to temporarily store flows. Depth restricted due to potential hazard to vehicles, pedestrians and adjacent property.	0.2 m
Minor roads	Roads with speed limits up to 30 mph where depth of water can be controlled by design	0.1 m
Recreational areas	Hard surfaces used typically for basketball, five-a-side football, hockey, tennis courts.	0.5 m; but if area can be secured, 1.0 m
School playgrounds	Playgrounds can provide significant flood storage. Extra care should be taken to ensure safety of the children.	0.3 m
Playing fields	Set below the ground level of the surrounding area and may cover a wide area, offering significant flood volume.	0.5 m; but if area can be secured, 1.0 m
Parkland	Has a wide amenity use. Often may contain a watercourse. Care needed to keep floodwater separate and released in a controlled fashion to prevent downstream flooding.	0.5 m; but if area can be secured, 1.0 m
Industrial areas	Low value storage areas. Care should be taken in the selection as some areas could create significant surface water pollution.	0.5 m

Source: adapted from Balmforth et al. 2006.

3. Estimate volume of storage provided and include in a hydraulic model if appropriate.

Maximum flood depth and topographical data on the storage location can be used to estimate the volume of storage available at different locations. Where a hydraulic model is being used to simulate flood flows, the beneficial impact of temporary storage can be determined from the model for different flood events.

4. Specify outlet arrangements.

The temporary storage may empty to the urban drainage 'minor' system or to a river or flood channel passing through an outlet flow control device. In some circumstances it is necessary to empty the stored water by pumping. In other circumstances it is possible to rely on infiltration, and even evaporation, though in these cases emptying times are longer, creating a significant delay in returning the area to its primary function.

5. Consider health and safety issues.

The main health and safety considerations are likely to be:

- Access and escape routes for people
- Water depth (as seen in Table 3.1)
- Water velocity, as a potential hazard for people needing to walk through moving water
- Tripping hazards (especially when the hazard is submerged)
- Clear public information on the dual use of the area
- Maintenance to clear debris.

3.5. Drainage systems

Urban drainage systems need to be able to deal with both wastewater and stormwater whilst minimizing problems to human life and the environment, including flooding. Urbanization has a significant effect on the impact of drainage flows on the environment: for example, where rain falls on impermeable artificial surfaces and is drained by a system of pipes, it passes much more rapidly to the receiving water body than it would have done when the catchment was in a natural state. This causes a more rapid build-up of flows and higher peaks, increasing the risk of flooding (and pollution) in the receiving water. Many urban drainage systems simply move a local flooding problem to another location and may increase the problem. In many developed counties there is a move away from piped systems, towards more natural systems for draining stormwater. This is considered in detail later in this section. In many locations throughout the world, however, main drainage systems have never existed.

3.5.1. Sewers and drains

Where the drainage system of an urban area is piped, by a 'sewer system', there are two approaches in use: 'combined' or 'separate'.

The older parts of many cities (New York being an example) are drained using the combined system, whereby wastewater and stormwater are mixed and are carried together. The system takes the combined flow to the point of discharge into the natural water system, commonly via a wastewater treatment plant that discharges treated effluent. During heavy rainfall events, the stormwater flow will greatly dominate the wastewater flow in terms of volume, but it is hardly ever viable to provide sufficient capacity throughout the system for stormwater resulting from heavy rainfall, as the system would operate at a small fraction of its capacity during dry weather. Instead, structures are included in the system to permit overflow to a nearby watercourse. During significant rainfall events a significant volume of the flow is likely to overflow, rather than to continue to the wastewater treatment plant. As the overflowed water is generally a dilute mixture of wastewater and stormwater, these structures are designed hydraulically to prevent larger, visually offensive solids from being discharged to the river. However, the inescapable fact is that combined sewer overflows inevitably cause some pollution (Butler and Davies 2011).

In the urban areas served by a combined system, capacity is similarly exceeded by extreme stormwater flows. Under these circumstances, the 'surcharging' of the system may cause flooding of the urban surface and, as the flood water will include wastewater, there are associated pollution and health implications.

In a separate system, wastewater and stormwater are drained by separate pipes, often constructed in parallel. Wastewater is carried to the wastewater treatment plant, whereas stormwater is usually discharged direct to the nearest watercourse. The problem of combined sewer overflows is thereby avoided, but there are still challenges: stormwater discharge is usually untreated, and this may cause pollution. Stormwater may enter the wastewater pipe either through mistaken or unauthorized connections; there may also be infiltration of groundwater at pipe imperfections. Because of the relative proportions of wastewater and stormwater during heavy rainfall, these additional inputs may significantly reduce the capacity of the pipe for the wastewater it was designed to carry. Figure 3.8 is a highly simplified representation of a combined and separate system showing only a few branches.

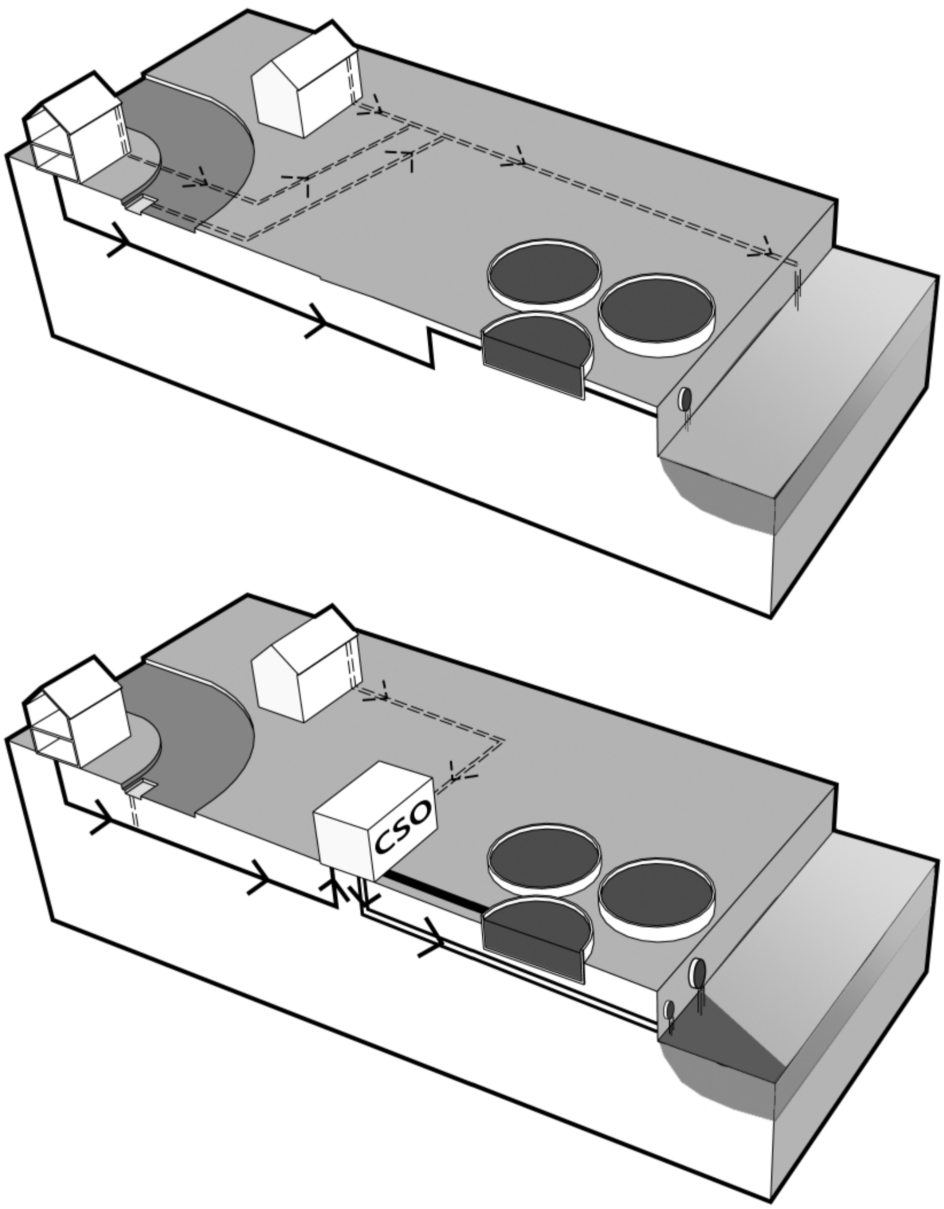

Figure 3.8: Combined system (top) and separate system (below). Source: BACA, Adapted from Butler and Davies 2011.

In urban areas without conventional piped sewer systems, disposal of excreta and wastewater is likely to be localized, though in some cases simplified (shallow and small diameter) pipes are used. Stormwater is most likely to be carried by open drains, typically unlined channels along the side of the street. Better constructed channels may be lined with stone or concrete (Photo 3.5), and may be integrated into the urban landscape (Photo 3.6). Open drains are far cheaper to construct than stormwater sewers, and although they can easily become blocked by debris or refuse from the surface, such blockages are more easily monitored and removed than in piped systems.

Maintenance is vital, not only to remove obvious obstructions, but also cleaning out deposited sediment, and then disposing of the material so that it does not go back into the drain. In heavy rain, the capacity of an open urban drainage channel may quickly be exceeded; in a well planned system, overflow should be to a specified 'major system' (described in Section 3.4.2) such as a road which can act as a drainage channel.

Where there is no adequate system for disposal of wastewater, there is a high likelihood that open drains will be contaminated by foul sewage. This could come from contributions from areas without sewers, or from discharge from simplified sewerage which does not lead to an adequate treatment facility. Open drains may also be misused for the disposal of domestic solid waste. Where the quality of stormwater carried in open drains is an issue for these reasons, there may be limited opportunities for using semi-natural systems of urban drainage that rely on the storage or infiltration of stormwater (considered in Section 3.4.4) because of public health issues.

Photo 3.5: New urban drainage in Mafalala neighborhood, Maputo, Mozambique.
Source: BBC News

Photo 3.6: Reconstructed urban drainage in Acapulco, Source: UN-HABITAT

3.5.2. Major versus minor systems

As discussed above, when the capacity of a drainage system is exceeded, the resulting 'exceedance flow' is generated on the urban surface. Under these circumstances the drainage system may be seen as consisting of two components: the 'minor system' (consisting of the sewer pipes or open drains described above) and the 'major system' (on the surface). The latter may consist of 'default pathways' taken by the flood flow, such as roads, paths or incidental storage areas. Alternatively 'design pathways' may have been created specifically to cope with exceedance flow. Design pathways include floodways, retention basins, or designated areas of public open space for temporary storage. On a small scale, some adaptation to existing urban features like road profiles and curb heights can improve the effectiveness of pathways for extreme events.

Significant components of a design pathway can be elements of urban infrastructure that have a dual role: for example, as a road (at times when there is no flood) and as a flood channel. The Kuala Lumpur Tunnel discussed in Case Study 3.4 is an example of this approach to infrastructure.

Another large scale project of this type is the refurbishment, upgrading and extension of the system of floodways in Jakarta which is presented as a Super Case Study elsewhere in this volume.

Case Study 3.4: Kuala Lumpur SMART Tunnel, Malaysia

Kuala Lumpur, the capital of Malaysia, is situated in the mid-upper reaches of the 120 kilometer long Klang River which drains a catchment of some 1,288 square kilometers. In the 1970s, a flood mitigation master plan was developed which incorporated a number of engineering options, including upstream storage, poldering, pumped drainage, and improvement of the drainage capacity of the Klang River and its major tributaries.

The Stormwater Management and Road Tunnel (SMART) project was designed both to divert stormwater and to re-route traffic away from the inner city. The scheme consists of a 9.7 kilometer long tunnel, nearly 12 meters in diameter, which runs to the east of the city centre of Kuala Lumpur. During moderate storms, the bottom section of the tunnel channels excess water without stopping the traffic flow. In case of severe storms, all traffic is evacuated and automatic watertight gates opened to allow floodwater flow. The tunnel has combined storage capacity of three million cubic meters.

The construction cost of the SMART Tunnel project was approximately US$515 million. As it was recognized that as well as the need to mitigate flooding there was an equally urgent imperative to relieve traffic congestion in the city, an innovative solution was proposed in which a tunnel would be used to carry road traffic except during flood events. Part of the total cost of the stormwater relief was offset by tolling the traffic congestion relief. Through this approach, one tunnel will provide flood and traffic improvements to Kuala Lumpur at a cost that is far less than two separate measures. The case demonstrates the potential of flexible, multi-purpose approaches to infrastructure design.

Sources: Wilson 2005; Krause et al. n.d.

Photo 3.7: Roadway/flood channel Yemen. Source: Bill Lyons/World Bank

3.5.3. Interface with river systems

Urban drainage systems are a subset of flood conveyance. Whichever way they are designed, they must discharge to rivers or other flood conveyance systems. It was reported that over 55,000 properties were flooded during the summer 2007 floods in England. Two-thirds of the properties flooded were affected because drains and sewers were overwhelmed (Defra 2008). However, the sewer system cannot be considered in isolation, since its capacity is reduced by rising levels in the receiving waters. Where capacity of an urban drainage system is the dominant cause of flooding, the flood risk can be reduced by increasing capacity (for example, by increasing the size of pipes or channels), but this is appropriate only where there is sufficient capacity in the system downstream.

A practical example of urban drainage in context can be seen in Case Study 3.5 below and also in the Mozambique Super Case Study elsewhere in this volume.

Case Study 3.5: North and East Greater Tunis Flood Protection

In Tunisia, two-thirds of the total population lives in urban areas, with about 20 per cent living in Greater Tunis. Major flood events caused by heavy rainfall have been recorded in 2003, 2004, 2006 and 2007. The most recent floods in 2006 and 2007 caused significant economic damages, and disruption of vehicular traffic. Drain blockages lasted for several days.

Water sector management ranks high in the country's economic and social development agenda. In response to these problems, a flood protection scheme is being implemented and is scheduled to be completed in 2014. The scheme consists of the following three components:

- Remote protection - construction of large and small dams, with catchment ponds to control runoffs - designed to protect the urban areas and farmlands and to store the water to be used for both irrigation and domestic consumption
- Close protection - deviation of wadis and watercourses outside the urban areas; development of wadis and watercourses crossing urban areas; and construction of flood reducing basins upstream of urban areas
- Stormwater drainage within urban areas - construction of sanitation networks, made of primary and secondary collectors for the drainage of stormwater.

Rapid urbanization in Greater Tunis has altered the physical environment generating higher surface runoff that often exceeds local drainage capacity, thereby causing localized flooding problems. Construction and rehabilitation of drainage systems can be successful in reducing both flood risk and flood impacts.

Source: AfDB 2009.

3.5.4. Semi-natural systems, 'SUDS'

As discussed above, a key characteristic of many artificial urban drainage systems, as compared with natural systems, is a more rapid build-up of flows and higher peaks, causing an increase in flood risk. It is possible to return the catchment response to a more natural state by using more natural methods of drainage. These use the infiltration and storage properties of semi-natural devices such as infiltration trenches and swales (both discussed in Section 3.6.2) or ponds, all of which slow down the catchment response, reducing the peak outflow and thus lowering the flood risk.

Such drainage systems not only help in preventing floods, but also improve water quality. In addition they can enhance the physical environment and wildlife habitats in urban areas. In the US and other countries, these techniques are termed 'best management practices' (BMPs), as a subset of Low Impact Development (LID). In Australia the approaches are part of 'water sensitive urban design'. The term SUDS (Sustainable Urban Drainage Systems) is well-established in the UK (Woods-Ballard et al. 2007; Butler and Davies 2011).

SUDS devices are most effective in combination, in the form of a 'management train', as illustrated in the How To section 3.5.7 which shows the arrangement and components of such a sequence.

Wherever possible, stormwater should be managed in small, cost-effective landscape features located within small sub-catchments, rather than being conveyed to and managed in large systems at the bottom of drainage areas. Water should be conveyed elsewhere only if it cannot be dealt with locally.

Like all drainage systems, SUDS are designed to provide capacity for a storm event of a particular frequency. For more extreme events, exceedance flows are likely to be generated and must be carried by the major drainage system, as discussed above in Section 3.5.2.

Many SUDS devices are based on infiltration to the ground, the risk of groundwater pollution is an important consideration, especially where surface runoff is likely to be polluted and the groundwater is used for drinking supplies. The design of a permeable pavement system, for example, can be adjusted to allow infiltration, or not, in order to account for this (discussed in Section 3.6.3 below).

The main types of SUDS devices, all of which are discussed later in this chapter, can be listed as:

- Inlet control
- Infiltration devices
- Vegetated surfaces
- Permeable paving

– Filter drains
– Infiltration basins
– Detention ponds
– Retention ponds
– Constructed wetlands.

Inlet control devices provide storage close to the point where the rainfall is first collected. Rooftop ponding uses the storage potential of flat roofs; as this creates an additional load there is an increased need for water tightness, as well as good maintenance of outlet control devices. A green roof is a planted area that provides storage, encourages evapo-transpiration and improves water quality. A water store, consisting of a water butt or a tank near to ground level, can store rainwater and make it available for garden use, though some outflow must be assured to provide capacity for subsequent rainfall.

Instead of connection to the drainage system, water collected from roofs can be diverted at the bottom of the downpipe to infiltrate in nearby stable pervious areas. Paved area ponding, to accommodate heavy rainfall, can be achieved by restricting inflow to the piped drainage system, thereby reducing flood risk downstream.

Detention basins are storage facilities formed from the landscape with controlled outflow. They store stormwater temporarily, and are dry between storms.

Retention ponds provide storage within a permanent body of water. They allow natural treatment of the water and provide environmental and amenity benefits.

Where there is a danger that ponds may become mosquito-breeding areas, a permanent open body of water is not appropriate. Detention basins must, therefore, be designed to dry out before the larvae have time to mature (one week or less) (Reed 2004).

The benefits of SUDS can be realized in existing urban areas by retrofitting. Its challenges tend to be associated with availability of space, and the difficulty of adapting existing systems. Local application of inlet control may be the most feasible approach.

3.5.5. Surface water management plan

The concept of a surface water management plan is to consider all aspects of localized surface water flooding, including urban drainage, groundwater, and runoff from land. On the wider scale this would be a component of a catchment wide management plan: this approach looks at the scope for reducing flood risk by identifying appropriate measures that could be taken upstream of the urban area. As seen in Case study 3.6 below, surface water management can be considered at a city scale and incorporated within wider city plans.

Case Study 3.6: New York City Green Infrastructure Program

As part of its 'Green Infrastructure Plan', the Department of Environmental Protection (DEP) in New York City incentivized green infrastructure projects to improve the quality of the city's waterways by capturing and holding stormwater runoff to reduce sewer overflows. Green infrastructure projects can include green roofs as well as tree pits, street side swales, and porous pavements for roadways. As explained in more detail in 3.5.4, these reduce the flood risks associated with piped urban drainage systems by using the infiltration and storage properties of more natural drainage systems. Private property owners, businesses, and community organizations are eligible for project funding that use green infrastructure, with particular preference given to projects that can create further benefits such as decreased energy use for cooling buildings and increased community ownership.

Green infrastructure has the potential to be cost-effective as DEP modeling showed that combined sewer overflows (CSO) volumes will be reduced at significantly less cost than using conventional measures. The success of the initiative will depend on considerable support from local communities and businesses in developing and introducing innovative ways to deal with stormwater.

Sources: NYC Department of Environmental Protection (DEP); NYC Green Infrastructure Plan: http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_ExecutiveSummary.pdf

3.5.6. Further reading

Butler, D. and Davies, J.W. 2011. Urban Drainage, 3rd edition. UK: Spon Press.

3.6. Infiltration and permeability of urban areas

Urbanization affects the natural water cycle. When rain falls, some water returns to the atmosphere (through evaporation or transpiration by plants); some infiltrates the surface and becomes groundwater; and some runs off the surface. Since urbanization increases the proportion of the surface that is impermeable, it results in more surface runoff and reduced infiltration (Figure 3.9). As we have seen, surface runoff finds its way to a watercourse far quicker than groundwater and therefore increases flood risk, and if the surface runoff is conveyed via a piped drainage system the effect is even more pronounced.

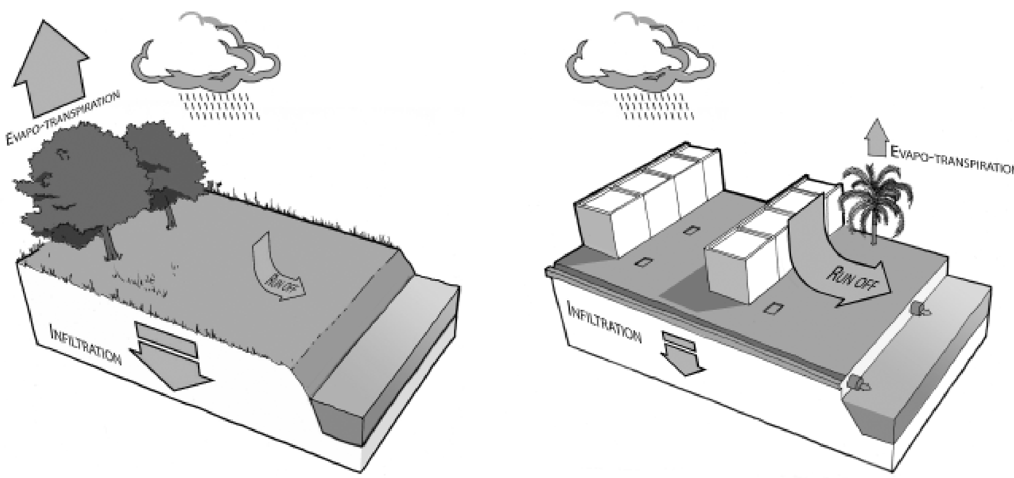

Figure 3.9: Effect of urbanisation on infiltration and runoff. Source: BACA, adapted from Butler and Davies 2011.

Increasing infiltration via improved permeability in urban areas can reduce flood risk, but in many cities the opposite is occurring. The increasing densification of towns and cities implies that every space is utilized to the maximum for the use of urban dwellers. This leads to an increase in hard surfaces and a decrease in permeability of any open space left after the construction of buildings. An example of this is the paving of front gardens in the UK to allow for parking spaces: in one part of London, 68 percent of the area of front gardens is now hard-surfaced, and the figure is rising. Leisure and recreational uses also tend to involve impermeable surfaces. Cost-cutting measures designed to limit the regular maintenance of green spaces can also lead to the concreting or de-greening of spaces.

A major characteristic of most SUDS systems (as discussed above) is to increase permeability and therefore infiltration. The use of SUDS is promoted in the UK via formal Building Regulations, which state that ‘surface water drainage should discharge to a soakaway or other infiltration system where practicable’. Planning guidance in England, specifically related to development and flood risk, also strongly favors the use of SUDS in new developments. Measures like these have the effect of increasing infiltration, and are steps in the right direction in terms of preventing flood risk from increasing as a result of urbanization.

3.6.1. Infiltration devices

These include soakaways and infiltration trenches. A soakaway is an underground structure, typically circular in plan, which facilitates infiltration into the ground. An infiltration trench is a linear excavation, usually stone-filled, achieving the same aim with a greater area of exposure to the ground. These devices are only suitable in ground with suitable infiltration properties, positioned above the level of the water table at any time of year. Filter drains are perforated or porous pipes laid in a trench containing granular fill and are typically located in the verge of a road to collect water from the road surface and carry it away. Infiltration basins are open depressions in the ground which collect water and allow it to be absorbed gradually.

Photo 3.8: Infiltration through greening of car park in Washington, DC. Source: J Lamond

3.6.2. Vegetated surfaces

Swales are grass-lined channels which allow the infiltration, storage and conveyance of stormwater. Small swales can run beside local roads, large swales beside major roads, and swales may also form landscaped channels for conveyance of stormwater. Filter strips are gently sloping areas of vegetated land. Swales and filter strips delay and reduce stormwater peaks, and trap pollutants and silts. See Photo 3.8 above.

3.6.3. Permeable paving

Permeable paving creates a surface that allows infiltration, either because it is porous, or because specific openings have been provided (for example, the spaces between paving blocks). The most common applications are for car parks, but lightly trafficked roads and driveways are also suitable. The sub-base (Figure 3.10) provides storage for rainwater, typically in the voids between granular particles. The collected water may then be allowed to infiltrate into the ground; alternatively, where it is important to protect groundwater from pollution, the base and sides may be sealed, and water flows to a piped outlet, but far more slowly than it would in a piped system.

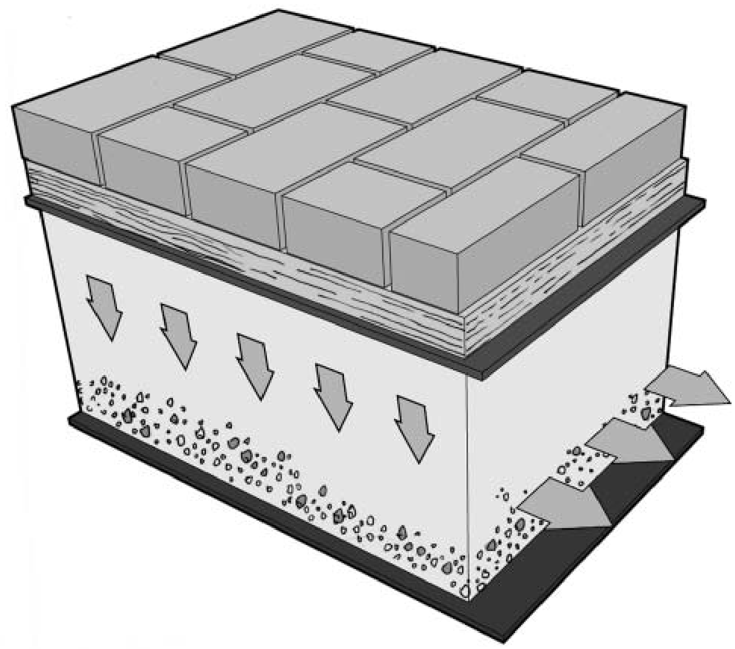

Figure 3.10: Permeable pavement – typical vertical section. Source: adapted from Butler and Davies 2011.

The only serious restriction on infiltration in urban areas is where there may be a risk of polluting groundwater that is used as a water resource.

A significant solution to the problem of increased and more rapid rainfall runoff is by using the system of development permitting. Guidelines need to be issued giving examples of how urban design can maximize infiltration into groundwater. Permits are then only authorized if such appropriate measures are included in the construction works. On a wider level, urban area administrations need to draw up a land use management and zoning plan, which recognizes the need for open spaces that can act as temporary rainfall storage, as well as being an urban recreational amenity.

Some agricultural practices reduce infiltration, and these increase flood risk to urban areas downstream. Adapted agricultural practice to reverse these effects includes conservation tillage, ploughless cultivation and avoiding bare soil. The preservation and extension of existing wetlands and forests in the upstream areas of a catchment enhances infiltration, and in addition reduces runoff through evapo-transpiration. Primary forests with broad-leafed trees are much more effective in reducing runoff than planted pine species.

3.6.4. Further reading

CIRIA. 2007. The SUDS manual. London, CIRIA.

3.6.5. How to maximize the effectiveness of SUDS

Sustainable urban drainage systems (also, as seen above, known as Stormwater Best Management Practices (BMP) or water sensitive urban design) have been seen as an effective and attractive alternative to conventional drainage schemes because of their advantages in handling runoff and urban stormwater at source and reducing the burdens of flow and pollutants on receiving systems.

SUDS devices are most effective when arranged in a series which mimics natural catchment processes, in the form of a ‘management train’. In this way, the passage of water through the urban environment is slowed, maximizing the opportunity for infiltration and pollution control before the release into artificial channels or watercourses. In planning a management train, progressive stages in the management of runoff can be identified: inlet control, source control, site control and regional control. Particular SUDS devices are suitable at each of these stages (Figure 3.11). Devices at the top of this sequence should be used wherever possible as inlet control and source control can provide the most benefits.

Method

1. Identify appropriate SUDS devices

2. Link them in the form of a management train

3. Ensure that the plan increases permeability and optimizes infiltration

4. Consider the potential for SUDS to enhance the urban landscape

5. Detailed design stage

1. Identify appropriate SUDS devices

In order to select an appropriate set of devices it is necessary to understand characteristics of the urban area or development site in terms of land use, hydrology, geology and flood risk and environmental assessment. The requirements in terms of surface water management and pollution control and the capacity of downstream systems must also be taken into account. This will usually require extensive surveys. Once the requirements have been determined the appropriate devices that best meet the requirements can be selected using their particular characteristics as described in 3.4.4 and Table 3.2 below.

Table 3.2 SUDS selection matrix

SUDS group	Technique	Net Land Grab	Cost	Runoff volume reduction	Suitable for flow rate control 100 year event	Maintenance	Habitat creation potential
Retention	Retention Pond	H	M	L	H	M	H
	Subsurface storage	L	M	L	H	L	L
Wetland	Various	H	H	L	L	H	H

	Submerged gravel	M	H	L	L	M	M
Infiltration	Infiltration trench	M	L	H	L	L	L
	Infiltration Basin	H	L	H	H	M	M
	Soakaway	L	M	H	L	L	L
Filtration	Surface sand filter	L	H	L	L	M	M
	Subsurface sand filter	L	H	L	L	M	L
	Perimeter sandfilter	L	M	L	L	M	L
	Bio-retention / filter strip	H	M	L	L	H	H
	Filter trench	L	L	L	L	M	L
Detention	Detention basin	M	L	L	H	L	M
Open channels	Conveyance swale	H	L	M	H	L	M
	Enhanced dry swale	H	M	M	H	L	M
	Enhanced wet swale	H	M	L	H	M	H
Source control	Green Roof	L	L/H	H	L	M	H
	Rainwater harvesting	L	H	M	L	H	L
	Pervious pavements	L	M	H	L	M	L

Further matrices showing the suitability of SUDs devices by land use, site characteristics, catchment characteristics and amenity and environmental requirements can be found in The CIRIA SUDs manual.

2. Link them in the form of a management train.

Figure 3.11 presents the stages of a SUDS treatment train and the recommended devices at each stage.

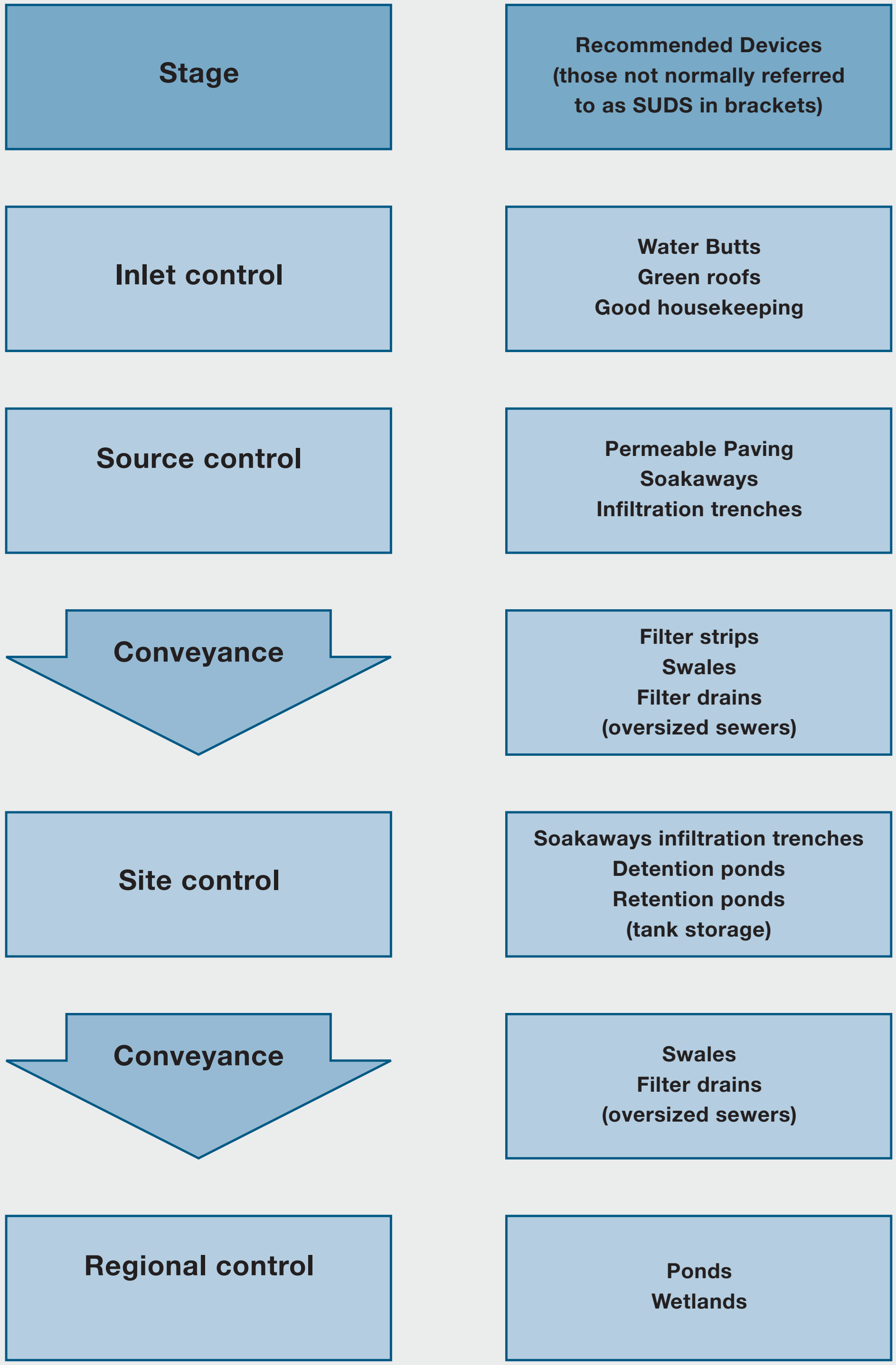

Figure 3.11: SUDS management train. Source: adapted from Butler and Davies, 2011.

3. Ensure that the plan increases permeability and optimizes infiltration

This is achieved through land use planning and control, ensuring that new developments maximize infiltration (see Section 3.5), and by greening urban areas (see Section 3.6.1). Relevant SUDS devices are identified below. For areas without serious pollution concerns the maximization of infiltration replenishes the water table and reduces peak run off.

Devices whose aim is specifically to facilitate infiltration:

- Soakaways
- Infiltration trenches
- Infiltration basins

Devices which encourage infiltration as part of their function:

- Swales
- Filter strips

Devices which encourage infiltration in specific applications:

- Permeable paving

4. Consider the potential for SUDS to enhance the urban landscape.

This can be achieved in a number of ways:

- By ensuring that ponds and other SUDS features are designed to be aesthetically pleasing, offer amenity value and are integrated effectively in the landscape
- By integrating water features that have a drainage or flood risk- reduction function into urban design
- By restoring streams that have been heavily engineered as urban channels to a more natural state
- By reopening ('daylighting') culverts (see Section 3.2.5).

5. Detailed design of system

Having selected appropriate devices and designed a management train, it is then appropriate to proceed to a detailed design of the individual features, including their inflow and outflow to the next feature to determine whether the whole system fulfils the original requirements in terms of flow and pollution control. Standard drainage software is acknowledged to be a poor approximation for SUDS devices particularly for infiltration devices which are highly sensitive to prior soil conditions and permeability.

Common Problems

The maintenance of SUDS is just as important – maybe more so – than traditional systems. The sustainability of the train depends on the functioning of every element and the ownership and responsibility for maintenance of all features should be established in advance. As SUDS trains often involve open systems, the potential for use for waste disposal and blockage is high, but the advantage of open systems are that any problems are more readily apparent and the users can see and deal with many problems quickly and easily.

In dense urban areas, competing land use requirements may make the installation of features unacceptable or too costly. Devices with low net land requirements such as soakaways or devices with dual purpose are preferred in such circumstances, such as permeable pavements, rainwater harvesting, green roofs and amenity features.

Resources and Costs

Costs of SUDS are of the same order as that for conventional drainage systems but it is of course important to take into account the whole life costs of regular maintenance and operation costs. Construction costs for simple devices such as infiltration basins and swales can be very low and use local labour and materials. More expensive options such as soakaways, filter drains, green roofs and permeable pavements require greater expertise and higher capital costs to install – up to ten times the cost of simple devices for equivalent storage capacity. However increased construction and maintenance costs must be balanced against land costs which are likely to be a significant component of the total costs for simple devices such as swales and ponds.

As an example the cost of installing permeable paving varies widely depending on the system, for example concrete blocks or permeable asphalt. However they are generally more expensive than typical asphalt (it can be up to 50% higher than non-permeable equivalents according to Boston MAPC (2011)) and the maintenance costs will also be higher. Despite this a study for the UK concluded that retrofitting permeable paving would be highly cost beneficial (Gordon-Walker and Harle, 2007) and the cost benefit for new installations would be higher.

Expertise to design and install SUDs systems is less commonly available than for conventional drainage and the availability of design software is lower implying that the design costs for SUDs may be higher than for conventional systems. However the potential for dual benefits in terms of treatment and amenity make these systems worth the consideration.

3.7. Groundwater management

In unsaturated ground, rain infiltrates into the ground and percolates downwards until it reaches the water table, below which the pores and cavities of the ground are saturated with water. Here the water moves laterally, generally slowly, under the influence of the gradient of the water table and the form of any underlying impermeable stratum. The water-bearing strata, or 'aquifers,' may consist of unconsolidated materials like sands and gravels, or consolidated materials like sandstone and limestone. Where the vertical space between two impermeable layers is saturated the aquifer is said to be 'confined'.

Aquifer recharge is enhanced by infiltration created through interventions like SUDS. In urban areas additional recharge may result from leaks in water supply pipes or drainage systems.

Groundwater discharge provides the base flow in rivers and continues during long periods without rainfall. Where the water table, or the surface of the aquifer, intersects the ground surface, groundwater is released via springs. During floods there can be rapid changes in groundwater outflow especially from confined aquifers.

In addition, groundwater management is necessary to prevent land subsidence, which leads to even greater problems in low-lying areas.

3.7.1. Groundwater flooding

Groundwater flooding is most likely to be a problem in areas that are low-lying and have water-bearing rock strata at the ground surface. An example is the Argentinean capital city of Buenos Aires: groundwater causes flooding of basements, rising damp in domestic dwellings, malfunction of in-situ sanitation systems, overloading and overflowing of sewers, and disruption to the urban infrastructure (Foster 2002). Flooding by groundwater can be hard to model and, therefore, hard to predict because the below-ground processes are complex and the properties of the ground can be highly non-homogeneous. Groundwater flooding is also characterized by the fact that the effects may be of long duration, lasting for weeks or months before groundwater levels lower sufficiently to alleviate the problem.

As some of the strategies for reducing flood risk involve increasing infiltration, the levels of groundwater may rise: this may have both positive and adverse impacts on flooding, for different areas and communities. The main method of controlling groundwater flooding is by pumping; the level of groundwater can be reduced by sustained abstraction and disposal of the water in a location where it will not infiltrate directly back into the aquifer. If the water is of sufficient quality it can be piped into the main supply, where this exists, either with or without treatment. Extracted water may also be used for low-grade industrial purposes, cooling, or irrigation of non-agricultural land elsewhere, although care needs to be exercised to ensure that the quality of such groundwater is fit for the intended purpose, following WHO and the Food and Agriculture Organization of the UN (FAO) guidelines and standards. Energy for pumping, treatment and the cost of transportation of water to the intended usage site are also major considerations.

3.7.2. Land subsidence

Where groundwater levels are lowered as a result of abstraction there is a risk of land subsidence. This can be a particular problem in coastal areas as has been identified by the World Bank Coastal Megacities report: large deltas are sinking at rates at up to six centimeters per year due to land compaction or extraction of groundwater. The Pearl River and Mekong deltas are noted as being particularly vulnerable (World Bank 2010a).

The regulation of groundwater abstraction can be a thorny legislative issue, involving the consideration of who currently owns the rights to abstraction and how they may be restricted, as well as pricing issues (IGES, 2008). Charging for groundwater has been implemented for example in Jakarta, Bangkok (see Case study 3.7 below), Bandung and Tianjin. However the effectiveness of such measures is often undermined by low pricing and the exemption of agricultural use.

Case Study 3.7: Combating Land Subsidence in Bangkok

Greater Bangkok, Thailand, witnessed widespread exploitation of groundwater starting in the 1950s, leading to significant land subsidence and damaging to urban infrastructure, as well as concerns regarding sea intrusion into the aquifer. Measures such as banning the drilling of water wells in critical areas, together with licensing and charging for metered or estimated groundwater abstraction, were all introduced but took some years to be implemented. Measures undertaken by the Government (costs stated in Thai Baht):

- 1969: Land subsidence given public attention

- 1978: Enforced Groundwater Act, B.E. 2520 (1977); the start of licensing for groundwater activities
- 1983: Critical Zone identified (four provinces)
- 1984: Groundwater tariff of 1 Bt per cubic meter imposed (six provinces)
- 1992: Groundwater act amended
- 1994: Tariff increased to 3.5Bt per cubic meter (six provinces)
- 1995 All provinces must pay groundwater charge; critical zone expanded (seven provinces)
- 2000-03: Tariff increased to 8.25Bt per cubic meter (in critical zone)
- 2003: Groundwater Act amended
- 2004: Tariff increased to 8.5Bt per cubic meter (in critical zone). Groundwater preservation charge imposed in critical zone

The groundwater pricing mechanism in Bangkok can be seen as a successful example. Charges were slowly increased until 2003, and an additional charge entitled "groundwater preservation charge" was introduced in 2004. Groundwater is now more expensive than water from the piped public water supply scheme. By combining a strict pricing system with expansion of public water supply, total abstraction was reduced from 2,700 million liters per day in 2000 to 1,500 million liters per day in 2005, and land subsidence was also significantly reduced. The groundwater preservation charge is innovative because it is earmarked for research and groundwater conservation activities by the Groundwater Act.

This example illustrates the difficulties encountered in trying to control groundwater levels; it is not easy to find the right balance of tariffs to achieve a reduction in abstraction. However the measures undertaken by the Bangkok municipality have resulted some positive outcomes and similar measures could yield benefits elsewhere.

Sources: Babel 2008; World Bank 2010b; IGES 2008.

Provision of alternative water sources is an essential element of any program to prevent groundwater extraction. An increase in the number of water treatment facilities and the encouragement of rainwater harvesting, or other surface water management techniques, can assist somewhat here, although this will reduce replenishment of the aquifer. Addressing water demand is another alternative strategy.

3.7.3. Rainwater harvesting

The term rainwater harvesting refers to reuse of stored water, including water purification, and can form part of a sustainable drainage system as described in Section 3.5.4. Most commonly, reuse will be for purposes which are less sensitive to water quality (such as irrigation, washing or toilet flushing). In this case, water from a roof may be diverted to a large underground tank; in some regions the stored water is used for drinking, though it must usually be filtered or treated if it used for this purpose. Case study 3.8 below gives an example of the successful implementation of such a system in Korea. In cases where water quality is important, the 'first flush' of rainfall, which can be particularly polluted, should be diverted away from the storage facility. Water from rainwater harvesting schemes can also be used for groundwater recharge.

The process is seen as having multiple benefits (UNEP/SEI 2009):

Provisioning

- Can increase crop productivity, food supply and income
- Can increase water and fodder for livestock and poultry
- Can increase rainfall infiltration, thus recharging shallow groundwater sources and base flow in rivers
- Can regenerate landscapes increasing biomass, food, fodder, fiber and wood for human use
- Improves productive habitats, and increases species diversity in flora and fauna

Regulating

- Can affect the temporal distribution of water in landscape
- Reduces fast flows and reduces incidences of flooding
- Reduces soil erosion
- Bridges water supply in droughts and dry spells
- Can provide habitat for harmful vector diseases

Cultural

- Rain water harvesting and storage of water can support spiritual, religious and aesthetic values
- Creates green oasis, or 'mosaic' landscape which has aesthetic value

Supporting

- Can enhance the primary productivity in landscape
- Can help support nutrient flows in landscape.

In the specific context of flooding, there are three potential direct benefits:

- Harvesting water can reduce peak flows. When implemented on a grand scale this is sometimes known as stormwater harvesting, but small scale collection of rainfall can also reduce flooding, if adoption is widespread within a community.
- Harvesting water can assist with replenishing groundwater levels, thus helping to prevent ground subsidence. Many documented cases exist where rainwater harvesting has conserved groundwater. Recharging is seen in India where the Central Groundwater Board oversees artificial recharge of groundwater both in rural and urban areas. An example is the Ghogha project in rural Gujarat, which uses 276 recharge structures in 82 villages (Khurana and Seghal 2005).
- In a flood situation, when water supplies may become disrupted or contaminated, the collection of rainwater may be a more reliable and potable supply, as is seen in northern Bihar in India. If storage tanks are provided at emergency evacuation points, then the problems of water supply for evacuees may be alleviated.

Case Study 3.8: Rainwater Harvesting at Star City, Seoul

Rainwater harvesting was incorporated into a major real estate development in Seoul. Star City is a shopping and housing project consisting of more than 1,310 apartments and provides accommodation for more than 4,000 people. The basic design idea was to collect up to the first 100 millimeters of rainwater falling on the development and to use it for gardening and sanitation purposes, as well as tap water.

An entire floor below the ground with a total area of 1,500 cubic meters is used as a water storage area which can store up to 3,000 cubic meters of water in three separate tanks. Two of the tanks are used to collect rainwater from the rooftop and the ground. This reduces flood risk in the area during the monsoon season, while simultaneously being used for water conservation. The third tank is used to store tap water in the case of emergency. It is expected that the system will save about 40,000 cubic meters of water per year, which is about 67 percent of the annual amount of rainfall over Star City.

Moreover, because the system harvests rainwater on site, it reduces the energy required, and therefore the CO2 emissions for water treatment and transportation. This project is considered very successful and the local government passed a city-wide regulation to further promote rainwater harvesting in new developments.

Source: UNEP 2009.

The technique for single household roof rainwater harvesting systems is the simplest of all. Its sophistication depends on the level of capital investment. The main component of such a system is collection of water through roof catchment and piping it to a tank underground or to the cisterns directly. The main materials used for roof rainwater harvesting system are concrete, tiles, fiberglass, slates, galvanized iron, and aluminum sheets. The pipes used for conveyance purposes are mainly PVC, which is cost effective. However they have their own negative effects in terms of health hazards. Therefore regular cleaning and monitoring of such systems are recommended. Some systems have options for filtration and disinfection of collected water.

Similar systems are also used in larger institutions for example schools; and company buildings, and the collected water is sometimes stored separately in different storage tanks and then supplied for non-potable purposes which are quite effective. In case of collection of rainwater through runoff from stormwater or heavy rainfall, the techniques like storing it in low-lying ponds or reservoirs are cost effective. However these reservoirs need regular cleaning and monitoring for effective use of the water afterwards.

The material of construction for storage tanks are generally concrete, polythene, steel, and fiber glass. The quality of the water collected may be significantly affected if tanks are not properly cleaned at regular intervals, as pollution from debris, dirt, animal droppings, rodents, insects and other solid materials can occur. The technique of rainwater harvesting in natural reservoirs helps in restoring water to its natural hydrological cycle, to some extent through underground seepage which is minimal in urban areas because of asphalt cover. Such techniques not only help cities to be self-reliant with their water storage capacity but also assist in the restoration of city drainage systems by not letting them overflow to cause urban floods.

Examples of successful implementation of rainwater harvesting are seen in Australia where commercial rainwater harvesting concerns are profiting from concerns about water availability. The potential exists for flood-prone areas to develop community-based commercial harvesting programs.

3.7.4. Further reading

LILLYCROP, W.J., PARSON, L.E., and IRISH, J.L. (1996). Development and Operation of the SHOALS Airborne Lidar Hydrographic Survey System. SPIE Selected Papers, Laser

Remote Sensing of Natural Waters: From Theory to Practice, 2694, 26-37.

UNEP/SEI (Stockholm Environment Institute). 2009. Rainwater Harvesting: a lifeline for human well-being. UNEP.

Wang, M., Zhou, Y. and Nie, L. 2009. Storage Capacity Analysis of Rainwater Tanks For Urban Flood Mitigation. Paper presented at COST22, Paris, November 26-7, 2009.

UN-HABITAT. n.d. Rainwater Harvesting and Utilization. Blue Drop Series Book 2: Beneficiaries & Capacity Builders. UN-HABITAT.

3.7.5. How to optimize a rainwater harvesting system for flood control

Rainwater harvesting is a green and sustainable option for increasing the supply of water in areas of water scarcity where the conventional water supply has failed to meet the demand of the community. This system has been used since ancient times. However in many cases it has declined in importance partly due to lack of need as piped water supplies improve and because of the lack of information and technology within rapidly expanding urban environments.

However it is now recognized that as well as providing a relatively clean and reliable source of water, rainwater harvesting can also prove to be an important technique for flood mitigation.

The traditional “linear” approach of managing large amounts of water in times of peak rainfall over a wide area involves diverting the water using sewers or rivers consisting of a line of conveyance. The “areal” approach of managing rainwater at source within a watershed, especially in urban areas, by collecting and then storing the water in numerous tanks and storage structures, can reduce peak runoff and help in reducing peak flow. The water thus stored can be used for non-drinking purposes resulting in water conservation. It can also be used for drinking purposes if proper purification measures can be installed. Rainwater harvesting can be treated as an innovative solution to prevent urban flooding.

Method

1. Understanding the rainfall patterns

2. Determining the technique

3. Delegation of roles and responsibilities

1. Understanding the rainfall pattern and the flood objective

To construct any effective rainwater harvesting system for secure water supply it is important to understand the physical factors affecting the rainfall regime of the area, for instance to have an idea of the total inflow and outflow of water. In an urban area, and with the added aim of flood mitigation, it is very important to have proper knowledge of the total cycle of water input and output. This involves quantity of rainfall in mm/year, pattern of rainfall i.e., type and total amount of rainfall, peak discharge rate and time, total runoff, the capacity of collection surface area (m2), storage capacity (m3), daily consumption rate, number of users, and the costs and alternative sources of water. A total system approach integrating rainwater harvesting into water treatment and supply should be subject to the same stringent hydraulic design as conventional piped systems.

For the purposes of flood control, the major considerations of the design should be to ensure that sufficient storage is available at times of peak flow to reduce the run off and prevent flooding, and that this storage is quickly made available to accommodate the next peak event. This is complementary to but could also conflict with the aims of a harvesting system solely for water supply where overflowing may be less of a problem and heavily polluted run off would not be acceptable. Ideally if a rainwater harvesting system has flood mitigation as a primary part of the purpose there should be storage and uses of the water that can accommodate or treat polluted run off.

However one useful advantage of rainwater harvesting is that much of the technology used is flexible and incremental with relatively little effort required for construction, operation and maintenance. In addition, such systems tend to fail gracefully: that is, if water is initially stored in a dispersed way at source, overtopping will probably not cause more problems than if the system were not installed. Therefore some improvements can be achieved quickly and cheaply even without full understanding of the system.

2. Determining technique

There are different types of rainwater harvesting systems. Techniques used for such purposes are determined by the type of rainwater harvesting system suitable in an area depending on the size and nature of the catchment available. The main components of rainwater harvesting for optimal flood control are primarily water collection, conveyance and storage. Therefore the most important aspect of consideration is to understand the impermeable surfaces generating run off relative to the storage capacity in the area.

Collection Options

Roof systems are the most common. They can be simple small roof collection systems for single households, larger roof collection systems for large commercial buildings, and collection systems in high rise buildings.

Suitable materials include:

- Galvanized corrugated iron or plastic sheets, or tiles.
- Thatched roofs made from palm leaves (coconut and palms with tight thatching are best). Other thatching materials and mud dis-color and contaminate the rainwater, often by allowing access to rats.
- Unpainted and uncoated surface areas are best. If paint is used it must be non-toxic (no lead-based paints).
- Asbestos-cement roofing does not pose health risks – no evidence is found in any research. However, airborne asbestos fibers (from processing and cutting) do pose a serious health risk of mesothelioma (asbestos-related cancer) if inhaled.

Land surface catchment systems and stormwater collection systems in urbanized areas are also possible. They are important for flood control but less common and tend to have a higher pollutant content.

Conveyance Options

Water can be stored at the point of collection, for example in roof tanks, which can be a great advantage if these tanks are situated in safe locations. Normally the water is channelized by installing rainwater channelization systems ranging from simple gutters to sophisticated filtration devices.

Timber or bamboo is also used for gutters and drainpipes; for these materials regular replacement is better than preservation. Timber parts treated with pesticides to prevent rotting should never come into contact with drinking water.

Storage options

Storage needs to be appropriate for different reuse types and may also be linked to mains systems for security of supply during dry periods. Simple home-based systems can be jars and water barrels. Larger systems use roof tanks, surface tanks or underground storage.

Materials for surface tanks include metal, wood, plastic, fiberglass, brick, interlocking blocks, compressed soil or rubble-stone blocks, ferro-cement and concrete. The choice of material depends on local availability and affordability – and weight if they are to be situated on the roof. In most countries, plastic tanks are also commonly available.

Sub-surface tanks require a water lifting device such as a pump for emptying. Materials and design for the walls of sub-surface tanks or cisterns must be able to resist the soil and soil water pressures from outside when the tank is empty (upward pressure can cause tanks to float in high groundwater areas). Damage can also be caused by tree roots and heavy traffic. Usually concrete is used, strengthened with steel. While there are experiences of using green materials such as wood, bamboo and basket work as alternatives to steel for making concrete tanks, these have not always been successful.

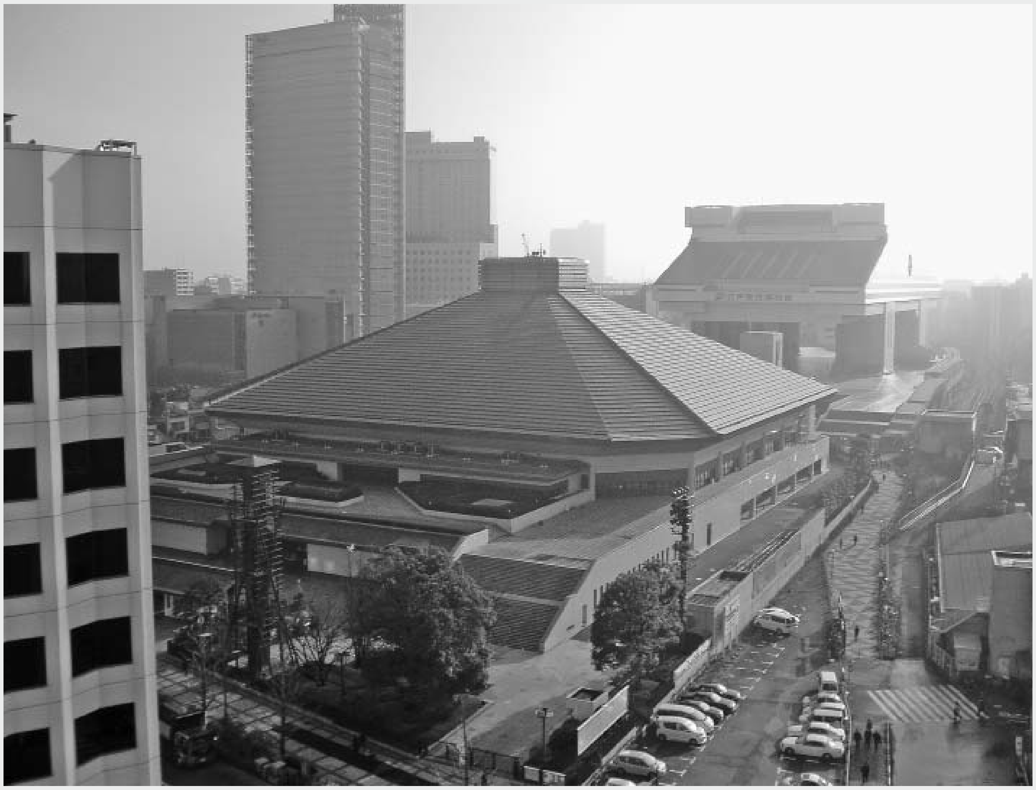

Photo 3.9: The Kokugikan sumo wrestling arena rain water harvesting system in Tokyo, Source: Japan Wikicommons

The storage of rainwater in numerous small tanks and reserves helps in reducing peak runoff and controlling overflowing of drainage infrastructure. This is more cost effective than storing rainwater in larger reservoirs or improving the carrying capacity of the drainage infrastructure through upgrading in urban areas. This however requires effective public participation and awareness generation.

3. Delegation of roles and responsibility

As mentioned earlier, the success of water harvesting systems rests on how well the system is organized and managed. Delegation of responsibility to undertake the smooth running of the system is crucial. It is important that roles and responsibilities are allocated at both individual and community levels. Participation from different stakeholder groups, for example from both from the community and commercial sectors, is essential too. Proper mandates for new constructions based on size and storage capacity of buildings should be released beforehand, and permission should be sought and granted before construction.

The role of local government is not only to develop incentives and help the participants to organize but also to keep a close eye on the entire process in the long term. A special role could be assigned to the disaster management authority in monitoring the water levels within the storage systems to ensure adequate capacity for extreme rainfall and also water availability during emergencies. An online GIS system based on manual measurement or remote sensing can be installed for management of such a system.

Public participation and technical control from different organizations are necessary for effective performance of the system, and therefore central monitoring is useful for such purposes. Monitoring and management of the system by the public and local authorities coupled with modern techniques can be very useful for mitigation of urban flooding. Such a system is successfully running in Seoul metropolitan area where the changing increased range of rainfall created the problem of urban flooding. The case of Kobe city (Japan) and Sumida city are also important examples of using rainwater harvesting as a response to natural disasters (UNEP, 2005)

Further reading

UNEP (2005) Rainwater Harvesting and Disaster Management, http://www.unep.org/pdf/RWH/disaster_management.pdf

3.8. Wetlands and environmental buffers

3.8.1. Introduction

Measures for reducing the amount and speed of rainwater runoff in urban areas can include utilizing wetlands, both natural and man-made, and increasing the amount of green vegetation. From the flood management point of view the key purpose of wetlands and environmental buffers is to act as flood retention basins and hence reduce the flood risk to built-up urban areas.

These 'greening' measures can be at a micro level, such as gardens and grass verges of streets. On a wider scale, there is the provision or designation of managed green areas within the urban space, such as an interconnected network of designated wetland areas, linked to existing natural wetlands through a program of tree and hedge planting. Such steps have a multitude of other benefits, apart from retarding and reducing the volume and timing of rainfall runoff and flooding to surrounding areas. These benefits include reducing the 'urban heat island' effect, reducing the level of CO2, as well as the reduction of run-off together with the enhancement of ground water storage by more infiltration through the soil.

The creation of green spaces such as riverside corridors, parks and tree-lined streets also assists in responding to climate change and could indirectly further reduce flooding in urban areas. It has also been observed (Faculty of Public Health/Natural England. 2010) that with a higher percentage of green space and green infrastructure, post-flood human psychological pressures are reduced as they create a healthier urban environment and promote recreation.

The study by the Faculty of Public Health in association with Natural England (ibid) also estimated that 1.3 million trees could catch 7 billion cubic meters of rainwater per year, which would significantly reduce the load on stormwater drainage, thereby preventing flooding. Some of the established practices of such green infrastructure and green space are the creation of green roofs, community woodlands, landscaping around buildings, tree-lined streets, urban parks and gardens.

Within the context of wider urban planning, policies can be drawn up which address the need to zone natural or man-made buffer zones within and around urban areas. Policies have to adequately address the differing functions of such buffer zones, including their role in flood management. Other functions include benefits to flora and fauna habitats, the ability of such areas to allow any sediment in the flow to be deposited and also the ability of such wetlands to remove nitrate by the take up of vegetation. Case Study 3.9 of Ghana illustrates the functions that such buffer zones can perform and also how zoning can be related to distance from a river or water-body. An inter-disciplinary approach has to be followed which involves all parties that have vested interests, including local people as well as institutions with remits for flood management, wetlands, forestry and protected areas and also those for water quality.

Case Study 3.9: Buffer zone policy for managing river basins in Ghana

The Water Resources Commission (WRC) in Ghana formulated a policy document in 2008 on how buffer zones are to be created, protected and maintained. It is important to emphasize that the preparation of this new policy involved a wide range of stakeholder participation. The policy follows a decentralized approach that gives the city authorities more responsibilities in relation to water resources management.

The way in which development has been taking place entailed a shift from the traditional buffer zone practices towards usages of river banks that can enhance economic growth. Such economic-driven approaches have often resulted in pollution and degradation of the buffer strip along the rivers. This is particularly the case when they are close to, or flow within, high density urban settlements. It was, therefore, suggested that customary bylaws on buffer zones be enforced by the local communities.

Over the years, various departments and agencies in Ghana have introduced policies, bye laws and regulations in relation to the width of buffer zones. However, in most cases they were introduced without any stakeholder engagement and they adopted a sectoral point of view.

Existing buffer zone widths in Ghana vary from 10 meters to 100 meters. This range determines the minimum buffer width that is necessary to sustain the river ecosystem and corresponds to the various organizational conditions in the buffer zones. The main objectives of the policy were the introduction of a regulation which incorporates the various specifications as given in existing regulations, and at the same time is flexible in its conditions to fully accommodate the real needs and priorities of the local population.

Source: Water Resources Commission 2008.

River floodplains within or immediately upstream of urban areas can be managed as periodic wetlands. This can allow for diversion or natural flooding, providing storage in the floodplain, thereby attenuating the flooding peaks of the river system.

The appropriate management of existing wetlands upstream of urban areas can go a long way to reducing flood risks. At the same time it is possible to manage the wetland in a sustainable manner for flora and fauna as well as the human use of resources. A good example of this approach can be found on the Agusan River in Mindanao, the Philippines. The city of Butuan lies at the mouth of the river and is at risk from flooding from both the river and also the sea. The Agusan wetland area lies upstream of Butuan City and has a difference in water level of six meters between the wet and dry seasons, as shown in the comparative photographs in Photos 3.10 and 3.11.


Photos 3.10 and 3.11: Agusan wetland area dry and in flood, Source: Alan Bird

The wetland area was registered under the Ramsar Convention in 1999 and is the most important freshwater site in the country. The indigenous inhabitants of the wetland have adapted their way of life to cope with such a wide seasonal range in flooding, living on floating homes and carrying out seasonal fishing. Management plans need to be drawn up for such areas and a mechanism for achieving compliance with the plan needs to be established. A model wetland management plan can be found on the website of the SPCW (n.d.).

3.8.2. Key components and data requirements for implementation

The key components of managed wetland and environmental buffers are:

- Natural wetland areas within or upstream of the urban area that can be managed by controlling water inflow and outflow.
- The construction of man-made managed wetlands with inlet and outlet control structures.
- The linking of existing natural or man-made wetlands by creating a network of link channels. These channels can be planted with appropriate species of vegetation.

- The zoning of land use within the urban area and also any wetland upstream of it. The zoning will restrict the type of development and human activity that can take place in the wetland and buffer areas. An effective system for ensuring compliance has to be in place.
- The drawing up of a planting program for the urban area with the objective of maximizing vegetation cover.

All of the above items should be carried out in a participatory manner involving all people who have vested interests within the area.

Accurate topographic mapping of the area will be needed. This can be superimposed upon a satellite imagery base such as that found on Google Earth (n.d.). In addition, it will be necessary to have rainfall data and river flow measurements and, ideally, to produce a hydro-dynamic flood model of the area.

3.8.3. Use and benefits

The development of existing natural wetlands upstream of an urban area is best carried out as part of an overall catchment management plan. The locations where man-made wetlands can be established will become apparent when the results of the hydro-dynamic model are analyzed. Within urban areas there may be difficulties and conflicts of use, as land values are likely to be higher than those wetland locations upstream.

As discussed above, the direct benefits of appropriately designed and operated managed wetlands are to reduce the impacts of flooding within an urban area. The direct benefits of vegetation planting are an improved urban landscape and provision of recreation and amenity areas.

The indirect benefits of managed wetlands, however, are to allow sediment to settle out of the floodwater and also increase surface water quality by reducing nitrogen levels. However, this requires careful management to reduce the risk of algal blooms during the warmer times of the year. In addition, wetlands can provide flora and fauna habitats, and greater overall bio-diversity of the urban and surrounding areas. The planting of vegetation should contribute to a reduction in CO2 levels.

The risks involved with the provision and management of wetland areas are increased if there is insufficient understanding of the present flooding pattern. A worst case scenario would be where additional or other areas of developed urban land are flooded if the capacity of the wetland is insufficient to safely hold the flood water. The question of land tenure is critical, however, especially if the identified sites for managed wetland require acquisition from non-government owners.

3.8.4. Essential and key considerations

A good knowledge of the existing flooding pattern is essential before drawing up a network of wetlands and interconnecting channels. An inter-institutional planning approach is required with a clear understanding of which institutions have what responsibilities. The selection of potential wetland sites will need to consider their present ownership and land value.

The construction and management of wetlands for the purpose of reducing the risk of urban flooding can be carried out as a stand-alone intervention. However, increased benefits are likely to occur if these measures are carried out as part of a basin-wide (catchment) management plan. Similarly, the planting of vegetation within urban areas could be carried out as a stand-alone measure, but would have increased benefit if it were planned and implemented as part of an overall management plan for the urban area, which would include a land use planning and zoning component.

3.9. Building design, resilience and resistance

Where buildings are situated in the floodplain, even if they are protected to some extent by structural flood defenses, there will still remain some residual risk of flooding. Careful design of buildings can reduce the vulnerability of buildings to flood damage and can therefore reduce the residual risk and enable occupation of floodplain areas. This can be particularly important for existing settlements which cannot be relocated, or where the advantages of floodplain occupation outweigh the cost of building design.

3.9.1. Description

There are a number of building design improvements that can be used to reduce the effects of flooding. Different approaches can be implemented, depending on whether they are added to an existing building or constructed as part of a new building. Three main approaches are flood resilience or wet flood proofing, (which allows the water in to a building); flood resistance, or dry flood proofing, (which keeps water outside a building); and flood avoidance (such as raising buildings on stilts or raising the land below the building, thus vertically removing the building from the risk of flood).

Generally flood avoidance is most appropriate for new builds, but it is possible to retrofit stilts or plinths below existing buildings dependent on the construction technique.

Photo 3.12: Housing raised to avoid flooding in Shrewsbury, UK. Source: J Lamond

Each of these design solutions may be more or less appropriate depending on the level of the risk and the background environmental conditions of the location, such as climate, soil conditions, pollution, and seismic activity. These strategies will not, however, be available to low-income groups living in informal settlements. Such groups may be particularly susceptible to flooding because they may located in low-lying flood-prone land, where any drains are less likely to be maintained either by the municipal authorities or by the community.

3.9.2. Purpose

Typically a building design solution to flooding is aimed at reducing the damage that occurs to the building fabric, fixtures and fittings from the impact of the flooding (floodwater, debris); the after effects of the floodwater (subsidence, corrosion, rot, mould, swelling); and the repair of the building for resumed habitation (cleaning, sanitation, repair and replacement, electrical or structural testing).

Floodwater can have a significant impact on both building integrity and recovery. At its worst it can cause structural collapse, potentially resulting in loss of life as well as property. Furthermore the building itself can become a hazard, as debris can cause damage to other buildings or injure people. Overall, as described in Chapter 2, floodwater damage to a building can be costly to resolve, carry long-term health risks, take a long time to complete, and cause social trauma.

Three approaches are indicated:

- Flood resilience (wet proofing) helps to reduce the damage when floodwater enters the building, particularly structural damage, but it does not prevent floodwater entering.
- Flood resistance (dry proofing) seeks to prevent water from entering the building, to reduce damage to the building, the fixtures and fittings, possessions and reduce the effect on occupants.
- Flood avoidance aims at avoiding the floodwater entirely, by locating buildings above the flood level, elevating or raising buildings above the flood level, or to allow buildings to rise with the floodwater.

3.9.3. Key components

Vernacular and contemporary architecture varies with local climate, available materials and long standing traditions. It is not practical to propose a generic design which will suit all flood prone areas, but in considering flood-proof building design, the key components relate to the main construction elements of a building, the rooms and furnishings:

1. Sub-structure (foundations) and basement construction
2. Super-structure (the building frame or envelope, including walls, floors, roof, windows and external doors)
3. Services (the electrics, plumbing and heating)

4. Fixtures and fittings (internal partitions, doors, appliances, floor-coverings)

5. Furnishing (any loose laid items, such as chairs and tables)

6. Safe refuge (above flood level)

7. Provisions (first aid kit, torch, blankets, clean water etc).

All components must be considered. For example, building design which prevents damage to the building by restricting access to the building using barriers also needs to allow for safe refuge on an upper floor, otherwise lives may be endangered because escape from the building is hampered.

It is also important to consider all the ways in which floods can act on these building components. Flood actions can be categorized as:

- Hydrostatic (lateral pressure and capillary rise)
- Hydrodynamic (velocity, waves, turbulence)
- Erosion (scour under buildings, building fabric)
- Buoyancy (lifting the building)
- Debris (items in the water colliding with the building)
- Non-physical actions (chemical, nuclear, biological).

(Kelman and Spence 2004)

In a high-velocity flood, these actions, particularly the hydrodynamic and debris types, are likely to overwhelm many building design features. Therefore, design should always take into account the likely flood attributes. An example of flood and typhoon resistant housing is examined in Case Study 3.10.

Case Study 3.10: Flood and Typhoon Resilient Housing in Vietnam

A disaster risk reduction initiative aimed to reduce the impact of typhoons and floods on housing was implemented in the Thua Thien Hué Province in Central Vietnam by the Development Workshop France (DWF), funded by Canadian International Development Agency (CIDA) and EU Humanitarian Aid department (ECHO).

The program which ended in 2008 involved individual households and the local community throughout the process. Each year, the program targeted more than 4,000 direct beneficiaries and reached over 100,000 people through awareness campaigns. The aim was to reduce vulnerability through the integration of storm resistant techniques in existing and future buildings. The program presented specific design principles, including:

- The balcony roof, which is a high risk item, should be structurally separate from the main roof of the house
- The connections between all individual parts of the structure, from the ground to the ridge, have to be very strong to withstand adverse weather effects
- Doors and shutters should allow the building to be closed up
- All parts of the roof and wall structures must be tightly connected
- Roof sheets or tiles must be held or tied down
- Trees should be planted to form windbreaks.

The Xangsang Typhoon in 2006 confirmed that this approach is broadly correct. Some characteristics of the program are context specific, but the approach can be adjusted to work in other countries and different contexts. In particular, the transfer of responsibilities to the local community needs to be emphasized, given that this significantly contributed to the effectiveness of the initiative.

Source: UNISDR 2007.

Resistant and resilient measures include items such as door barriers to prevent water ingress and actions such as moving power sockets higher up on a wall, in case water does enter the property. Components can be either temporary (door and window guards) or permanent (backflow prevention valves). However, in new buildings it is usually preferable for measures to be permanent.

Flood resilient design seeks to prevent flood damage to the components of the building including the effect that floodwater has on the sub-structure and superstructure. It may also include sacrificial elements of a building, for instance wallboards that can be removed and replaced. Sub-structure and superstructure should be designed to allow water to drain away, such that the building can dry out quickly. Services should be located above the potential flood level: this means all electrical outlets, fittings, junctions (including within wires), and distribution boards. Fixtures and fittings should be designed to avoid complete damage when inundated by water, and consideration should be given to furnishings that will not cause an obstacle during a flood. Safe refuge should be provided above flood level; this can be on the first floor, but for greater flood depths an access hatch out of the roof may be needed for rescue purposes.

The final key component of flood resilience is to consider provisions that will be required during a flood: quantities will depend on the potential duration of the flood, but would include things like preserved food, clean water, a torch (wind-up type, or spare batteries will also be needed) or candles and matches, blankets and a first aid kit, including drugs for diarrhea and dysentery.

Flood resistant design seeks to prevent water entering the building. There are many entry points which need to be considered: windows and doors, floor voids (particularly suspended floors), cracks or gaps in walls, air vents or air bricks (designed for ventilation), service ducts and pipes, such as toilets and drains, or seepage through floors (particularly earth or stone floors where there is no damp proof membrane). A flood resistant design must tackle all of these elements. In addition, the quality of building components is critical, as failure of any one element can compromise the whole design.

Flood avoidance, for an existing building located in the floodplain, would seek to raise the building above the flood level. This approach is illustrated in Photo 3.13 as applied to housing and in Photo 3.14, showing a municipal building in the UK that has ground floor garaging and a raised escape route.

If the ground level of a building is to be raised, the structural integrity of the earth and foundations, which the building is to rest on, must be considered. If, however, a building is to be elevated as a whole, the integrity of the columns or structure, that the building is to be raised on, must be considered. In both cases debris, weight of the floodwater and scouring can affect the building sub-structure.

Photo 3.13: Houses raised on stilts to avoid flooding in Bangladesh. Source: Alan Bird.

Photo 3.14: Municipal building in the UK with ground-floor garaging. Source: J Lamond.

3.9.4. When and where to use the 'solutions'

Building design solutions are most appropriate where there are no other means of flood prevention or where flooding would affect the functionality of critical infrastructure: power stations, communications centers, hospitals and emergency services facilities all need to continue operating during floods. This approach may also be appropriate where there is a high risk that other flood protection measures may be ineffective or prone to failure.

Ideally buildings should be located to avoid flood risk. However, many thousands of buildings are already located in floodplains, and in this case flood resilience measures could help to reduce risk.

As a rule of thumb, flood resistance should only be used where flood duration is short and flood depths are ideally below 1m, although some guidance places the acceptable depth lower, at 600mm. It is wise to assess the structural integrity of a building before installing resistant measures. This is because the pressure from flood water could cause walls and windows to collapse, water flows can erode the surrounding ground, and deep water can cause floating debris such as trees and cars to collide with the building. Flood resilience is, however, feasible at higher depths of water and for longer duration floods. It is also easier to apply to existing buildings where resistance is inappropriate, but can be less acceptable to occupants

Table 3.3 shows where and when it is appropriate to consider flood proofing measures, for existing buildings, based on flood depth, velocity and construction types.

Flood Proofing Matrix	Measures								
	Elevation on foundation walls	Elevation on Piers	Elevation on posts or columns	Elevation on piles	Relocation	Walls and levees	Floodwalls and levees with closures	Dry flood proofing/ resistance	Wet flood proofing/ resilience

Flood Characteristics										
Depth	Shallow (<1m)	√	√	√	√	√	√	√	√	√
	Moderate (1-2m)	√	√	√	√	√	√	√	X	√
	Deep (>2m)	√	√	√	√	√	X	X	X	X
Velocity	Slow (<1m/s)	√	√	√	√	√	√	√	√	√
	Moderate (1-2m/s)	√	√	√	√	√	√	√	X	X
	Fast (>2m/s)	X	X	√	√	√	X	X	X	X
Flash Flooding	Yes	X	√	√	√	√	√	X	X	X
	No	√	√	√	√	√	√	√	√	√
Ice & debris flow	Yes	X	√	√	√	√	√	X	X	X
	No	√	√	√	√	√	√	√	√	√
Site Characteristics										
Location	Coastal floodplain	X	√	√	√	√	√	X	X	X
	Riverine floodplain	√	√	√	√	√	√	√	√	√
Soil type	Permeable	√	√	√	√	√	X	X	X	√
	Impermeable	√	√	√	√	√	√	√	√	√
Building Characteristics										
Foundation	Slab	√	√	√	√	√	√	√	√	√
	Sub-floor void	√	√	√	√	√	√	√	√	√
	Basement	√	X	X	X	√	√	√	X	X
Construction	Concrete / masonry	√	√	√	X	√	√	√	√	√
	Wood/ other	√	√	√	X	√	√	√	X	X
Condition	Excellent to good	√	√	√	√	√	√	√	√	√
	Fair to poor	X	X	X	X	X	√	√	X	X

Table 3.3: Flood Proofing Matrix. Source: Adapted from USACE.

Individuals or businesses may use these measures to protect their property, without reliance on state support and can do so to the standard of protection and longevity that they wish.

3.9.5. Benefits and risks

Flood resilient, resistant or avoidant building design can help buildings to survive a flood, reducing financial loss and improving the likelihood of survival for occupants by providing safe refuge. These approaches can reduce the recovery time, allowing people to continue to occupy a building during a flood or to evacuate and return to a building after a more severe flood.

Improvements to the building design may also reduce secondary risks, such as fires, (particularly those caused by the inundation of electrical systems by floodwater or debris); pollution (from fuels and other materials leaking into the floodwater); health problems (from sewage polluting the floodwater); and the growth of mould.

Better building design may also reduce the need for and therefore the cost of evacuation. If buildings can be occupied during the flood, this will reduce the disruption to businesses and therefore the financial losses incurred. Appropriate building design can also make properties more insurable, and, where relevant, reduce premiums by reducing the payout costs borne by the insurance companies. This should also provide more stability in the insurance sector, which otherwise may be unable to resource payouts following major flood events. It may also form the last means of flood protection, but if it should this fail then the building or occupier could still be at risk. This form of flood risk measure may, however, reduce the perception of risk by occupiers, leading to issues such as a 'false sense of security'.

Building occupants typically prefer resistant or avoidant building design strategies, as they protect the interior of the property from damage. These are only effective, as discussed above, with relatively shallow flood depths or with high quality reinforced construction that can resist hydrostatic pressures. In urban situations, floodwater is likely to carry debris and contaminants, increasing the risk of damage, particularly to resistant buildings, but equally increasing the preference for resistant or avoidant construction.

Building design solutions, particularly flood resistance, require an adequate standard of workmanship to be effective.

3.9.6. Key considerations

It is essential to have a good understanding of the flood hazard (as discussed in Chapter 1) when choosing the most appropriate building design solution. It is also important to understand any relevant planning regulations or building codes which may prevent the implementation of a building design solution, (such as restriction on the height of the building, or choice of materials), or conflicts with other codes relating to construction in earthquake or hurricane prone areas.

The cost of incorporating building design solutions will depend on the complexity of the intrinsic construction, although it is often found that the payback for the additional investment will be recovered after a single flood event (Bowker et al 2007).

As a part of integrated flood risk management, building design relies to some extent on the accompanying implementation of non-structural measures such as land use planning and flood zoning; flood awareness campaigns; forecasting and early warning systems; evacuation planning; emergency planning and rescue; damage avoidance actions; temporary shelter (safe havens); business and government continuity planning; flood insurance; compensation; and tax relief.

3.9.7. Other sources of information and further reading

Asian Disaster Preparedness Center (ADPC). 2005. Handbook on Design and Construction of Housing for Flood-Prone Rural Areas of Bangladesh. Pathumthan, Thailand.

Bowker, P., Escarameta, M. and Tagg, A. 2007. Improving the flood performance of new buildings. Flood resilient construction. Defra. UK.

CEPRI. n.d. Construction in flood-prone areas. Vulnerability of building structures. CEPRI

CEPRI. n.d. Construction in flood-prone areas. Diagnosing and Reducing the Impact of Flood Hazards. CEPRI

FEMA. 2009. Building Science for Disaster-Resilient Communities: Flood Hazard Publications FEMA I-782. http://www.fema.gov/library.

3.10. Flood defenses

The threat of flooding has been present since people began to settle close to rivers and coasts in order to maintain trade and communication links. For centuries, therefore, it has been necessary to protect these areas from flooding, by building defenses that supplement natural features such as river banks.

Flood defenses are intended to reduce the risk to people and the developed and natural environment from flooding. They are constructed to protect against flood events of a particular magnitude, expressed as risk in any one year: for example, defenses in urban areas may be built to provide protection against flood events of a size which might occur, on average, once in one hundred years. It is important that flood defenses are considered as part of a strategic, integrated approach to flood risk management that considers the knock-on impact on the risk of flooding along the remainder of the river.

3.10.1. Inland flood defenses

There is no absolute definition of 'inland' but by implication it includes all river (or fluvial) defenses and excludes those defenses located on the coastline and in the sea. Tidal and estuary areas where rivers and the sea interact by their nature fall between inland and coastal defenses.

Flood defense seeks to reduce the risk of flooding and to safeguard life, protect property and sustain economic activity. Walls and embankments (levees or dykes), placed strategically around settlements or adjacent to water courses, can prevent ingress of water to inhabited areas. The construction of earth embankments is a long established method for confining river flows within the channel, as in Bangladesh where over 5,600 kilometers of earth embankments have been constructed (Haider n.d.).

The height of such structures is calculated to resist the majority of floods but total protection can never be guaranteed. Failure of these defenses can cause rapid flooding of often intensively used areas. The structure of flood walls and embankments has been described above in Section 3.3.3.

Maintenance work needs to be carried out on flood defense structures, but other work is also required to control rivers and bank-sides such as annual removal of channel vegetation and regular dredging.

Flood defenses can be very costly to design, construct and maintain and will, therefore, usually require significant investment by governments. Schemes will require careful design by experts, including structural and hydraulic engineers with a good understanding of the risks and nature of the floods anticipated. Schemes will also, normally, be required to be fully evaluated and appraised to ensure they are not only technically, but also environmentally and economically sound.

Hard-engineered defenses and levees require the construction of permanent structures, which can occupy land that is in short supply. Many such systems are also very expensive, although earth systems may often be multipurpose structures and may form the basis for other infrastructure or even residential or commercial development. In Japan, for example, super levees provide both flood defense and community development (APFM 2007).

3.10.2. Demountable and temporary flood defenses

Within an urban environment, where space is limited and access to river spaces, roads, infrastructure and buildings is essential, there may be a need for demountable and temporary measures. The advantage of such measures is that they can be installed just before or during a flood, but under normal circumstances the space and access is unchanged.

Demountable flood defenses are structures that have permanent and temporary elements. They normally have permanent foundations, with guides or sockets to install barriers when there is a risk of flooding. The barriers are then removed when there is no risk of further flooding, as in the Super Case Study on Cologne in this volume.

By contrast, a temporary flood defense is a system that can be installed during a flood event and then completely removed when no longer required. Sandbags are the most common form of temporary flood defense; however, they take time to fill and lay, and are difficult to handle. Even when properly installed, water may seep through sandbags, making them less effective than other temporary flood protection products, such as free-standing barriers designed specifically for the purpose. An example is illustrated in Photo 3.15.

Photo 3.15: temporary flood barrier deployed. Source: J Lamond

3.10.3. Property level defenses

Placing barriers across openings can be an effective defense against flooding if the structure is otherwise watertight, and both velocity and flood level are low. For regular urban flash flooding, the installation of such products can protect otherwise vulnerable buildings. Home-made boards and sandbags (such as those illustrated below in Photo 3.16) are often used but these are less effective than purpose-designed fittings. There is now a wide range of removable products available (including. flood skirts or guards, and air brick covers) that are designed to seal potential flood routes into a property, such as doors, windows, air bricks, sewers and drainage systems. These may be installed fairly quickly by property owners immediately before a flood (upon receipt of a flood warning, for example) and should be removed as early as possible after the flood water has receded. Products vary in their effectiveness and cost.

Photo 3.16: Homemade door guard. Source: J Lamond

Both demountable and temporary flood defenses are only functional when in a closed position and both require operational procedures for putting them in place.

3.10.4. Critical infrastructure

Critical infrastructure can be defined as the sites, facilities, systems and networks necessary for the functioning of a country and the delivery of essential services. The concepts of flood resilience and flood resistance are both important (as discussed in Section 3.9.1) here.

In the context of critical infrastructure, flood resilience involves designing or adapting an infrastructure asset so that, even if it is affected directly by flood water, it can still function or be quickly restored to normality. Flood resistance involves excluding water during flood events so there is no impact on normal function (McBain et al. 2010). Critical infrastructure should have protection to a standard that will withstand extreme events.

In the UK, the Pitt Review into the 2007 flooding, recommended protection from 1 in 200/0.5% chance of flooding in any one year as a minimum, and Balmforth et al. (2006) recommend a level of once in 1,000 years for highly critical facilities. As an example, in the UK the privately-owned electricity distributor Yorkshire Energy Distribution Ltd have assessed all their sub-stations and identified those critical to the network located in the floodplain. Protection of more than 24 substations involved installed flood walls with openings protected by floodgates (Flood Protection Association n.d.). Future protection from climate change, as discussed in Chapter 1, should also be considered.

3.10.5. How to select appropriate protection systems

The selection of appropriate flood protection schemes is an important part of any flood risk management strategy. Well-designed flood protection systems can help provide protection to entire communities, individual public buildings (such as hospitals and schools) and private residential property. Such systems can be used to safeguard property, homes and businesses and critical infrastructure as part of a coherent flood risk management strategy.

Poorly designed and selected systems can, however, result in even more damage due to what is known as the ‘levee effect’. This is where development proceeds behind a flood protection system in what is believed to be a safe area. If such systems are breached or overtopped because of improper design or inaccurate assessment of the depth of flood water anticipated, then the consequences can be much worse. It is important that a full understanding of the flood risk and the residual flood risk (i.e. that remaining beyond the capability of the flood protection system) is developed when designing such systems.

There are many different systems and solutions available and selection will depend on the specific circumstances of the property (or group of properties) being protected. Larger community-wide systems will require the design input of experts, including civil engineers and hydraulic engineers. The costs of such systems will need to include the manpower needed for deployment, as well as maintenance and storage facilities, where required.

Where systems are designed and selected appropriately, these can help protect people and property in the event of flooding and also provide some level of confidence in the intervening periods of a suitable level of protection, allowing for suitable investment and development to continue.

Method

1. Assess risk

2. Consider community preferences

3. Consider effectiveness and suitability of protection systems

4. Consider cost and manpower for deployment

1. Assess Risk

Protection of settlements already located in the floodplain and at risk from flooding as always starts with an assessment of the risk from flooding. Relevant features are the type, severity, frequency, depth, duration and speed of onset, as these all impact on the suitability of various flood protection options. A risk assessment appropriate to the level of protection considered may include detailed topographical survey, building assessment and hydrological modeling.

2. Consider community preferences

It is very common that multiple solutions are possible which may or may not meet with community approval and may be more or less difficult to implement. For example in a historic town centre the provision of a concrete wall will be likely to meet with opposition from local residents and wetlands may be poorly regarded in an area of high vector borne disease risk.

3. Consider effectiveness and suitability of protection systems

The suitability of various systems for classes of protection is shown in Figure 3.12 below.

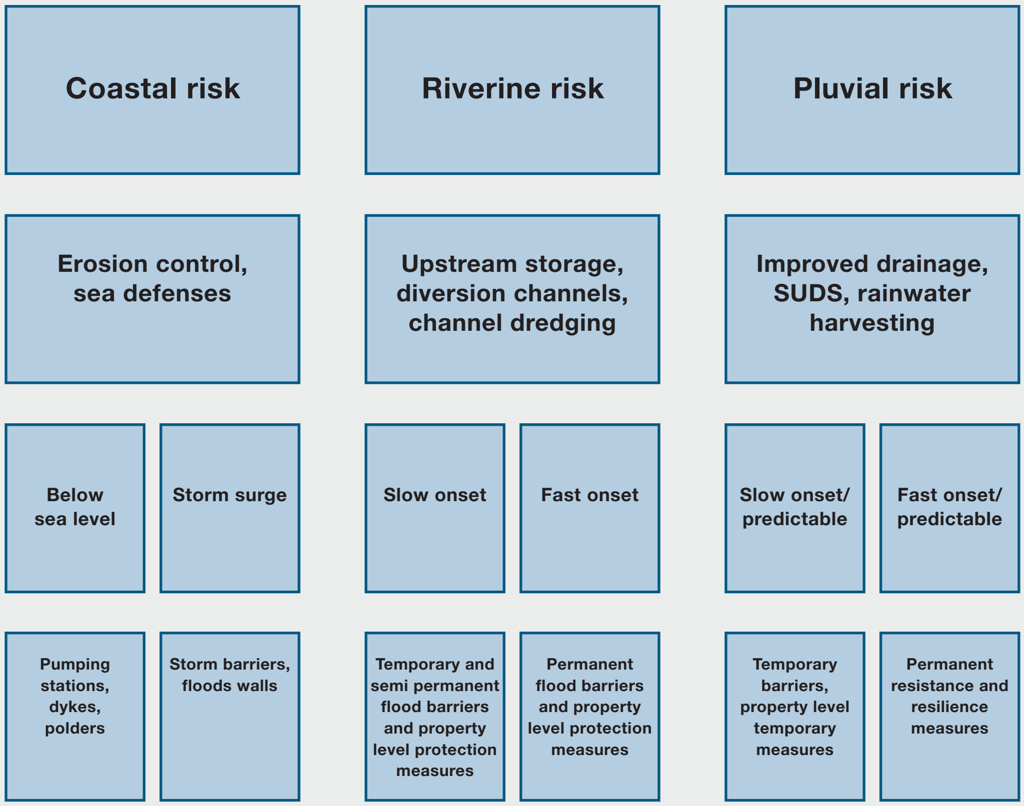

Figure 3.12 Suitable protection systems.

4. Consider cost and manpower for deployment

The variation between the costs of protection systems is vast. In developed countries, estimates for earth bunds are about half that for concrete or brick walls and one third that of typical proprietary demountable or temporary barriers. This is especially important for developing countries where the main costs of low technology solutions – i.e. labor – may be much lower than in developed nations rendering the cost discrepancies even greater. Using low-technology solutions and local labor and resources where possible can add to the sustainability of flood protection schemes, generates ownership and feelings of empowerment and provide employment for local people. However the limitations of such systems, particularly in urban environments may include increased land requirements (for earth bunds over concrete walls), lower protection levels (for sandbags over proprietary door guards) or lower durability (for earthworks).

3.11. Barrier and embankment systems for estuary and coastal flood protection

Defenses against estuary and coastal flooding from tides, storm surges and tsunamis form a key aspect of coastal area (or zone) management, and need to be considered within its context.

3.11.1. Coastal management

It is probably even truer for coastal protection than for other areas of flood management, that protection comes more from understanding the natural system than from intervening in it. Breakwaters and groynes are 'structural solutions' but their contribution to coastal protection is indirect not direct. Areas of coast that are most susceptible to change, so-called 'soft coasts', are influenced by coastal forcing (for example, by wave activity and tides) and by geology. Some areas of coast may have achieved relative equilibrium in response to these influences, whereas others may be undergoing significant change. Artificial intervention can easily disrupt any equilibrium, and factors like rising sea levels can potentially affect all coastal areas.

'Integrated coastal management' is a general term to describe an approach which aims to consider the combined effects of all activities taking place at the coast, and to seek sustainable outcomes. It considers the coastal environment as a whole, including coastal land, the foreshore and inshore waters. 'Shoreline management' refers more specifically to approaches to managing the actual coastline taking into account the risks of flooding and coastal erosion.

In cases where it is technically unfeasible, or unjustifiably expensive, to provide engineered solutions to coastal flooding, (due to severe erosion processes, for example) then there may be no option but to arrange a managed retreat. This is particularly the case in countries like Bangladesh where the river and coastal morphology processes are very dynamic. Such a decision can be hard to implement as, in effect, it admits human defeat in trying to engineer nature; it is often done by default, by taking no action.

In coastal parts of Bangladesh the rebuilding of the embankments after the 1991 Cyclone faced this issue. In some places a managed retreat was formalized by building new multi-purpose flood embankments that doubled as roads and linear resettlement locations for displaced people. Decisions had to be made as to the likely rate of future erosion and the number of years in which it was deemed economic to build a new flood embankment before it too was eroded away.

3.11.2. Coastal structures

Many coastal engineering structures are aimed at both providing flood protection and arresting coastal erosion. Groynes are shore protection structures typically of timber, rock or masonry, constructed perpendicular to the shoreline, to retain or increase beach material that is subject to long-shore transport. Breakwaters may be connected to the shore, detached, or constructed at ports or harbors. They reduce the impact of wave action through their mass and shape and thereby exert an influence on coastal erosion and deposition. A sea wall is fundamentally designed to dissipate wave energy. Traditionally they have been the dominant form of coastal defense to the upper shore, but they have a significant impact on the natural processes and are therefore now seen as a solution of last resort.

Where sea walls are still needed, modern designs aim to avoid problems that result from any direct reflection of wave energy by including features such as a sloping face, a curved top, and rock armoring (rap-rap) at the toe. Embankments in coastal areas with the primary function of flood defense, but not wave energy dissipation, can be classed with embankments, levees and dykes and are covered in Section 3.3 and 3.10. Case study 3.11 gives an example of dykes used as a flood protection measure in a coastal zone.

Photo 3.17 shows what can happen if unplanned informal development occurs. It is obviously better to design any embankment with the participation of local people with the aim of maximizing their use.

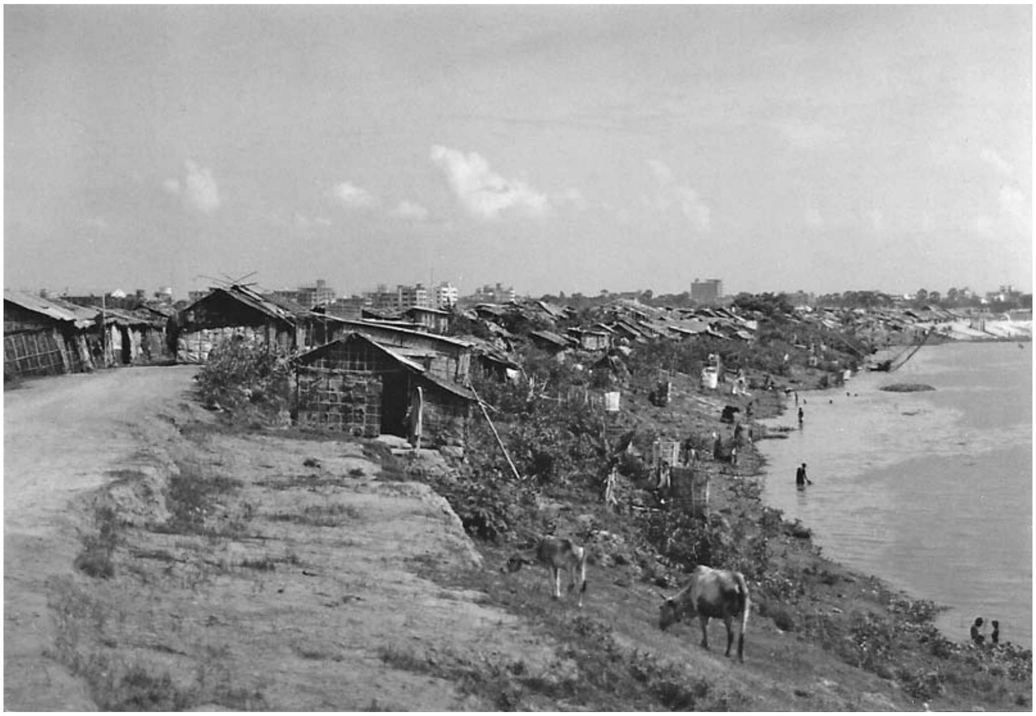

Photo 3.17: Multipurpose embankment with erosion. Source: Alan Bird

Protection against tsunamis has been attempted using substantial sea wall structures, but significant re-evaluation of the approach taken to design is taking place following the March 2011 tsunami in Japan.

Case Study 3.11: Camanava anti-flood project 2003-2011, The Philippines

The cities of Caloocan, Malabon, Navotas, and Valenzuela, collectively known as the Camanava cities, in the Philippines, sit on top of centuries of prehistoric alluvial deposits built up by the waters of the Pasig River and on land reclaimed from Manila Bay. The Pasig River bisects the city of Manila and features considerable land reclamation along the waterfronts. Some of the natural variations in topography have been evened out due to the urbanization and development of the city.

Flood risk in the area is high and increasing. To begin with, an estimated 20 typhoons impact upon the Philippines every year from the Pacific. In addition the coastal plains around Manila Bay are so low and flat that the one meter elevation extends 10-20 kilometers inland and normal spring tides only 1.25 meters high extend many kilometers inland.

Even small rises in relative sea level will, therefore, translate into large inland encroachments. It is estimated that the area is facing a sea level rise of one to three millimeters per year due to global warming. There are also issues of land subsidence, caused by excessive groundwater extraction, which is lowering the land surface by several centimeters to more than a decimeter per year.

Camanava cities were severely hit by Typhoon Ketsana/Ondoy which was the most severe typhoon in the 2009 Pacific typhoon season. A week after Ketsana, Typhoon Parma also hit the northern Philippines, worsening the situation. Together, the storms killed over 1,000 people and caused damage and losses amounting up to US$ 4.4 billion (2.7 percent of the country's GDP).

The scope of the flood protection work planned comprises:

- A 8.6 kilometer long, 2 meter high earth polder dike to enclose and protect the Malabon and Navotas areas that are already at or below mean sea level
- Five pumping stations with ancillary floodgates
- Six independent floodgates
- One navigation gate
- One rectangular box culvert
- Some river improvement works.

The designers plan to pump floodwaters out of the polder during low tides. However, it is already recognized that in extreme conditions sustained southerly winds can raise sea level significantly for days, which will render the structure ineffective. Even discounting storm waves, surges driven by typhoon winds can reach sea level to overtop this height. Changes to the original plans have been blamed for recent flooding, however delays have been caused to the project by funding difficulties and the need to resettle residents to facilitate construction may also have contributed.

This example illustrates the fact that even with significant investment of $100 million dollars or more, flood risk can be reduced but not completely eliminated. Further measures will still be needed to address this residual risk.

Sources: Frialde 2010; Antonio 2011; Rodolfo and Siringan 2006; Antonio 2009; DPWH 2009; Echeminada 2010

3.11.3. Flood barriers

A flood barrier provides temporary protection from particularly high tides, or storm surges, at a point where water flow or shipping would otherwise be allowed to pass freely. It is usually just one component in an artificial or natural flood protection scheme. Flood barriers are major and often innovative civil engineering structures. Well-known examples include the Delta Works in the Netherlands and the Thames Barrier in London (Photo 3.18).

Photo 3.18: The Thames barrier, Source: Nick Dennison

Daily high tides and those on a lunar 28 day cycle not only threaten coastal flooding but also affect the ability of rivers to discharge flood waters resulting from rainfall inland. The design and operation of flood barriers must take into account the possible coincidence of high tides and upstream flooding. Storage in coastal urban areas may be needed to control the timing of discharges in relation to tides, rather than to achieve flood peak attenuation.

An additional potential benefit of barriers is the opportunity to generate significant quantities of sustainable electric power through a flood barrier. This is starting to look more feasible than previously, now that existing sources of non-renewable power are rising in cost.

3.12. References

Asian Disaster Preparedness Center (ADPC). 2005. Handbook on Design and Construction of Housing for Flood-Prone Rural Areas of Bangladesh. Pathumthan, Thailand.

AfDB (African Development Bank). 2009. "North and East Greater Tunis Flood Protection Study, Greater Tunis." AfDB.

Antonio, R. F. 2009. "Camanava anti-flood project a success." *Manila Bulletin*.

—— . 2011. "Flood management master plan updated." *Manila Bulletin*.

APFM (Associated Programme on Flood Management). 2007. *The role of land use planning in flood management. A Tool for Integrated Flood Management*. Geneva: WMO.

Babel, M. S. 2008. "Groundwater Management in Asian Coastal Cities: A proposal for climate change impact and adaptation study." Paper presented at the Asian Science and Technology Seminar, Bangkok, March 11.

Balmforth D, Digman C, Kellagher R and Butler D. 2006. *Designing for exceedance in urban drainage – good practice, C635*. London: CIRIA.

Barker, R. "Design Strategies – Flood Resilience." Baca Architects, RIBA Sustainability Hub, RIBA, London.

Barker, R. "Design Strategies – Flood Resistance." Baca Architects, RIBA Sustainability Hub, RIBA, London.

Boston Metropolitan Area Planning Council 2011 Low Impact Development Toolkit. Boston, Boston MAPC.

Bowker, P., Escarameta, M. and Tagg, A. 2007. *Improving the flood performance of new buildings. Flood resilient construction*. London: Defra.

Butler D. and Davies J.W. 2011 *Urban Drainage, 3rd edition*. UK: Spon Press.

CEPRI. n.d. "Construction in flood-prone areas -vulnerability of building structures." CEPRI.

CEPRI. n.d. "Construction in flood-prone areas - diagnosing and reducing the impact of flood hazards." CEPRI.

CIRIA. 2007. *The SUDS manual*. London: CIRIA.

Defra (Department for Environment, Food and Rural Affairs). 2008. *Improving*

Surface Water Drainage. Consultation to accompany proposals set out in the Government's Water Strategy. London: Defra.

DPWH. 2009. "CAMANAVA flood control project 88 percent complete." DPWH.

Echeminada, P. 2010. "DPWH to investigate unfinished Camanava flood control project." *Philo Star*.

Faculty of Public Health/Natural England. 2010. *Great Outdoors: How Our Natural Health Service Uses Green Space To Improve Wellbeing, Briefing Statement*. London: Faculty of Public Health/Natural England.

FAGANELLO, E. & ATTEWILL, L. 2005 Flood Management Strategy for the Upper and Middle Odra River Basin: Feasibility Study of Raciborz Reservoir. Natural Hazards 36, 273-295.

Federal Interagency Stream Restoration Working Group. 2001. "Stream Corridor Restoration, Principles, Processes and Practices." US Department of Agriculture, Natural Resources Conservation Service.

FEMA (Federal Emergency Management Agency). 2009. "Building Science for Disaster-Resilient Communities: Flood Hazard Publications, FEMA L-782 / December 2009." Washington DC: FEMA.

Flood Protection Association. n.d. http://www.floodprotectionassoc.co.uk/cms/documents_case/Flood_Control_-_YEDL_Case_Study.pdf.

Foster, S. and Garduño, H. 2002. Argentina: Mitigation of Groundwater Drainage Problems in the Buenos Aires Conurbation Technical & Institutional Way Forward. Washington DC: GW Mate/ World Bank.

Frialde, M. 2010. "MMDA installs CCTV camera to monitor flood pump stations." *Philo Star*.

Gordon- Walker, S., Harle, T. & I., N. 2007 Cost-benefit of SUDS retrofit in urban areas. Bristol, Environment Agency.

Google Earth n.d. http://www.google.co.uk/intl/en_uk/earth/index.html.

Haider, N. n.d. "Living with Disasters – disaster profiling of districts of Pakistan. National Disaster Management Authority (NDMA), Government of Pakistan. http://www.ndma.gov.pk/.

Halcrow. n.d. "Wroclaw flood prevention scheme." http://www.halcrow.com/Our-projects/Project-details/Wroclaw-flood-prevention-scheme-Poland/.

HYDROPROJEKT (nd) Raciborz Dolny Reservoir (dry polder) on the Oder river. Warsaw. http://www.hydroprojekt.com.pl/en,Flood-Protection-of-the-city-of-Wroclaw.html

IGES (Institute for Global Environmental Strategies). 2008. "Groundwater and Climate Change: No Longer the Hidden Resource - Second IGES White Paper." http://www.iges.or.jp/en/pub/whitepaper2.html.

IWPDC (International Water Power and Dam Construction). 2010. "Modernization of the Wroclaw floodway system." Accessed 30 September 2011. http://www.waterpowermagazine.com/story.asp?sc=2057879.

Kelman, I. and Spence, R. W. 2004. An overview of flood actions on buildings." *Engineering Geology* 73: 297-309.

Khurana, I. and Sehgal, M. 2005. "Drinking Water Source Sustainability and Groundwater Quality Improvement in Rural Gujarat." Paper presented at 12th International Rainwater Catchment Systems (IRCSA), "Mainstreaming Rainwater Harvesting," New Delhi, November 2005.

Krause, R., F. Bönsch,, W.E. and Waschkowski, K. n.d. "SMART-Project, Kuala Lumpur - Tunneling with Hydro-Shield - Analysis of the Logistics." Project, Wayss & Freytag AG. http://www.smarttunnel.com.my/construction/images/news/special/SR03.pdf

Lovett, R.A. 2011. "Why Mississippi floods were expected." *Nature News* May 13. http://www.nature.com/news/2011/110513/full/news.2011.289.html.

McBain, W., Wilkes D. and Retter, M. 2010. *Flood resilience and resistance for critical infrastructure C688*. London: CIRIA.

Pepper, A.T. and Rickard, C.E. 2009 *Fluvial Design Guide*. Bristol: Environment Agency. Chapter 8.

PWRI (Public Works Research Institute Japan). 2009. "Water Related Risk Management course on disaster management policy programme." ICHARM publication no 9, PWRI, Japan.

Reed, B. 2004. *Sustainable urban drainage in low-income communities – a scoping study*. Loughborough: WEDC. http://www.dfid.gov.uk/r4d/PDF/Outputs/R81681.pdf.

Rodolfo, K.S. and Siringan, F.P. 2006. "Global sea-level rise is recognised, but flooding from anthropogenic land subsidence is ignored around northern Manila

Bay, Philippines." *Disasters* 30 (1): 118-39.

SPCW (Society For The Conservation Of Philippine Wetlands). n.d. http://www.psdn.org.ph/wetlands/national_conference_2009/wetlands_conference_11.htm.

Tanaka, T. 2011. " The Project for Capacity Development of Jakarta Comprehensive Flood Management (JCFM)". Presentation by JICA at Workshop on Global flood risk management, 25th 26th May 2011, Jakarta.

UNEP (United Nations Environment Programme)/SEI (Stockholm Environment Institute). 2009. *Rainwater Harvesting: a lifeline for human well-being*. Geneva: UN.

UN-HABITAT. n.d. Rainwater Harvesting and Utilization. *Blue Drop Series Book 2: Beneficiaries & Capacity Builders*. Geneva: UN.

UNISDR. 2007. *Building disaster resilient communities: good practices and lessons learned*. Geneva: UN.

USACE (U. S. Army Corps of Engineers). 1988. *Tests of Materials and Systems for Flood Proofing Structures*. Washington, DC: Army Corps of Engineers, p.89.

Wang, H.G., Montoliu-Munoz,. M., GeoVille, G. and Gueye, N.F.D. 2009. "Preparing to Manage Natural Hazards and Climate Change Risks in Dakar, Senegal: A Spatial and Institutional Approach." Washington, DC, USA. World Bank.

Water Resources Commission of Ghana. 2008. *Final Draft Buffer Zone Policy for Managing River Basins in Ghana. August 2008*. Water Resources Commission of Ghana.

International Water Association (IWA) Water Wiki. n.d. "A rainwater harvesting benchmark for Korea." (Created March 20, 2011.) http://iwawaterwiki.org/xwiki/bin/view/Articles/SeoulsStarCityArainwaterharvestingbenchmarkforKorea.

Wilson, R. 2005. "Design of the SMART Project, Kuala Lumpur, Malaysia - a unique holistic concept." Mott MacDonald.

Woods-Ballard B., Kellagher R., Martin P., Jefferies C., Bray R. and Shaffer P. 2007. *The SUDS manual - C697*. London: CIRIA.

World Bank 2008. "Project Information Document (PID). Concept Stage." WB Report No.: AB4043. World Bank, Washington, DC.

—— . 2007. "Flood Management in Jakarta: Causes and Mitigation." World Bank, Washington, DC.

—— . 2010a. "Climate Risks and Adaptation in Asian Coastal Megacities." World

Bank, Washington, DC.

——. 2010b. “Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India.” World Bank, Washington, DC.

Wynne, A. 2011. “Engineers fight Mississippi floods.” New Civil Engineer, May 19. http://www.nature.com/news/2011/110513/full/news.2011.289.html.

BABEL, D. M. S. (2008) Groundwater Management in Asian Coastal Cities: A proposal for climate change impact and adaptation study. Bangkok, Water Engineering and Management, AIT.

IGES (2008) Groundwater and Climate Change: No Longer the Hidden Resource. *IGES White Paper*.

THE WORLD BANK (2010) Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India. Washington, The World Bank.

Community activists in the flooded Chatuchak District set up a large barrier of sandbags along with pumps in an attempt to protect the Moo Baan Kredkaew housing development from being inundated, Bangkok, Thailand (2011). Source: Gideon Mendel

Chapter 4

Integrated Flood Risk Management: Non-Structural Measures

Chapter 4. Integrated Flood Risk Management: Non-Structural Measures

4.1. Introduction

Chapter Summary

This chapter describes non-structural measures used to manage the risk of flooding for cities and towns and their inhabitants. These measures do not require extensive investment in hard-engineered infrastructures, as typically do structural measures, but rely instead on a good understanding of flood hazard and adequate forecasting systems. There are four main categories, as follows:

- Increased preparedness
- Flood avoidance
- Emergency planning and management
- Speeding up recovery and using recovery to increase resilience.

Many of the measures, such as early warning systems, will form part of any flood risk management scheme. They can be seen as a first step in protecting people in the absence of more expensive structural measures, but they will also be needed to manage residual risk where such schemes have been constructed.

The key messages from this Chapter are:

- Engagement of the community at risk and encouragement of citizen preparedness is critical to the success of non-structural flood risk management. Communication is, therefore, a key element.
- Land use planning and regulation of new development is a central measure for reducing future flood risk, particularly in rapidly urbanizing emerging economies.
- Many non-structural measures have multiple benefits, over and above their flood management role.

Chapter 3 described a number of structural measures for reducing the risk of urban flooding, within an integrated strategic approach. However it was noted that structural measures can never entirely eliminate flood risk – and may not always be an appropriate response to such risk. Problems with structural solutions include their high cost, the fact that reducing flood risk in one location may increase it in another, the possible complacency it produces in populations and the potentially increased impact if such structures fail or are overtopped.

These considerations, together with the need to address residual flood risk, have led to the development of non-structural solutions to flooding. Often described as 'soft' solutions, non-structural approaches are defined here as measures which are designed to keep people away from flooding and to reduce the impact of flooding on those people and assets still exposed to risk. They generally require little in the way of construction of physical infrastructure, and may therefore be less costly and quicker to implement than structural measures. In some circumstances, non-structural solutions can prove to be the most effective method of avoiding flooding and reducing its consequences.

This chapter describes non-structural measures in terms of four principal purposes: preparing for flooding, avoiding flooding, planning for and managing flood emergencies, and recovering from flooding. Section 4.2 considers the creation of better awareness of flooding through the medium of campaigns, which is vital for minimizing the impacts of urban floods. Flooding has specific and harmful impacts on public health: accordingly Section 4.3 details the ways by which health awareness campaigns can contribute to enhanced preparedness. Section 4.4 deals with the discipline of land use planning, which is a key to the avoidance of flood risk and to the reduction of impacts. The incorporation of flood zoning into land use planning procedures is highlighted. Section 4.5 covers flood insurance, risk financing, compensation and tax relief which all serve to reduce risk and damage through risk assessment – and to offset the financial risks of flooding. Section 4.6 covers the crucial practice of urban waste management. Improvements to the collection and disposal of solid and liquid waste can result in significant gains for mitigating flood risk and reducing impacts.

The chapter then discusses measures which result in the limitation of flood damage and the after effects of flooding. Section 4.7 details emergency planning, rescue and temporary shelter measures; Section 4.8 continuity planning for business and governments; Section 4.9 early warning systems; and Section 4.10 evacuation planning. Finally, Section 4.11 provides an overview of flood recovery and reconstruction methods and processes.

4.2. Flood awareness campaigns

4.2.1. Introduction

Flood risk awareness is the cornerstone of non-structural flood risk management. All actions to minimize the impact of flooding hinge upon stakeholders becoming aware these are both necessary and desirable. Ignorance of flood risk encourages occupation of the floodplain, in the first instance, and can allow appropriate building design practices to fall into disuse. In the event of a flood, the lack of awareness of risk can result in a failure to heed warnings to evacuate, thereby endangering lives. Many studies detail the low level of flood awareness exhibited by occupants of floodplains and other flood-prone areas (Waterstone 1978; Siegrist and Gutscher 2006; Ibrekk et al. 2005; Burby 2001; Lave and Lave 1991). Awareness may be naturally high in areas where flooding occurs regularly, but is often deficient in locations subject to low frequency but high impact events.

In an ideal world, heightened awareness of flood risk would lead to mitigation activities and to preparedness, which in turn reduce the impact of flood events as shown in Figure 4.1. In Afghanistan, for example, a drama-based disaster awareness campaign was conducted via the medium of national radio. This was found to have been very successful in raising awareness of flood risk and in maintaining natural forest flood barriers (United Nations 2007). The 'secret of success' in such campaigns is to trigger local debates around issues that are relevant to the communities at risk.

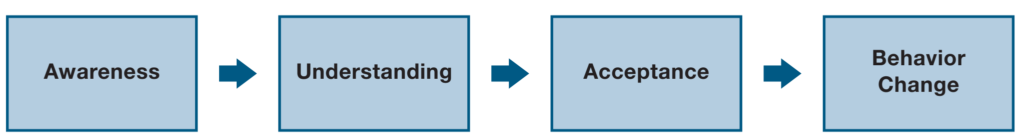

Figure 4.1: Communications continuum, Source: University Corporation for Atmospheric Research 2010

Raising awareness is only one part of a wider strategy of flood risk interventions. It should be accompanied by information on measures and steps which will mitigate the flood risk. This is illustrated in a Vietnamese scheme, which was targeted at a range of interest groups (including builders, teachers and school children); this proved successful in encouraging home owners to invest in flood- and typhoon-resistant buildings (United Nations 2007). Studies have shown, however, that to raise awareness of risk which cannot be reduced, is to engender a sense of helplessness which may lead to panic or risk denial (Waterstone 1978).

A focus on the practical actions to be taken in the event of a flood was, therefore, central to a campaign conducted in Algeria. The aim was to prevent a repetition of the fatalities that had occurred in the 2001 floods, when 700 people lost their lives. As one in three communes nationwide are at risk of total or partial flooding, the Algerian Civil Protection Agency (DGPC) needed to convey simple messages about things the public need to do. This involved open meetings at schools and community centers, followed by information disseminated via television, radio, text messages, and vehicle-mounted loudspeakers, all of which reach people in a very direct manner (ICDO 2009).

4.2.2. Awareness campaign design

Different interest groups need to be made aware of the risks they face and the steps that they can take to reduce these risks. The range of interest groups involved includes governments (at different levels), local agencies, businesses and individuals. Many people will fall into more than one of these groups, so the messages need to be consistent across interest groups and yet be targeted to the knowledge requirements of each group.

As a guide, the basic principles are that:

- Implementation should be sensitive to local cultures, conditions and perspectives.
- All sectors of society should be targeted, including both decision makers and members of the public, including children.
- Messages should be targeted at the appropriate level for each interest group.
- Campaigns should be sustained over time, with regular monitoring of their success.

As an example, an awareness raising campaign developed by the Environment Agency (the institution responsible for such work in England and Wales) which was first launched after severe flooding in 1998, had the following communications objectives:

- Keep flooding in the national consciousness
- Ensure people understand the impact of flooding
- Make flooding relevant to everyone who is at risk

- Break complacency and encourage action
- Demonstrate that the Environment Agency is a proactive partner in flooding for those at risk.

These objectives were achieved by using both a ‘top down’ and a ‘bottom up’ approach: national awareness campaigns were backed up by local flood fairs and activities designed to reach the population most at risk.

By contrast, a flood awareness campaign in Cambodia was more rooted in the community from the outset (MRC and ADPC 2007). Local stakeholders were involved in adapting materials for local conditions, and used stage plays and folk songs to disseminate information. Specific lessons learned from the project included:

- Increased capacity identified by local stakeholders
- Use of existing social and cultural practices yields better results
- Existing materials can be used – they just need adapting
- Creativity is a key in making the message heard
- Using local stakeholders to build capacity in itself generates awareness
- Focusing on the most vulnerable means that these sectors will be included.

4.2.3. Communications channels

The suitability of different communication channels will be dependent on the target audience and cultural considerations. It is important for communicators to realize that messages regarding flood risk are competing in an environment of ‘information bombardment’; this means that single messages are unlikely to make an impact. The literacy and language skills of the intended audience are also critical factors in campaign design. Examples of communication media include:

- Posters
- Brochure and leaflet drops
- Newspaper and magazine articles
- Home visits
- Television and radio (including ‘soap opera’ storylines).

- Art and photography exhibitions
- School art competitions and events
- Signage of past flood levels using flood poles
- Examples of appropriate building design
- Flood wardens
- Demonstrations
- Training
- Disaster day campaigns
- Adverts
- Merchandising
- Engagement in flood risk planning
- Songs and drama including street theatre
- Promotion by celebrities
- Mock exercises and preparedness activities
- Flood 'fairs' (where, for example, property-level resilience measures can be demonstrated by suppliers).

Case Study 4.1: Raising awareness of disaster risk through radio drama in Afghanistan

Afghanistan is prone to earthquakes and drought, as well as floods. Partly because of its mountainous geography, the country has some of the most isolated villages in the world. As around 80 percent of Afghans have radio sets in their homes, the approach adopted was to integrate disaster risk reduction (DRR) messages into a BBC World Service's educational radio program called 'New Home, New Life'.

It was anticipated that, once made aware of DRR, communities along with formal institutions would be able to actively participate in the development of local disaster management plans. The overall goal of this initiative was to support the development of disaster-resilient communities. To make the program as accessible and acceptable as possible to the listeners, comprehensive research on the context of the issues faced by the communities was first carried out.

To ensure relevance and effectiveness, the design team had to build a clear understanding of dialects, accents and people's motivations. The involvement of external partners with relevant experience such as the charitable organization Tearfund also supported the program in identifying key messages.

The initiative is supplemented by other interventions which go into more detail on some of the issues raised in the radio dramas. This includes a quarterly publication, which repeats the messages in cartoon format and is circulated by the partners to the local communities. In addition, the BBC World Service Trust produces children's publications to disseminate key messages, which can be used in formal and informal learning methods.

The program has been found to be a cost-effective and efficient way to reach the large section of the population who have radio sets in their homes, given that direct engagement with isolated communities is otherwise extremely difficult. Background research provided an accurate understanding of the real needs of communities and helped to identify relevant messages. The implementing agencies suggested that the project could be easily replicated, through state-funded radio programs, as part of DRR initiatives at community level.

Sources: UNISDR 2007; Tearfund n.d.

Care should be taken to select media which will not only reach the sectors of the population most at risk, but also those best able to target 'hard to reach' audiences. This may be due to the nature of the audience or their locations; an example is the targeting of women-led households in Cambodia (MRC and ADPC 2007).

In Senegal the methods used to communicate included plays, exhibitions, media broadcasts, teatime 'chats', interviews, photo exhibitions and open air conferences (Diagne 2007; IFRC 2010).

It is also a matter for debate whether the awareness of flood risk should be part of a general disaster awareness program, or should stand alone. In coastal areas there is a need to include earthquake risk with seismic induced tsunami coastal flooding. In communities at risk from multiple hazards, or cascading risks, a general 'hazard preparedness' approach may be appropriate. A balance has to be struck between the reduced cost on the one hand and dilution of focus on the other.

4.2.4. Visual clues in the landscape

Building awareness into the fabric of the community can be a way to alert both local and transient populations to the dangers they may face. In coastal resort areas in particular, the presence of large numbers of visitors may put those unfamiliar with the area at risk: this was the case in the December 2004 Indian Ocean Tsunami. Visual clues can include flood markers on buildings, bridges, poles or marked boundary lines. Visual clues to risk can be incorporated in awareness campaigns, but these need to be backed up by national or international acceptance of the meanings of the clues and symbols used.

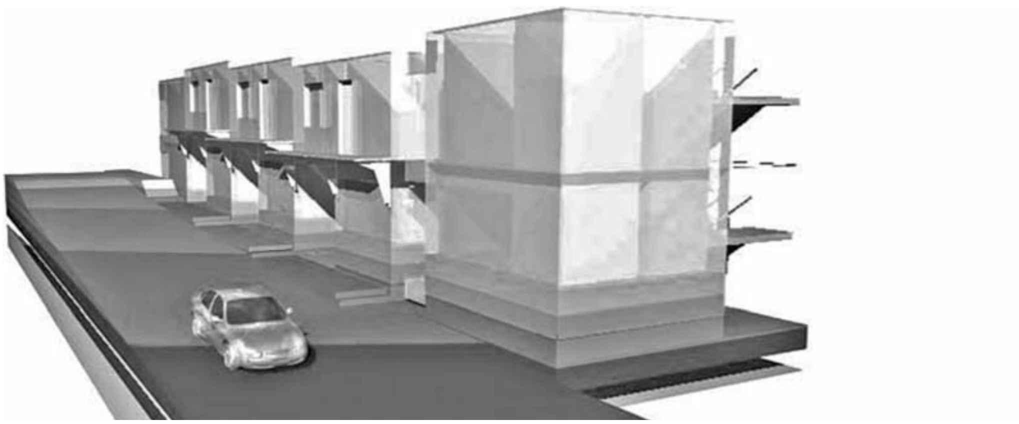

Figure 4.2: Intuitive landscapes highlight flood hazard areas within a development.
Source: Baca Architects

4.2.5. Monitoring awareness

The awareness of flood risk is likely to be heightened after an event or a flood awareness campaign. However, some communities can soon forget about flooding, or the effects of it on those who have survived a serious event. Measuring outcomes of flood awareness raising activities is, therefore, important, as the benefits will not be realized until a flood event occurs. It is also important to regularly monitor the level of flood awareness, so that new or heightened campaigns can be introduced as necessary. The impact of a campaign will inevitably diminish over time; new materials and channels may need to be introduced to get the messages across. Surveys of awareness not only serve the purpose of monitoring but can also be used to heighten awareness again. Occasionally, a flood warning and evacuation is activated but the ensuing flood is not as serious as predicted. These situations may undermine the credibility of awareness campaigns.

The immediate success of a targeted campaign can be measured against its objectives – did it reach the right audience and did they get the message? This can be expressed qualitatively (in that the audience now understands risk more fully) or quantitatively (in that individuals took specified actions, such as signing up for a warning service, or putting together a flood pack) (Emergency Management Australia 2000). For longer-term awareness programs, a longitudinal survey is appropriate to ensure that the level of awareness and activity is maintained. In England, for example, the Environment Agency regularly conducts a general survey on environmental issues which includes questions on the level of awareness of flood risk, as well as a checks on whether the population knows what to do, and who to ask, about flood mitigation. Drills and exercises are another useful way to monitor and maintain awareness within a community.

4.2.6. Considerations for a successful flood risk awareness campaign

For the success of any risk assessment program it is essential to reach every corner of the society and the people who are at risk. An awareness campaign is an instrument which helps in reaching the groups who are not easily reachable. It brings a total awareness in the society and helps in building risk resistance among community.

City managers are responsible for understanding the needs of every part of the urban society and making people aware of both the potential disasters and their associated risks. Such awareness can be made achieved by promoting awareness campaigns. Generally, the focus of such a campaign differs from one area to another, based on the needs of the local people. It is important for any awareness campaign to try and engage local communities so that maximum benefit can be obtained for the people at risk. The key is to prepare the people for future flooding and reduce the level of vulnerability as seen in Table 4. 1.

Table 4.1: Actions for flood risk awareness

Actions	Considerations/operations	Outputs
Defining target audience (s)	Public, professionals, hard to reach groups	Identified group of audiences

Audience need assessment What do they already know?	What do they need to know? Who do they trust? Any specific communications difficulty, language, formats?	Output brings together the knowledge and information about what exists and what is to be done to further improve awareness
Choose the message	A general risk awareness or specific actionable knowledge? The message will depend on the audience and objectives of the campaign.	Messages taking into account social, economic political and cultural factors are more effective
Set measurable objectives and specify what indicators to use	Examples are: Increased percentage awareness of risk Increased registration for warnings At-risk households having an emergency plan Businesses having a flood evacuation drill	Specific objectives are necessary for future operations, which will be carried out based on the results obtained
Determine communications channels	Use more than one channel, e.g. posters, brochure and leaflet drops, newspaper and magazine articles, home visits, television and radio (including, soap opera storylines), art and photography exhibitions school art competitions and events, signage of past flood levels using flood poles, examples of appropriate building design, flood wardens, demonstrations, training, disaster day campaigns, adverts, merchandising, engagement in flood risk planning, songs and drama including street theatre, promotion by celebrities, mock exercises and preparedness activities and flood fairs.,	Different communication channels will help in reaching a higher number of people and have a greater overall effect
Enlist support	Engage the local community and other agencies or voluntary organizations It is particularly important to enlist the support of the trusted advisers to communities	Inclusion of local community helps in engagement of the local people and giving proper attention to their specific needs

Disseminate	Implement the plan, perhaps several times, or on a continuous basis Care should be taken to actualize the aims which were intended at the planning stage.	Proper implementation of the plan as framed is important for effective results
Monitor awareness	Check against objectives	Continuous monitoring by the local community, and occasionally by higher authorities, can keep the system going and bring in more awareness among people.

4.3. Health planning and awareness campaigns

4.3.1. Description

An urban flood event requires immediate measures to ensure that citizens have safe drinking water, including appropriate excreta disposal, disease vector control and waste management. However, during and after a flood event is not necessarily the best time to communicate health messages to individuals and organizations, as they may be dispersed and not have access to the necessary resources. Health Awareness Campaigns are vital 'soft' interventions alongside hardware provision (waste water treatment, for example); together they can help preserve public health by increasing preparedness. Health awareness and hygiene promotion campaigns must not be carried out independently from water supply and sanitation, and vice versa.

Floods can make it difficult to maintain dignity and hygiene, and lead to an increase in the risk of disease in the following ways:

1. Widespread contamination by fecal material due to destruction, breakage or damage to sewage systems and latrines, and subsequent open defecation
2. Contamination of drinking water
3. Thick layers of silt, debris and other materials
4. Loss or lack of key hygiene items

5. Standing pools of contaminated water or sewage
6. Rotting corpses (human and animal) can lead to excessive fly breeding or contamination of water sources from insect feces
7. Increase in vector breeding
8. An adverse psychological impact due to loss, and a sense of despair.

An effective health awareness campaign will provide clear timely advice on how best to protect individual and public health during a flood and will facilitate a two–way dialogue such that feedback from the affected persons directly informs priorities and decision making.

Pre-flood campaigns are vital for risk mitigation and preparedness. Campaigns during, or post-flooding, will reinforce messages and mobilize communities into action to preserve public health.

Box 4.1: Public health priorities in the event of a flood

- Provide a minimum amount of water for drinking, cooking and washing
- Provide facilities for people to dispose of excreta safely, in places which young children and babies cannot access
- Ensure people have key information to prevent water and sanitation related diseases: focus on the diseases that pose the most serious threat, include the provision and use of oral rehydration therapy (ORT).
- Protect water supplies from contamination
- Publicize emergency contact details and sources of advice and information
- Ensure people have enough water containers to collect and store water cleanly
- Ensure that people have soap or alternatives for hand washing
- Ensure that public spaces such as markets have adequate water and sanitation.

4.3.2. Key Components of Health Awareness Campaigns

Urban residents may have received little or no previous hygiene education or health awareness training and are likely to be ill-prepared to respond to a flood. When this condition is combined with weak local or municipal government and staff who are themselves ill-prepared, a flood event can result in a complete breakdown of basic public services (water, sanitation and solid waste management) alongside a significant increase in the risk of accidents and disease. As a consequence, even a relatively minor flood can result in a dangerous increase in morbidity and mortality.

It is important to plan health awareness campaigns with an understanding of the type of flooding involved, its anticipated effects, probable duration and the likely impact on the urban population. This planning also has to take into account the current status of public understanding and awareness of health issues, as no two urban situations will be the same. Both the messages and modes of communication should be adapted for the particular situation and for different audiences. The messages should take account of beliefs and attitudes that regarding health, disease and hygiene and should appeal to the interests and priorities of different groups.

The health awareness interventions should be designed with participation and collaboration of all key stakeholders, to ensure that effective messages are developed, and that both clarity and consistency apply to the communication strategy. The relevant government ministries (such as environmental health, social welfare, health, education) should be involved, as well as influential leaders, opinion formers and agencies working in the WASH (the now commonly used acronym used for water supply, sanitation and hygiene promotion) or health cluster. Different sections of the community should participate, including the more vulnerable groups such as low-income groups, women, children, aged and disabled people.

Health awareness is required by three distinct groups of people:

- Municipal staff, volunteers and health professionals
- The general public and in particular vulnerable groups
- Media workers.

4.3.2.1. Municipal Staff, Volunteers and Health Professionals

In flood-prone urban areas, pre-flood campaigns should be undertaken to prepare staff to deal with the changed public health conditions which are likely to ensue post-flood. Municipal staff and volunteers should receive training on how to carry out an initial rapid assessments (an example of which is shown in Box 4.2); prioritize actions; quickly install appropriate technologies to contain excreta (particularly in areas of high population density, such as flood shelters); and establish effective coordination within the WASH sector.

Box 4.2: Essential Questions for the Initial Rapid Assessment of Water Supply

- What type of water resources do people in the different parts of the city rely on and which are the main affected zones?
- Is water mostly supplied from modern water treatment works through pipeline distributions, or through other systems? (e.g., private boreholes, open wells or similar sources)
- Which areas of the city are most affected by the disruption to water services?
- Which public or private services are still working or could be rapidly rehabilitated?
- How to identify strategic locations (such as health centers, shelters) or other areas requiring rapid assistance with supplies of bottled water, water tankering or water treatment kits.

Source: adapted from: Global WASH Cluster 2009(a).

The training should also include post-flood responsibilities to disseminate appropriate priority messages to the public and special vulnerable groups to preserve health and hygiene. One important outcome of a pre-flood health campaign is that it should identify those valuable partners – government, non-government and volunteer – who, with training, will enhance available manpower for the post-flood relief activities and awareness campaigns to preserve public health.

Health professionals should be trained and motivated to carry out a flood risk assessment of their own facilities such as health posts and hospitals so local flood mitigation measures are undertaken to reduce the risk of these facilities becoming dysfunctional during a flood. With pre-flood health awareness training, health professionals will be better able to maintain basic curative health services and respond effectively to the new demands created by the floods. They should know what to expect and have the necessary knowledge, awareness and capacity to provide specific advice and support to protect public health during a flood.

4.3.2.2. Public

Pre-flood Health Awareness Campaigns for the public need to provide at least a minimum level of awareness to reduce the uncertainty and risk in the event of a flood. They should target the most vulnerable, for example by working through women's groups, especially in the poorer communities and reaching children through campaigns in schools. Developing links with concerned agencies and training volunteers should ensure resources are available for the health awareness campaigns and other relief activities that will be needed.

4.3.2.3. Media

As important stakeholders in health awareness campaigns in the event of a flood, it is valuable to work in advance with the media – newspapers, radio, TV, and the Internet – to prepare materials for subsequent campaigns. There are numerous tools available for rapid assessment and communication planning for health awareness campaigns in an emergency; these may include guides for developing print materials, radio spots and other interventions (examples are in UNICEF 2006; Global WASH Cluster 2009(b),(c) and (d); Oxfam 2001).

4.3.2.4. Post-Flood Health Awareness Campaigns

The staff resources required for campaigns include public health promoters for water, sanitation and vector control; children's health promoters; and both water point and latrine attendants. Examples of job descriptions and training modules are available (Oxfam 2001), along with other useful information such as notes for teaching about oral rehydration and the materials required for family hygiene kits or clean up campaigns (examples in UNICEF 2006).

When using volunteers or outreach workers for hygiene promotion, additional monetary incentives should not be paid. If a larger number of volunteers are trained their workload will be less and the system stands a greater chance of being sustainable. Incentives in kind (soap or oral rehydration salts kits) however, may be used to motivate volunteers initially. In the event of a serious outbreak of disease, it may be appropriate to include payment for a finite period of time for additional work that may be needed to halt the spread of the disease (Oxfam 2001).

During a flood it will be important to focus efforts. Very early in any flood event, a rapid needs assessment will enable this focusing to be appropriate to the specific needs; for example, it may be identified that effective excreta disposal in flood shelters and improvements in hand washing are likely to yield the greatest benefits. Raising awareness about ORT may also be extremely effective to mitigate an outbreak of diarrheal disease (Oxfam 2001).

Post-flood, the media can play a major role in public outreach, with carefully selected messages that are consistent and targeted. Messages should be kept to a minimum, as experience shows that too many messages dilute available resources, confuse the community and may reduce the likelihood of achieving changes in practice (Global WASH Cluster 2009a). Hand washing with soap is likely to be a priority, as hygiene behaviors can achieve the greatest health impact. The safe disposal of excreta and the use of clean water for drinking will also be essential. The actual message will need to be defined according to each situation.

The public – men, women and children – can take action themselves to reduce public health risks by, for example, appropriate point of use (POU) treatment of water, and practicing effective hand washing at key times. All sections of the affected population should make the best use of, and realize the need to maintain in good order, the water and sanitation services provided as explained by IASC (2008). There should be distribution of appropriate hygiene items including, for example, household sanitary kits and sanitary materials for women.

4.3.3. When and where to use Health Awareness Campaigns

Any flood-prone city or town would be well advised to invest in a health awareness campaign, both pre-flood and post-flood, irrespective of what type of flood is anticipated. An assessment in advance of the likely public health risks during a flood in that location (including, for example, impacts on water treatment works, or probable disease vectors where appropriate) will guide the design and prioritization of any campaign to make it more cost effective.

4.3.4. Benefits

An effective public health campaign will reduce death and disease caused by flooding. Specifically, pre-flood health awareness campaigns will:

- Develop knowledge, understanding and build the capacity of municipal staff and volunteers to work effectively and efficiently post-flood, to preserve public health and reduce mortality and morbidity.
- Provide guidelines on key elements of an initial rapid assessment of public health risks and build capacity to institute an appropriate, rapid and coordinated WASH response.
- Protect health service capacity from the impacts of flooding.
- Post-flood campaigns will help preserve personal and public health by giving the public immediately relevant knowledge and awareness to complement the hardware relief interventions.

The health and hygiene information is also applicable in non-flood situations and, as such, will have a knock-on effect of improving public health in general. Health awareness campaigns to deal with urban floods sit very comfortably alongside other, more traditional, health campaigns such as mother and child health, anti-malaria and HIV/AIDs awareness. The same professional staff and volunteers can and should be involved.

4.3.5. Risks and weaknesses

There are few risks associated with promoting health awareness in urban areas prone to flooding. The challenge is to ensure that this is carried out effectively, as far in advance of floods as possible and in close coordination with the structural mitigation and relief interventions.

Cities may face particular challenges, such as providing sanitary excreta disposal options for low income settlements, or maintaining waste disposal services during the flood. Given the relative poverty of many affected municipal authorities and local governments, there may also be issues around obtaining resources to invest in public health flood preparedness, when structural interventions could appear more politically advantageous.

4.3.6. Essentials and key considerations

The affected population should be made aware of their rights and entitlements to relief and recovery operations; this is particularly relevant to the rights to protection for specific groups of persons (such as internally displaced persons; women, children and adolescents; the aged; people living with HIV/AIDs; persons with disabilities; single parent households; ethnic and religious minority groups; and indigenous peoples). IASC (2008) discusses these issues in more detail. Case Study 4.2 demonstrates an instance of how children can be involved.

Public health campaigns can only provide knowledge and understanding, which may do little practical good without tangible interventions such as provision of clean drinking water, chlorine tablets or safe waste disposal sites. However, as stressed in this section, without pre- and post-flood 'soft' interventions (specifically aimed at promoting awareness of how to preserve health and hygiene during floods), the 'hard' interventions are unlikely to be effectively mobilized or, even if mobilized, will by themselves be of minimal use.

Catastrophic outbreaks of diseases are not inevitable after a disaster: they do not spontaneously occur. However, the keys to preventing disease are to be prepared, to educate and motivate both the appropriate officials and the public, and to promote the meeting of basic sanitary needs.

Case Study 4.2: Flood risk management and children's participation in Mozambique

During disasters, children are usually among the most vulnerable groups within the affected population, while at the same time they tend to be the least informed. In the Morrumbala and Mopeia settlements in Zambezia Province, the second-most populous of Mozambique's ten provinces, community leaders, teachers, and local education authorities, along with the government agencies responsible for disaster response, were supported by Save the Children, UNICEF and ECHO to carry out a DRR project that actively involved the children living in flood-prone areas.

The project aimed to increase the understanding of flood risk in children between the age of 12 and 18. A number of communication methods, including an educational game called 'The River Game', brochures, a school magazine, radio slots and theatre were used to inform children about disasters. They were also encouraged to share their concerns and understanding about disaster risk with their peers, parents and other community members.

During the 2008 floods, communities along the Zambezi River showed better preparedness and response than in previous years, partly because of the project. In particular, it was observed that:

- When flood warning was declared families were moved to higher ground;
- During the evacuation people took with them key documents such as, ID cards, social welfare documents and birth certificates;
- Communities showed better health and hygiene practices in the resettlement camps;
- Communities developed systems to ensure the protection of children from exploitation and abuse; and,
- Children avoided dangerous routes on their commute.

The project influenced behavior change at the individual and community level which lead to the adoption of more appropriate disaster responses to flood risk. Children have been empowered to engage in disaster preparedness and response in their communities, while multi-stakeholder partnerships at the local, provincial and national levels promoted replication of the initiative to other affected parts of the country.

Source: Dale et al. 2009.

4.3.7. Further reading

CDC. 2008. Re-entering your flooded home (Emergency Preparedness & Response) http://www.bt.cdc.gov/disasters/mold/reenter.asp.

ECHO. 2005. Model guidelines for mainstreaming water and sanitation in emergencies, protracted crises, linking relief, rehabilitation & development and disaster preparedness operations. European Commission.

Global WASH Cluster. 2009(e). Hygiene Promotion in Emergencies, Lessons Learned from Koshi Flood Response. http://www.un.org.np/reports/UNICEF/2009/2009-05-01-Hygine-Promotion.pdf.

Godfrey, S. and Reed, B. 2011. Cleaning and disinfecting wells. WHO/WEDC Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies.

Geneva: WHO/WEDC. http://wedc.lboro.ac.uk/resources/who_notes/WHO_TN_01_Cleaning_and_disinfecting_wells.pdf.

Oxfam. 2009. TBN 7 - UD Toilets and Composting Toilets in Emergency Settings http://www.oxfam.org.uk/resources/learning/humanitarian/tbn_drafts.html#eco.

Rouse, J.R. 2005. Solid waste management in emergencies. WHO Technical Notes for Emergencies, N° 7. Prepared by WEDC. http:// www.who.int/water_sanitation_health/hygiene/emergencies/solidwaste.pdf.

WEDC. 2005. Essential hygiene messages in post-disaster emergencies, WHO Technical Note no. 10 http://wedc.lboro.ac.uk/who_Technical_notes_for_emergencies/10%20%20Essential%20hygiene%20messages.pdf.

WHO Technical Notes for Emergencies, N° 6. Prepared by WEDC. http://www.searo.who.int/LinkFiles/ List_of_Guidelines_for_Health_ Emergency_Rehabilitating_water_treatment_works.pdf.

WHO. 2006. Guidelines for drinking-water quality, third edition, incorporating first and second addenda. http://www.who.int/water_sanitation_health/dwq/wsh0207/en/.

4.3.8. How to conduct a health awareness campaign

It is essential to provide clear advice to the public and groups that are particularly vulnerable, on how best to protect their individual and public health during a flood. In urban areas where floods are anticipated, or which regularly flood, campaigns should be undertaken in advance. This will prepare people for the likely changed public health conditions which will ensue during a flood and post-flood.

The focus of an awareness campaign will differ from one area to another and from one disaster to another. It must be designed to meet the specific needs of the people. An awareness campaign must engage local communities so that maximum benefit can be obtained for the people at risk.

Method

1. **Campaign design**
2. **Pre-flood preparedness for municipal staff, volunteers, media and health professionals.**
3. **Pre-flood basic public health awareness.**

4. **Immediate flood onset public mobilization and information dissemination.**
5. **Flood public health awareness (i.e. during a flood).**
6. **Campaign monitoring, evaluation and improvement.**

1. Campaign design

For any awareness campaign it is essential that both the message and the means of communication are chosen to meet the specific needs of the target audience. This means that for different groups (eg. health professionals, media professionals, general public, hard to reach groups) both the messages and the communication tools used (e.g. formal training sessions, posters/brochures, leaflet drops, newspaper and magazine articles, home visits) will be different. Awareness is required before the flood (i.e. preparedness); other different messages are needed at the immediate flood onset (i.e. emergency awareness) and still others during the flood (relief, recovery and rights).

A 'Core Team' of public health champions needs to be established to guide the awareness campaign and ensure coordination between sectors and agencies. This team should meet with and motivate key senior municipal and appropriate government department staff (e.g. water supply, sanitation, health etc.) and leaders of concerned volunteer agencies (e.g., the Red Cross/Crescent, community resident associations) – as well as work with them to develop a strategy for a coherent and comprehensive pre- and post-flood health awareness campaigns. Media representatives should be included, as is appropriate (see below).

2. Pre-flood preparedness for municipal staff, volunteers, media and health professionals.

Senior water supply, sanitation and public health staff of the municipality should receive training in a range of topics including probability of flood; likely type of flood; warning and duration; probable impact; possible evacuation needs and implications for mortality and morbidity public health priorities in the event of a flood; action planning; the importance of both hardware (emergency water supply, distribution of hygiene kits etc.) and software interventions (community mobilization, personal hygiene awareness, public campaigns etc.) and the need for coordination. Action plans should be developed during the training that include initial rapid assessment, identification of immediate priority actions, basic service provision during floods, normal service rehabilitation, monitoring and reporting. Participative discussion of previous flood experiences will bring out useful information and also encourage ownership of the agenda.

This detailed preparedness training will be carried out by sector technical staff to ensure appropriate action plans are developed and understood by concerned staff. Mock exercises should be included in collaboration with volunteer agencies, wherever possible, to enhance preparedness and practice essential collaboration and inter-agency communication.

To motivate and mobilize health services it is vital to organize and run training for health professionals in both government and private health facilities to ensure understanding of anticipated health implications of flood and encourage preparedness. Health administrations must be motivated to carry out flood risk assessments for health centers and hospitals, and support flood mitigation actions so as to help ensure health facilities stay operational during flood events.

Identify the most appropriate champions in various media (e.g. newspapers, TV, radio and internet) and motivate them on the important role of the media in raising public health awareness during a flood. Prepare and run training with media representatives to inform and prepare them for their role. Share available tools and encourage them to pre-prepare messages, print material, radio spots, etc.

3. Pre-flood basic public health awareness.

Work with concerned agencies to design a training strategy to reach a cross-section of the public with basic public health awareness and personal hygiene messages in event of a flood. Prepare training materials and train ‘health awareness trainers’ from both official and voluntary agencies. The awareness program should be rolled out, piggybacking activities wherever possible onto on-going programs such as anti-malaria or HIV/AIDs awareness, and using existing structures such as schools and neighborhood organizations. Ensure inclusion of vulnerable groups, such as the aged, disabled, and poor communities.

Monitor and review pre-flood public health awareness activities. Depending on the periodicity of floods, the public health awareness may require regular repetition and would not be a ‘one-off’ event but an on-going activity.

Concerned voluntary agencies should be encouraged with advice and training to work with communities, especially the most vulnerable communities, to prepare flood risk management plans.

4. Immediate flood onset public mobilization and information dissemination.

The immediate emergency information dissemination campaign should coordinate and disseminate information to public through appropriate media, volunteers and public officials. Information and messages will be prioritized to preserve life, ensure safety and promote public health This will include messages on flood severity, evacuation arrangements, status of basic services including water supplies, location of relief centers and operational health facilities, information on distribution of emergency relief food and non-food items, etc. Publicize emergency telephone contact numbers and ensure adequate and well informed response capacity to provide up to date information (eg. evacuation, drinking water, medical aid etc.). Monitor the process and ensure messages effectively reach particularly vulnerable groups.

Continue for as long as the emergency situation pervades. It will be vital to coordinate effective feedback from field agencies to inform the emergency response. It needs to be a two-way communication strategy. Develop and adjust messages as information arrives from rapid assessments (water, sanitation, health services etc.) and as evacuation and relief programs get underway.

5. Flood public health awareness (i.e. during a flood).

Based on the pre-flood preparations and working with government, media and volunteer partners (refer 1. and 2. above), carry out the pre-prepared flood health awareness campaign. Prioritize key messages such as preventing contamination of and treating drinking water and effective hand washing at key times. Coordinate messages with relief and recovery programs such as health and safety advice for clean-up campaigns, advice for families to return safely to flooded homes etc. Use the campaign to promote dialogue with communities to make decisions about providing and managing WASH facilities during the flood event (refer WASH Cluster 2008a).

Ensure continued coordination of effective feedback from field activities to identify needs and priorities (for example disease outbreaks, new pollution risks etc.). The campaign should ensure that the affected population is aware of their rights and entitlements to both relief and recovery operations (Refer IASC 2008).

6. Campaign monitoring, evaluation and improvement.

A well-designed health awareness campaign strategy will clearly define anticipated outputs; incorporate a monitoring system to ensure effective implementation; and include an evaluation process to assess impact and guide subsequent improvements.

4.4. Land use planning and flood zoning

In growing and expanding urban settlements, flood hazard may be seen to be of lesser importance than other land management concerns, such as providing land for existing or new businesses or housing. Ongoing development and encroachment of floodplains and other flood-prone areas is a consistent problem throughout the urbanized world. The need to integrate flood risk management into land use planning is vital in order to minimize the rise in exposure to hazard, and to seek to manage the consequences of flooding.

Two of the most effective regulatory systems are land use planning and the finance and insurance sector, which is discussed in the next section. Both seek to control unregulated development of the floodplain, the former by land use plans and development frameworks to guide and control development and the latter by imposing minimum design standards for finance and insurance provision.

Understanding potential flood hazard risk, natural processes of water catchment areas, watercourses and floodplains enables planners and decision makers to develop appropriate land use frameworks. The control of development through such frameworks can reduce flood hazard by allowing natural processes to occur such as storage or the flow of floodwaters within the floodplain and in turn, reduce the exposure of communities to the hazard. Conversely, lack of guidance may put communities at risk through inappropriate development that prevents natural processes and intensifies the flow of water through increased hard surface areas, particularly those located in high risk areas.

4.4.1. The inter-relation between land use planning and flood risk management

Land use planning provides a policy and regulatory mechanism that enables diverse and often conflicting objectives to be integrated and addressed in a development framework – with this process and its output, is referred to as 'integrated land use planning'. Integrating flood risk management objectives and principles into land use planning is an essential component of contemporary flood risk management. Through its formulation and implementation, land use planning:

– Identifies appropriate area(s)/location(s) for specific land uses

– Determines what risks are associated with specific land uses in specific locations

- Determines and identifies sensitive or important societal or environmental features
- Details minimum requirements/expectations of particular land use types.
- Put simply, it determines what urban development is required and where it should go.

Land use planning is understood in many ways. This book differentiates between the terms land use planning and spatial planning. Land use planning, which is often also referred to as physical planning, although this term is passing out of use, refers to the detailed planning of the ways in which buildings and land are used. It usually incorporates the regulatory dimension by which land use is overseen. Spatial planning is typically seen as a broader set of ideas and practices which give geographical expression to a polity's social, economic and other policies. Spatial planning occurs at the strategic level of overall guidance and encompasses land use planning.

The interaction between land use planning and flood risk management is mutual. Urban land use plans should ideally be integrated within a suite of flood management plans which may include river basin management plans, coastal management plans and surface water management plans. Such plans are likely to be the responsibility of different governmental departments or agencies and the urban use plan will be informed by these dedicated flood management tools. Land use plans, on the other hand, will incorporate flood risk alongside other priorities, land availability and environmental hazards while broader spatial plans will need to balance the need for urban growth with the desire to limit flood risk.

Spatial planning is undertaken at scales from national through to municipal or city level; detailed land use planning takes place at neighborhood down to plot level. This broad structure of how these respective plans relate and interact with one another is referred to a hierarchy of plans, and reflects a concept in planning known as comprehensive planning. Spatial planning enables the preparation of land use plans that are intended to facilitate and direct development over a period of time. Often strategic plans at a national level will set out a development vision or objective that aims to cover a longer development period of say 10-15 years while more detailed or operational level plans at either municipal or city level plan may only work on a 5 year cycle. That said, these time periods are arbitrary and largely informed by the legal apparatus and structure of government(s).

Very importantly, flood risk management needs to be first embedded at the urban or land management policy level in order to ensure that plans are prepared with due consideration to such matters. Situating particular objectives at a policy level within multiple institutions requires integrated governance and operational frameworks to be in place. In the first instance, the development of a policy position or objective is required. For flood risk management, a water or environmental department of a relevant authority may be responsible for this. This agency/department would normally then be responsible for setting out a series of statements (complemented with spatial maps) that provide guidance to other government/decision making agencies and the community. Guidance may include information about high risk flooding areas, anticipated changes over time, minimum height levels for development and environmental management principles. From a land use planning perspective it is the integration of these broader principles that are determined at a policy level into the planning process that is vitally necessary.

Cross-institutional working, integration and locating policy positions into the planning process is, however, often not achieved. Competing objectives coupled with 'silo' working practices often mean that one arm of government is at odds with another: spatial planning often in fact draws out or highlights these challenges.

Contemporary planning practice requires consideration of numerous and often conflicting objectives. The need to accommodate rapidly growing populations, and provide adequate infrastructure, appropriate land for commercial and industrial development, open space, and adequate protection of the environment all in a constant state of flux and change is challenging. The level of complexity continues to evolve as rates of urbanization increase in developing countries, and consideration of natural disasters and climate change becomes more pronounced. In response to this, planners and decision makers have begun to incorporate the concept of 'risk' into planning practice and developed the approach of risk- based land use planning. Risk-based land use planning is a spatial risk management approach that prioritizes risk mitigation and adaptation objectives by using conventional land use planning tools. It is broadly captured in three main stages: appraising risk, managing risk and reducing risk.

Spatial and land use planning incorporates many factors and datasets. The concept and approach for preparing an integrated land use plan is layered. In the first instance, a base map/plan is developed. Generally this is a topographical and natural features map and where available it also incorporates cadastral data. This base map is then incrementally built upon to enable a spatial understanding of all other features such as the location of infrastructure, buildings, open space, green belts, coastal areas, nature reserves and watercourse or catchment areas. It is this layering approach that enables policy makers to adequately plan for community needs and aspirations while also acknowledging and addressing potential hazards and risks.

Technology now also aides land use planning and management. In particular, the use of Geographical Information Systems (GIS) provides the ability for government authorities to capture relevant urban data and present this in a spatial manner. GIS enables the creation of databases that can include information about natural and built assets, and the extent of a natural feature such as watercourse or catchment area, and presents this information spatially. For example, a government authority may create a natural features database with one component representing all available data on the floodplain. This data is then converted to a spatial format so the outcome is that a relevant municipal official can, by loading an electronic map of an area, select a specific location and be able to access all the relevant information about the floodplain for that particular location. The benefit of this to both government employees and the community is significant as it provides swift and concise information at the 'click' of a button. Obviously, in the context of rapidly growing cities and towns with a high level of informal or less formal land development, there are limits to data availability and the capacity of staff and authorities. The potential however for GIS to be a positive support tool for decision makers and the community is great. The following case study presents the functionality of GIS in the aftermath of the 2010 Queensland floods.

Case Study 4.3 GIS Queensland Flood

The Queensland Reconstruction Authority, the agency responsible for reconstruction following the 2010/2011 floods, together with the Department of Environment and Resource Management (DERM) has used GIS and satellite imagery to aid the reconstruction effort. Mapping products have been developed and are supporting the formulation of policy and tools for decision makers and members of the community.

A number of GIS mapping outputs have been created. These include the 2010/2011 captured interim floodline which was developed using spot aerial imagery, available satellite imagery and local information captured during the 2010/2011 events. The interim floodline is publically available on the Authority's website, and feedback was encouraged to ground truth the interim floodline.

In addition to capturing the actual event, the Authority has led a body of work to ensure a better understanding of Queensland's floodplains and to establish a better correlation between floodplain management and land use planning. This two-part guideline entitled Planning for stronger, more resilient floodplains provides planners and decision makers with specific guidance to ensure that flooding potential is considered in the land use planning process.

Through a layered and integrated approach, the Authority and DERM developed a unique methodology to geospatially identify Queensland's floodplains. This is particularly important in areas where flood studies have not yet been undertaken in order to provide high level guidance in land use planning processes. A number of state-wide datasets including soils data, stream ordering, pre-cleared vegetation, contour information and recorded gauging station information were combined with satellite imagery and available aerial photography, including that of the 2010/2011 floods, to understand potential areas of flooding across every relevant river catchment in Queensland.

Figure 4.3: Example of GIS map. Source: Queensland Reconstruction Authority and Department of Environment and Resource Management.

Through the use of this technology and information, a state-wide mapping product known as the Interim Floodplain Assessment Overlay was developed. In all, 116 river catchments in Queensland have been mapped. This represents all relevant areas of the state. Part 1 of the Guideline – Interim measures to support floodplain management in existing planning schemes included the mapped product both electronically and in a hard copy, alongside a supporting guideline and a development code. The aim of the toolkit is to provide an interim response for municipal bodies, specifically Councils, to be able to incorporate the mapping and the development code into their existing planning schemes. It will therefore be used by planners and decision makers to ensure there is a consideration of flood potential when preparing or assessing development proposals. The voluntary toolkit is provided to Councils for local verification and refinement based on any more readily available data at the local level.

The Authority has also prepared Part 2 of the Guideline – Measures to support floodplain management in future planning schemes. Part 2 is focussed on providing Councils with floodplain management guidance in the preparation of their new generation planning schemes – and specifically to help ensure policy can be developed and embedded from the strategic framework into appropriate land use zones and therefore to support informed decision making through the development assessment process. Part 2 also provides specific fit-for-purpose approaches to undertaken flood investigations and studies that are targeted and suitable to the local catchment needs and priorities.

Planning for stronger, more resilient floodplains is ensuring that the lessons learnt from the summer of 2010/2011 are being translated into the land use planning process now and into the future.

Source: Queensland Reconstruction Agency.

Drawing the principles and approaches outlined above, and as an illustrative example, a concept plan will often be prepared for a particular area. A concept plan enables a graphic presentation of the desired form of development for the area. It is not detailed planning and does not specify the form of development at individual plot level but provides information on desired development patterns in relation to major environmental and infrastructure features. The preparation of a concept plan is not possible in all situations. It is a very practical and useful tool, however, to communicate preferred types of development and their locations. It can also be integrated into GIS format, so it is possible for a decision maker or government employee to select a particular location (for example, a flood plain or catchment area) for information on the environmental considerations for the desired development.

A concept plan needs to highlight major infrastructure (existing and future), transport corridors, environmental features such as water courses, and areas that are suitable for particular land uses such as residential, commercial, open space, community and education. The Figure below represents an Australian Local Government example whereby a concept plan that incorporates flood data has been prepared for a township area.

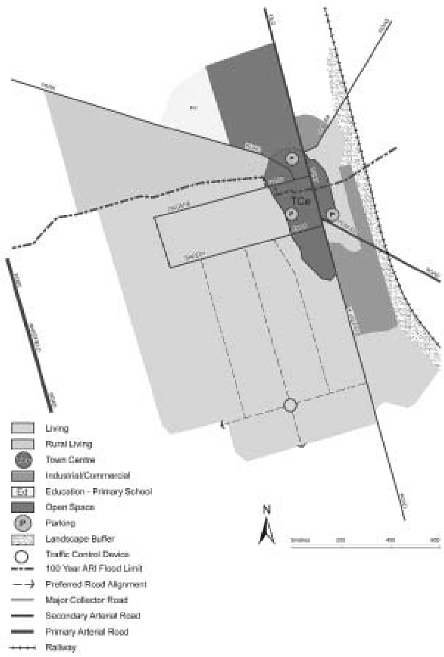

Figure 4.4: Concept plan map, Source: Department of Planning and Local Government, South Australia

4.4.2. Integrating land use planning and flood risk management

4.4.2.1. Embedding policy: Cross-Institutional working

Flood risk management needs to be embedded at a policy level. This requires relevant and responsible agencies/departments/institutions to establish policy positions that provide guidance to other arms of government and the community. Like land use planning and the concept of a hierarchy of plans, policy adopts a similar principle. At the strategic level, policy is articulated in broad statements and sets out a vision or strategic direction of a particular issue. In the instance of flood risk management, this may include policy on the long term management of the flood plain and achieving appropriate flood risk management. As policy documents move from the strategic to operational, and like spatial plans, greater detail is provided and may include specific policy objectives to achieve environmental management or appropriate standards for buildings to improve a community's resilience to flood risk.

The integration of policy at a cross-institutional level of government requires governance frameworks that encourage coordination and communication. As outlined previously, this is often difficult and in many cases is not achieved. To achieve this cross working and integration of policy often requires legislative provisions. That is, a land use planning Act/regulation should include reference to water resource legislation and that consideration of a particular plan/objective of this legislation must occur for development to proceed.

Again, it is often the reality that legislative reform is required in order to achieve this level of integration. Even when the appropriate legislative and policy frameworks exist, urban planning often highlights the inherent conflict between various and competing objectives. Flood risk management in particular has the capacity to highlight this through seeking to remedy/manage development in high risk areas from flood events that may be considered highly valuable for residential or commercial development. Despite these challenges, embedding policy and cross-institutional working is essential for effective spatial and land use planning to take place. Where such arrangements are absent, silo working practices will persist and the relevance of urban planning diminished.

4.4.2.2. Understanding flood risk and determining flood zones

Understanding how an area may be affected by a flood event enables policy and decision makers to design appropriate development frameworks and undertake development that takes into account the potential impacts of flooding. Understanding flood event(s) is often framed within the context of risk or the probability of a particular type of event occurring. This risk or likelihood of an event is then expressed spatially to detail the anticipated extent of floodwaters. Chapters 1 and 2 provide greater detail on understanding flood hazard mapping and flood risk.

The preparation of flood zones is the most common method to categorize particular thresholds of probability and the associated spatial implication or extent. For example, common storm probability thresholds are:

a. Less than 0.1 percent (low probability of flooding)

The chance of flooding in this area is less than 0.1 percent (1 in 1000) per year

b. Between 0.1 percent and 1 percent (medium probability of flooding)

The chance of flooding in this area is greater than 0.1 percent (1 in 1000) but less than 1 percent (1 in 100) per year

c. Between 1 percent and 5 percent (high probability of flooding)

The chance of flooding in this area is and greater than 1 percent (1 in 100) but less than 5 percent (1 in 20) per year

d. Greater than 5 percent annual exceedance probability (AEP) (functional floodplain, or floodway)

The chance of flooding in this area is greater than 5 percent (1 in 20) per year.

These thresholds provide a framework for planners and decision makers to determine appropriate development policy using a risk based planning approach. Understanding these thresholds and how they relate to a geographical area represents the 'appraising' risk step. It is important to note that these thresholds are influenced by a range of factors both natural and human-induced. Areas that have a greater probability of being affected by flooding, as described above, are often situated within a natural catchment area near a watercourse. Human-induced factors may include the level of development in a particular level and the hard surfaces present which impact the flow of urban runoff and in turn an areas ability to cope with a particular type of flood event. Land use planners need to understand that all areas will fall within one or other of these flood zones and that there is relationship between each of the zones. These relationships will continue to change over time as natural processes evolve and human settlement and development increase.

Flood zones provide a spatial framework in which development can occur and are developed on the basis of flood hazard mapping and risk. Flood zoning allows greater flexibility in planning by restricting the development of highly vulnerable uses (such as residential houses) in high risk areas but permitting less vulnerable uses in lower risk areas.

4.4.2.3. Determining appropriate land uses

Reducing the exposure of vulnerable people and property is one of the components required to reduce flood risk. The concept of appropriate is determined by identifying the vulnerability of different land uses to flooding. The appropriateness of any given use is determined based on the vulnerability to flooding of the building type or its occupational use. For example, a hospital is typically considered a highly vulnerable use and, therefore, it is more appropriate to locate hospitals in areas at lower probability of flooding.

Although the predominant approach to vulnerability is considered from a human and economic perspective, in determining appropriate land use(s) consideration must be given also to potential environmental impacts. For example, as the UK example below details, hazardous waste facilities are highly vulnerable as are any land uses that have the potential to have a damaging impact on the environment should the required environmental protection measures be compromised by flooding.

A list of land uses should incorporate current and projected land uses. These can be grouped into categories.

Table 4. 2 is an example of the UK categorization and the uses according to vulnerability.

Table 4.2: Flood risk vulnerability classification, Source: CLG 2006

Essential Infrastructure	Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk, and strategic utility infrastructure, including electricity generating power stations and grid and primary substations.
Highly Vulnerable	Police stations, ambulance stations, fire stations and command centers and telecommunications installations required to be operational during flooding. Emergency dispersal points. Basement dwellings. Caravans, mobile homes and park homes intended for permanent residential use. Installations requiring hazardous substances consent.

More Vulnerable	Hospitals. Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels. Non–residential uses for health services, nurseries and educational establishments. Landfill and sites used for waste management facilities for hazardous waste. Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.
Less Vulnerable	Buildings used for: shops; financial, professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non–residential institutions not included in 'more vulnerable'; and assembly and leisure. Land and buildings used for agriculture and forestry. Waste treatment (except landfill and hazardous waste facilities). Minerals working and processing (except for sand and gravel working). Water treatment plants. Sewage treatment plants (if adequate pollution control measures are in place).
Water-compatible Development	Flood control infrastructure. Water transmission infrastructure and pumping stations. Sewage transmission infrastructure and pumping stations. Sand and gravel workings. Docks, marinas and wharves. Navigation facilities. Defense installations. Ship building, repairing and dismantling, dockside fish processing and refrigeration, and compatible activities requiring a waterside location. Water-based recreation (excluding sleeping accommodation). Lifeguard and coastguard stations. Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

4.4.2.4. Creation of regulations and enforcement procedures

Land use plans incorporating flood risk management through the creation of flood zones, and development frameworks that specify appropriate land use(s) and patterns of development on this basis and that of vulnerability to flooding, provide guidance and clarity to individuals, organizations and businesses about what type of development can and will occur and where. However, this guidance is of little benefit in the absence of appropriate regulation(s) to legally control or restrict development. Such regulations will need to interface with existing land use control, planning and building control legislation and will be naturally limited by the strength of current land use planning procedures. For example, flood legislation in Germany (Case Study 4.4) was built upon an already stringent planning control system with good compliance, and is expected to have a long term impact on flood risk.

Typically regulations may cover:

- The appropriate uses for new development permitted in a designated zone
- The requirement for flood risk assessment for all new developments on site and downstream of it
- Minimum design standards (such as materials, access points, minimum floor level) for permitted development within a designated zone
- Compulsory drainage and surface water management plans
- Presumption against reconstruction of damaged dwellings within designated zones
- Compulsory retrofitting of flood protection measures.

Case Study 4.4: The German Flood Act 2005

National policies can contribute towards flood management and legislation forms a vital part of this approach. The flood control sections of the 2005 German Water Act exemplify good practice in this area, and have many features in common with other water and flood protection acts. The act embodies three core principles, which place stringent flood control obligations on government and individuals to manage flood risk in advance of flooding, as well as on the way flood zoning is managed and how warnings are issued:

- Surface waters have to be managed in such a way that (as far as possible) floods are held back, non-harmful water run-off is ensured and flood damage is prevented. Areas that may be inundated by a flood, or where an inundation may help to alleviate flood damage, have to be protected;

- Within the bounds of possibility and reasonability, any person potentially affected by a flood is obliged to undertake adequate measures to prevent flood-related risks and to reduce flood damage, particularly to adjust land use to a possible risk created for humans, the environment or material assets through floods;
- A land law shall stipulate how the competent state authorities and the population in the areas affected are informed about flood risks, adequate preventive measures and rules of behavior, and on how they are to be warned of an expected flood in a timely manner.

In practice this means that:

- Extensive improvements to flood zoning and mapping are occurring in accordance with this Act, as well as the European Water Directive. Importantly, public consultation is built into the process;
- New building in the floodplain is forbidden in most cases. Where it is permitted, the design of new construction is strictly controlled (for example, the placement of oil heating systems and computer control centers);
- Flood protection plans have to be drawn up for the 100 year flood and there must be consultation with both upstream and downstream riparian owners; and,
- Flood zone maps are to be integrated into all spatial maps and plans (such as land use plans and development plans).

Commentators have noted that for German flood risk management this Act is a promising shift away from the 'protection' mentality towards 'adaptive risk management.' However, the success of this shift in practice has yet to be realized.

Sources: Government of Germany 2005; Garrelts and Lange 2011.

In cities and towns where the compliance with land use planning regulations is lower, notably in burgeoning informal settlements, the regulations may need to be supported with community engagement, incentive schemes and strong enforcement regimes. Occasionally it may be possible or necessary to demolish high risk settlements and re-house the inhabitants via resettlement programs. The usual guidance and consultation procedures should apply and such programs should seek to target more than one development goal. The case study on Chengdu below illustrates how this has been achieved in China.

Case Study 4.5: Chengdu Urban Revitalization, China

As part of a revitalization scheme of informal settlement districts initiated in 1997 by the Chengdu Municipality and finished after five years, residents were moved away from the river bank into new accommodation. About 30,000 households were moved, which created space for a green buffer zone along the riverside.

The plan had several best practice features, including a clear target to reduce flood risk. In the past, houses in the informal settlements projected over the river and were often swept away by floods in the rainy season; this necessitated constant vigilance so that evacuation could be effected. After the rains stopped, families had to deal with the chaos brought about by the flood, resulting in great hardship, suffering and economic loss.

As part of the scheme, the two rivers, Fu and Nan, were de-silted and widened thus reducing flood risk to a 200-year return period expectation. Crucially, engagement of the local community ensured that the public participated in the scheme and resettlement was completed without litigation. Per capita living space rose by a factor of 1.4 and the relocation of the informal settlement dwellers significantly reduced congestion in the city. There was also the benefit of some 30 to 35 percent of owners also gaining property rights, which they had not held before. Green zones were created which improved the environment greatly and allowed for the construction of an award winning natural park area with water purification facilities which is now on the national tourist register.

The Chengdu case shows how land use planning which integrates flood risk considerations can be effective in both reducing flood risk and improving conditions for people living in informal settlements. It is important to highlight the fact that the participatory approach adopted in the resettlement scheme was a key contributing factor to its success.

Sources: UN 2001; UN-HABITAT 2002

Increasingly, there is also interest and much innovative thinking about how flood risk management concerns can be integrated within planning for new urban development in the 21st Century in ways that meet flood management objectives while simultaneously maximizing the utility and amenity of sites both large and small. The case study which follows illustrates a prominent UK example of such work.

Case Study 4.6: Long-term initiatives for flood risk environments: The LifE Project – Making Space for Water

In designing and building new urban developments, space for water needs to be integrated with sustainable design so that the means of managing flood risk become an asset for residents and to the wider urban community. Multi-functional land use that makes space for water, energy and play within built developments will become fundamental to adapt to the challenges of rapid urbanization and climate change. The LifE project, which received funding from the UK's Defra Innovation Fund as part of its Making Space for Water program, sought to identify how new development in flood risk areas could help to reduce flood risk overall and deliver zero carbon communities. The LifE project adopted a non-defensive approach to flood risk management, which marked a shift from traditional thinking by permitting water into sites in a controlled manner to make space for water.

Sustainability and climate change are amongst the main drivers for change in the way development in the UK is planned in the 21st century. These are manifested in the need to make developments zero carbon, conserve water, reduce unsustainable transport use, reduce overheating and manage flood risk.

There are potential benefits from measures introduced to respond to these issues but understanding which to prioritize is fundamental to good planning. Of these issues, flooding is the main risk to life and therefore should be the priority. However, simultaneous assessment of the other requirements helps to develop integrated proposals.

The LifE approach was based on integrated design and planning approach, through which:

- Buildings and uses are organized according to risk
- Land which is allowed to flood has multiple functions and is also used for less vulnerable activities, such as recreation, parking and renewable energy generation
- Neighborhoods are organized around public transport infrastructure and short walking distances.

Three principles apply:

- Living with Water: Adapting to increased flood frequency and severity, likely to happen with climate change
- Making Space for Water: Working with natural processes to provide room for the river and sea to expand in times of flood and reduce reliance on defenses, where possible.
- Zero Carbon: Providing all energy needs from renewable resources on site, such as wind, tidal and solar power.

Three sites in the UK that all suffered from various forms of flood risk were considered with the LiFE approach. Each site was located within a different part of the river catchment:

- Hackbridge within the upper catchment of the River Wandle
- Peterborough within the middle catchment of the River Nene
- Littlehampton within the lower catchment of the River Arun.

Figure 4.5: Hackbridge (Site 1), Source: BACA Architects

In Hackbridge (Site 1) an area of land at the heart of the development was ascribed multiple functions. The 'village/blue green' would provide a flexible informal recreation area that would provide current and future flood storage potential and space for an array of boreholes for ground source heat pumps. This area creates a focus for the development, increases the sales value of properties and improves access to the river for the wider neighborhood.

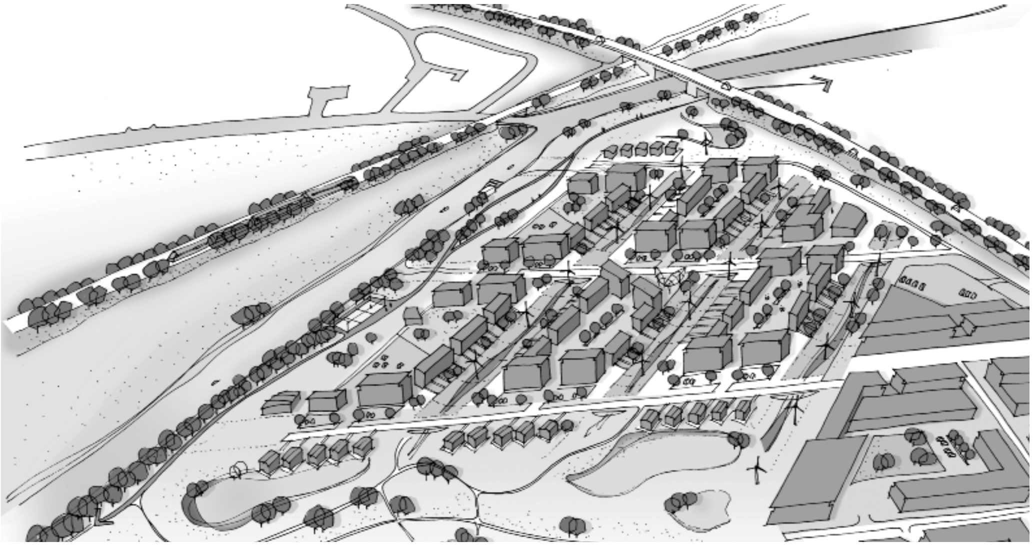

Figure 4.6: Peterborough (Site 2), Source: BACA Architects

In Peterborough (Site 2) 'rain and stream corridors' were introduced between buildings to create areas for rainwater attenuation and to create drainage and flood paths away from homes. The corridor widths were designed to allow generous daylight into taller buildings and provide separation from small wind turbines located at the centre. Striating (or 'striping') the master plan with soft landscaping to manage flood risk would provide a high quality environment and reduce air temperature in and around buildings, mitigating the urban heat island effect.

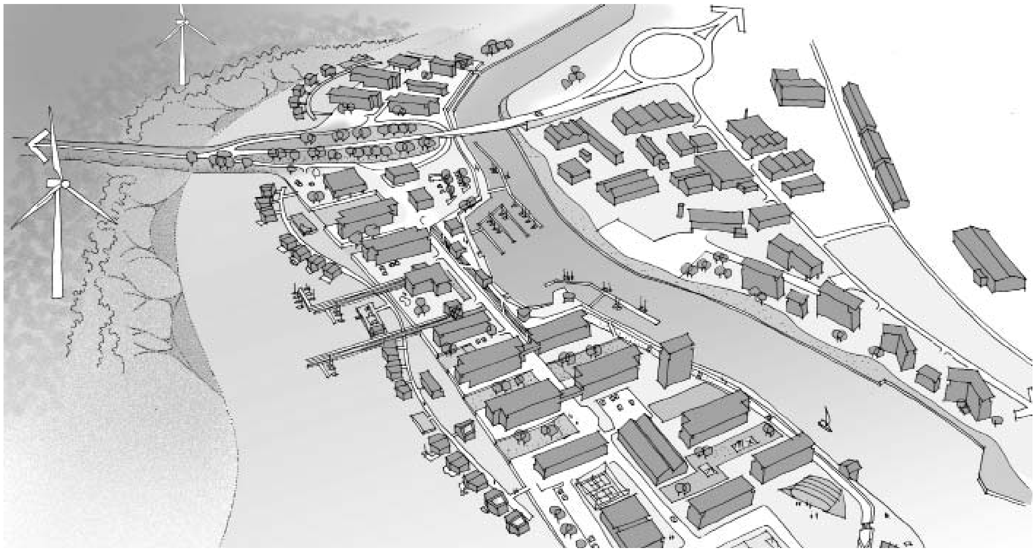

Figure 4.7: Littlehampton (Site 3), Source: BACA Architects

In Littlehampton (Site 3) a large area of land to the rear of the development site was designed for controlled flooding, to reduce water levels in the river and reduce the strain on existing defenses. This inland lagoon would provide water recreation adjacent to the development and habitat for wildlife in intertidal regions (mudflats and salt marsh) beyond. Twelve tidal turbines would generate energy for five hours during each successive ebb tide. The lagoons would be an attractive backdrop to the development and unique regional attraction.

The project had a number of policy lessons:

Flood risk management

Using modeling data it was possible to map the areas where flooding from the river would occur on each site in an extreme flood (1 in 100 or 1 in 200 year event) and also the extent that may occur with climate change. Overlaying this with topographical data allowed the depth, velocity and hazard to be assessed for differing flood events.

Having assessed those areas most likely to be flooded or most susceptible to change it was possible to plan to avoid building on the existing floodplain, to ring fence land that should be maintained as future floodplain and to identify surrounding land that could be set aside for reducing flood levels in the future. Land was planned to locate the most critical uses (hospitals, emergency services, power) in the least susceptible areas and the less vulnerable uses in more susceptible areas. At a higher resolution, development was organized so that landscapes would be affected by flooding first, followed by secondary paths and roads, then by parking, then less vulnerable buildings, then primary roads, then more vulnerable buildings – all before emergency escape routes and people would be affected. This enabled non-defensive flood risk management to be incorporated at a capital cost of between one and nine percent of the total development cost.

Renewable Energy

All three development sites included a combination of renewable energy solutions, notably biomass Combined Heat and Power (CHP) and solar photovoltaic panels (PVs), that would best suit the individual conditions.

Development and Amenity

Quality of life factors were integrated that help to make development sustainable, successful, thriving and improve the health of occupants. Minimum standards for outdoor playing space equates to approximately 36m2 per person. Higher density developments can have a requirement of 50 percent of the developable area to be for open space. This means, particularly in areas with high land values, that open space is often underprovided.

In each of the sites, use of the floodplain was the only feasible solution to meeting the open play standards. By considering the spatial needs for water, energy and open play from the beginning, these functions could be integrated into the design and layout of the site, to create more attractive and successful development plans. It also allowed more efficient planning, helping to reduce capital cost.

Source: Baca Architects with BRE and consultants.

4.4.3. How to produce urban land use plans that incorporate flood risk management

Integrated land use planning should be considered as an iterative process, and one that requires regular review and update. Land use planning that incorporates flood risk management principles requires planners and decision makers to think at macro and micro scales and across short, medium and long term time frames. The changing complexity of human and urban settlements means that if regular consideration, review and enforcement are not undertaken, land use plans lose their relevance and usefulness. It is essential therefore that land use plans can respond to the dynamics of human and urban settlements and are seen as an integral and constructive component of an area's development and future.

The following method will assist planners in the preparation of land use plans that incorporate flood risk management.

Method

There are eight broad stages to prepare a land use plan. It is possible that several of these steps are combined or carried out contemporaneously. The steps are as follows:

1. Determine the Study Area

2. Site Analysis

3. Flood Hazard Mapping

4. Land Use constraints/inventory plan

5. Development Framework

6. Development Parameters

7. Consultation

8. Regulation/Implementation/Enforcement.

1. Determine the Study Area

Land use planning can be undertaken at many scales from strategic national level planning through to detailed planning at individual plot scale. This method is applicable across all levels/scales of planning but largely deals with urban and town scale planning.

Determining the study area is a crucial first step in land use planning. The spatial extent of the plan enables the following steps in the method to be framed and the context understood. It is important to note, however, that while a spatial extent may be set this does not limit wider considerations such water catchment areas, water courses and inter-relationships with adjoining and adjacent administrative or political boundaries.

Spatial extent is usually determined by administrative boundaries. As land use planning often transcends these administrative boundaries it is necessary to understand how particular urban areas interface with other land uses, natural features and administrative/regulatory frameworks. A wider spatial plan may also be prepared that highlights strategic links or important considerations in relation to other administrative boundaries and the study area.

To determine the study area, first identify relevant administrative boundaries. These boundaries can be a national, municipal/district, city and local level. Integrated land use planning occurs at all levels.

The output of this step is an outer boundary that delineates the extent of an affected/relevant area.

Figure 4.8 below is one example of a study area. In this instance, the information shown includes the relevant administrative boundary but also the topographical features of the area. Inclusion of base data such as this is a useful and good contextual layer to include. Further, the map also includes a reference grid, whereby the viewer can ascertain very quickly where the study area is situated in relation to other areas.

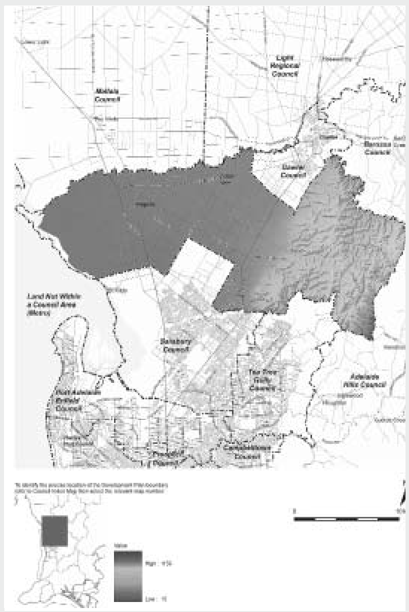

Figure 4.8: Example of a study area. In this instance, the information shown includes the relevant administrative boundary but also the topographical features of the area.

Source: Department of Planning and Local Government, South Australia

2. Site Analysis

Once the study area has been determined, it is necessary to undertake a strategic assessment/analysis of the area. Its purpose is to record and evaluate information within the relevant area (in its relationship to surroundings), and to use this information to inform an appropriate policy response. This process is to develop an understanding of what land uses exist within the area, identify natural features, identify major infrastructure, obtain where possible topographical data, identify the location and footprint of built form including both legal and illegal structures. The latter is especially important, as regardless of the legal status of development the impacts from and to such developments in a flooding event need to be considered.

The level of detail that may be captured at various scales of planning will differ. For example, at the municipal or city level planning scale major infrastructure such as roads and water facilities will be identified along with the location of natural features. However, unlike the more detailed neighborhood scale of planning, this may not show building envelopes but rather will include areas that are known to be built upon and, where available, cadastral boundaries.

3. Flood Hazard Mapping

Flood hazard mapping allows planners and policy makers to understand flood risk and make informed policy decisions. As seen previously, flood risk is determined by both historic data and modelling to determine the probability of a particular type of event over time.

For land use planning, it is necessary to determine what level of probability will be planned for. This assessment may change depending on the location and the types of land uses that are present or intended. This ‘risk' assessment is largely informed by human considerations and a desire to protect residents from harm and disruption. This concept is embedded in risk-based planning whereby the initial risk assessment will inform the following planning process. This assessment establishes the acceptable level of risk which then determines planning policy, standards and development priorities.

To enable policy makers in the assessment and decision making process it is necessary to obtain the most up to date flood hazard data. Chapter 1 outlines the process for preparing flood hazard maps. For land use planning, understanding the data is essential as the incorporation of flood risk management principles to land use planning is largely based on this data. Flood hazard zones are categorised based on the probability of a particular flood event. These categories are as follows:

- Less than 0.1% (low probability of flooding)
- Between 0.1% and 1% (medium probability of flooding)
- Between 1% and 5% (high probability of flooding)
- Greater than 5% (functional floodplain, or floodway)

Understanding the implications of each category is a critical tool in the planner's/policy maker's toolkit. These categories enable planners/policy makers to identify and understand the severity, spatial distribution and frequency of a hazard. Understanding the flood risk represents the first guiding principle of land use planning and flood risk management as it is ‘appraising risk'

The practical translation of this step is further developed in the following sections. However, it is important to note how this risk assessment is embedded into planning policy and the significance of this initial assessment to the wider planning process. The assessment at this stage determines what level of risk will be planned for and is considered acceptable and, in turn, what areas need to be protected, adapted or development restricted.

4. Land Use constraints/inventory plan

A constraints plan provides an important layer in the land use planning process. It details both the natural and human made constraints that will affect where development can and cannot go. It takes the information obtained in the proceeding steps and develops a spatial picture on how particular areas are affected or constrained. This can include highlighting areas within a floodplain; it can also include other natural features such as steep terrain, cliffs, coastal areas, open space reserves and nature parks. A constraints plan should also include other environmental assets or human development that may represent constraints such as hazardous industry and contaminated land.

A constraints plan provides the basis for which appropriate planning policy or a land use plan can be developed and informs the 'managing risk' step of integrating land use planning with flood risk management.

Figure 4.9 below provides an example of where by a base map that shows cadastral data that is overlain with data that shows the extent of a floodplain. This example, taken from and Australian Local Government Development Plan clearly shows how flood risk management is integrated into land use planning policy.

Figure 4.9: Base map that shows cadastral data that is overlain with data that shows the extent of a floodplain. Source: Department of Planning and Local Government, South Australia

5. Development Framework

A development framework incorporates the data compiled in the preceding steps and commences identifying particular areas that may be suitable for particular types of land uses. These identified areas can be referred to as zones. Zones do not have to include only one type of land use they can accommodate a range of uses. Contemporary planning practice encourages mixed use, responsive and adaptable urban spaces. For the purposes of integrated land use planning, this step in the process is particularly useful to identify areas that present mixed use or multi-functional opportunities, such as environmental features that may provide a dual function of flood hazard management and development of recreation areas or open space – and as seen in the LifE project above.

A development framework will also incorporate the preparation of flood hazard zones, based on the initial risk assessment. These zones provide a spatial presentation of flood risk. This information needs to be presented in a clear, concise and understandable manner. As such, it is common to see flood risk referred to through a numeric system, for example, flood risk 1 through to 3. This numeric system is then complemented through the use of graduated colour. A flood hazard map may have three hazard zones with 1 representing the least risk through to 3 representing the greatest risk. This level of risk presented visually through colour graduation.

A development framework or policy framework is the instrument that integrates all the information compiled in the preceding steps with principles of land use planning and management. A development framework needs to outline the development objectives or vision for an area(s) at a strategic level or policy level, that is, it details what the desired objective or aim over a particular time period of an area, for example an area identified to allow for future population expansion and development in the form of a residential area. Broad principles of development control or mechanisms for managing the urban environment should also be outlined. A comprehensive land use plan will balance the development objectives of an area/community with those also of the environment and long term sustainability.

A development framework needs to be reviewed and updated regularly. A common critique of land use plans is that they are static and non-responsive. Contemporary land use planning takes some steps to addressing this through the integration of infrastructure planning, hazard risk planning and community participation.

There are often many reasons why the preparation and management of land use plans is delayed. However, the preparation of land use plans provides an important mechanism for policy and decision makers to understand a wide range of issues, including flood risk and develop an appropriate strategy to facilitate land use planning and urban development. The capacity to develop, implement and enforce such plans whilst essential to the overall success of land use planning, should not prevent or stop attempts to prepare land use plans that encourage forward planning and preparation – particularly as it relates to flood risk.

6. Development Parameters

Development parameters provide a more detailed framework for which development can occur. It provides the overall objective(s) for an area. For example, the objective for a mixed use zone or area may be to provide residential, community and some retail facilities. This objective is then supported by guidance on minimum requirements or principles of development control. In the instance of flood risk management, these measures include minimum floor levels, specifying locations where particular forms of development are appropriate, and in some instances building materials.

Development parameters should also relate to natural or environmental features. The objective(s) for such features should include preservation and management and be supported by appropriate principles of development control. In the instance of an identified flood plain the objective should include allowing the natural flow and processes of the flood plain to function, and development control measures such that permanent structures and other development that will impede the flow of flood waters should not be developed. Appropriate land uses for such areas need to be specified, and may include open and recreational space and low impact farming.

In developing parameters for development it is preferable that consideration be given to how the land use over time may change. Land use planning will highlight areas where land may be attractive for particular types of development such as residential, but may be inappropriate for such development due to flood risk. The land use planning process provides a mechanism to redirect development to more desirable or appropriate locations by developing appropriate policy and development guidance.

Development parameters also need to include on site management techniques and reference to the inter-relationships of development off site. That is, if a large residential development is proposed what measures ought to be in place to manage the impacts of that development? For example, where should storm water run-off be directed? Is there a mains system whereby developments can discharge directly to or can the run-off be accommodated on site through the use for sustainable urban drainage system (SUDS) and the use of swales, landscaping, and water recycling?

A series of questions helps shape the preparation of development parameters. These questions provide the next layer of detail to the spatial data, constraints and risk mapping exercise and development framework. This thought process which enable the preparation of appropriate policy that incorporates all the layers of information and presents, through policy, clear requirements for development in particular locations and are often referred to as ‘principles of development control’.

Questions that assist this process for both steps 5 and 6 include:

1. What is the development objective?

2. What environmental assets are present?

3. What development constraints exist?

4. What and where is major infrastructure located/exist?

5. What type of development is appropriate in this area?

6. What opportunities exist to encourage multi-function or mixed use areas?

7. What types of changes are likely to occur over time e.g. pressure for urban land, informal development areas and climate change impacts?

8. What types of management controls are necessary?

Once this through process has been undertaken, it is possible to devise appropriate policy or development parameters. Development parameters do not need to be complicated and are often viewed as a tool to restrict development. Although restricting development in some situations is appropriate, in managing flood risk development parameters combined with a sound development framework can act as an enabling and pro-development tool. By preparing a land use plan that integrates the full breadth of issues affecting urban areas from urbanization and population growth, infrastructure planning, hazard risk management including flood risk it is a mechanism that provides certainty and legitimacy to the development process. Where frameworks and land use plans are absent it is difficult for authorities and communities to participate effectively in the planning process and/or development sector. Participation does not necessarily mean acting as a large scale developer, but rather members of the community understanding what influences and shapes their environment and having the opportunity to engage with this process and its outcomes.

7. Consultation

Developing a land use plan that is accepted by the community requires policy makers to engage with residents to understand views within the community and also identify challenges to implementation.

The consultation stage should clearly outline the development process and display the range of options that have, or are being considered. The options as presented through the consultation phase(s) should not be fixed and this needs to communicated during consultation to demonstrate to participants that their views are can be incorporated into the land use planning process. Land use planning is by its nature an iterative process and community consultation provides one means of contributing to this process.

Community consultation also provides a mechanism whereby natural assets and environmental features and their relationship to urban settlements can be highlighted and explained. Although land use planning considers many development scenarios and pressures, it provides an opportunity to raise awareness about flood risk and how this risk has been considered in the land use planning process. While pressure for housing or commercial development may be at the forefront of the community's mind, the implications of development being situated in high risk areas should provide the platform for engagement and the basis for developing land use plans that respond to both the economic and community needs as well as hazard management.

8. Regulation/Implementation/Enforcement.

Land use planning and policy and spatial plans are of no benefit to the community if they are not adequately enforced, or if the planning system is not seen as an effective mechanism for managing urban development issues.

In implementing a land use plan appropriate approvals or permissions need to be in place for persons wishing to undertake development. The process of obtaining permission needs to include the initial application phase whereby the proposed development type is put forward. The proposal should then be assessed against the relevant land use plan and policy framework to ascertain if what is proposed is an appropriate form of development in an appropriate location. Proposed development that is considered appropriate requires further scrutiny in the form of assessing if it meets the minimum design standards such as, siting, floor levels and building materials. Once all of these factors have been considered and the development deemed in accordance with the land use plan, permission should be granted.

Once planning permission has been obtained the development process does not cease. The construction of the proposed development and the monitoring of this activity are essential if the land use plan as devised is to be adhered to. Building inspectors have an important role in ensuring that approved development is implemented in the manner in which it is proposed, such as the correct location and finished/constructed to the appropriate standard. Construction and an inspection represent the final stage in the land use planning process. Should the development be compliant and consistent with the original permission, a 'certificate of compliance' or similar can be issued. This final stage is very important in regularising the development process but also in embedding standards and consistency. It also provides a mechanism whereby land and legal development are afforded some protection, as ensuring the appropriate permissions are in place and checking this becomes a pre-requisite for future purchases and land/development transactions. Compliance and enforcement of development standards represents the 'managing risk; step in risk-based planning.

The above outlines a land use planning system that functions in an integrated and efficient manner. In many circumstances however, the planning system and the ability for governments to discharge their duties effectively is severely challenged, particularly in the cities of developing countries. These capacity constraints need to be acknowledged and bridging mechanisms devised. Central to an effective land use planning system is the enforcement of relevant legislation and regulations. However, if the legislative framework is outdated and not reflective of current circumstances or the wants, needs and aspirations of the community it is very difficult for land use planning to be effective.

The practical reality of many planning systems in the developing world is that there is little government department integration, limited budgets, outdated office equipment and resources, limited data availability, conflicting legislative frameworks particularly as they relate to land tenure and land rights and finally, extended periods and often complicated decision making processes. These factors coupled with the rapid rate of urbanization and pressure on urban centres to provide for its population create a system that is under enormous pressure and is often rendered obsolete/irrelevant.

This how to guide provides the basis for preparing an integrated land use plan that incorporates flood risk management. It outlines the necessary steps, data requirements and necessary considerations when preparing a land use plan underpinned by an assumption that the planning system is effective and efficient. As acknowledged though, this is not always the case. However, preparation of land use plans should not be avoided because of these factors. Rather appropriate modifications and adjustments employed to reflect the local situation and acknowledging that this will continue to change over time. To inform this process the key points of integrated land use planning and flood risk management can be summarised below:

- Risk based assessment(s) is essential to all levels of planning
- Integrated land use planning is an iterative process
- Development frameworks and parameters do not need to be complicated
- Enforcement of land use plans is essential.

4.5. Flood insurance, risk financing, compensation and tax relief

4.5.1. Introduction

Insurance, risk financing, compensation and tax relief have two main purposes in the management of flood risk. Firstly, and most obviously, the provision of these financial mechanisms can be used by those at risk to offset their financial risk from flooding. Although these financial tools obviously do not prevent flooding, they allow recovery without placing undue financial burdens on those impacted by flood disasters. The advantages of flood insurance are clear, as recovery can be expedited and funds are not diverted from other priorities such as development. For low frequency but high impact events, the provision of insurance in particular spreads the risk of financial loss, centralizes the holding of disaster reserves, and should therefore be a more efficient method of financing disaster recovery. Because of this, governments are increasingly beginning to examine insurance as a risk management option: reinsurers such as Munich Re have identified the provision of insurance within developing countries as a major opportunity for the twenty-first century (Spranger 2008).

The second major function of disaster insurance, compensation and tax relief schemes is to reduce risk and damage, via the need for risk assessment and encouragement of risk mitigation (Cummins and Mahul 2009; Kunreuther 2002). If risk is correctly priced (in an actuarial sense) then the incentive to mitigate risks exists via premium pricing; many insurance contracts also implicitly require the policyholder to undertake reasonable risk reduction and mitigation activities and this obligation can be made more explicit, or mandatory, for coverage to apply. Similarly, compensation can be targeted to resilient reconstruction, whilst tax schemes have the potential to influence many aspects of reconstruction, including the use or set aside of flood-prone land.

As disaster relief funds are increasingly overstretched, and tend to divert finance from other important development programs, the main focus of this section is the potential to move towards insurance.

4.5.2. Level of insurance coverage worldwide

The coverage of natural disasters in general, and flooding in particular, varies a great deal across nations. For buildings, there is an estimated coverage of 40 percent of high income country losses, falling to 10 percent in middle income countries and less than five percent in low income countries. The UK is one of the best covered countries with 95 percent coverage; by contrast, Taiwan's coverage is below one percent. Although, following this, there is a perception that, flood insurance coverage is universally high in developed countries and the converse in developing countries, this is in fact not the case. Swiss Re has estimated, for example, that in the Netherlands flood insurance coverage is typically very low, whereas in Indonesia it may be as high as 20 percent (Gaschen et al. 1998).

Purchase of insurance is highly dependent on a number of factors, including its availability and cost, the level of the provision of disaster relief, general risk awareness, and attitudes to collective and individual risk (Lamond and Proverbs 2009).

In the UK there is a privately provided insurance cover enabling individuals to mitigate their flood risk. Flood cover is 'bundled' into standard insurance policies (as opposed to being sold as a separate policy, the method applying in the US for example) and is currently available almost universally. This state of affairs is due to a 'gentlemen's agreement,' known as the 'Statement of Principles' between insurers and the UK government (and Devolved Administrations in Wales, Scotland and Northern Ireland). The current agreement runs until June 2013 and is based on a division of responsibility whereby the government primarily funds flood defenses and in return insurers agree to pick up the residual risk and provide insurance cover to most properties at flood risk.

As a result, the majority of people who insure their property against fire and theft are also insured against flooding with an estimated 95 percent of domestic buildings covered. The advantage of this system is that domestic flood risk is transferred to the private market. Commercial flood risk is also potentially insurable in the UK and public infrastructure can be insured or self-insured by local authorities and infrastructure companies.

This leaves the central government supporting local authorities in the cost of emergency management, a fraction of the total costs from flood events. However, commentators have noted that this leads to complacency and lack of preparedness among residents at risk of flood and can lead to lack of incentive for the government to invest fully in flood defense (Lamond et al. 2009).

4.5.3. Requirements for market-based insurability

To qualify for insurance, risks have to be insurable. From an insurance provider's perspective insurability equates to:

– Risk that is quantifiable
– Risk that is randomly distributed
– A high enough number of policy holders to diversify risk
– Sufficient chargeable premium to cover the expected claims, and transaction costs, whilst remaining affordable to policy holders.

For market-derived insurance, a profit margin is also necessary.

In the context of flood risk, particularly in developing countries, the quantifiable aspect of insurability is problematic. Flooding is less predictable in its onset and outcomes than for other natural hazards; the availability and reliab of historic data in developing countries is low. The cost of insurance may also pose a problem for prospective policy holders in lower income countries. Many households already exist below economic subsistence level and have no money to spare for the purpose. Randomness and number of available policyholders are linked. In a mature market with good information and well-priced risk, the spread of risk should be appropriate. Even in the developed world, however, the steps in development of a mature market may involve insurers accepting patterns of risk which are less diverse and therefore have unaffordable premiums.

4.5.4. The dangers of adverse selection and moral hazard

Highly relevant in the context of flood insurance, adverse selection and moral hazard are two behavioral phenomena which undermine the efficient operation of insurance markets where there may be information asymmetry (i.e., policy holders know more about the risk they face than the insurer does). This leads to the potential for adverse selection. Those people who are poorer risks than the average will tend to insure; the informational problems imply that the risk will not be priced correctly.

As an example, flood risk is often assessed on an area basis, such as the average damage per property in a postal or zip code. But within a particular code some properties may be on raised ground whilst others are not. If insurance is not mandatory, then it is the residents on low ground who will buy insurance and their average claim will be higher than the code average. This results in an under pricing of risk and, potentially, claims which cannot be met from reserved premiums. The adverse selection problem is minimized where insurance coverage is high, or where cover is mandatory.

Moral hazard exists if there is no reward for risk mitigation behavior built into insurance products. Policy holders will therefore rely on insurance to offset their risk and undertake no self-protection. Policy holders will therefore rely on insurance to offset their risk and undertake no self-protection. This has been observed to be the case in the UK, where there is no effective mechanism for premium adjustment in the domestic market in consequence of self-protection, partly due to competition but also to transaction costs. The action of moral hazard results in increased damage costs and higher premiums for all. The use of excess charges, regulation and policy exclusions could potentially encourage self-protection (Kunreuther 2002) but may be difficult to enforce in a market-based system. Alternatively, awareness raising and education regarding the intangible and indirect impacts of flooding which can be avoided may also have a role here.

To avoid both adverse selection and moral hazard, insurers can employ rigorous and accurate risk pricing and take into account any mitigating activities. In developing countries, this may be difficult to do with certainty if they are in the early phases of insurance market development. It is unlikely to be cost effective for individual market based insurers to develop the information base necessary to price risk. This approach has often led to flood risk being regarded as uninsurable. Governments, donors and international financial institutions may have to play a role in generating information. It is also apparent that aggregating risk is liable to make the pricing easier, as the necessary level of detailed information reduces. Schemes which enforce insurance on individuals, or that insure a group of individuals – even to the level of nation states – will be easier for insurers to price and therefore be more attractive to them. It then becomes the role of the nation, or community peer pressure, to encourage risk mitigation in order to reduce their collective insurance premiums.

4.5.5. Micro-insurance

At the other extreme to market-based insurance is the increase in micro-insurance as a solution offered to the urban poor. Swiss Re maintains that micro-insurance on a commercial basis is the appropriate instrument for individuals above the international poverty line and living on up to US$4 per day. Below the poverty line, micro-insurance schemes will need some government or donor intervention. About half of current micro-insurance is offered commercially, with markets in Latin America the strongest. However, the non-life element of these schemes is very small compared to life insurance.

Examples of micro-insurance schemes for property loss from natural hazards include the Indian Afat Vimo or the mandatory Gujarat group-based housing insurance scheme (Swiss Re 2010). Sharia-compliant micro-insurance is also available and clearly relevant in nations with substantial Muslim populations where it is known as Microtakaful. Rheinhard (n.d.) defines the key elements of micro-insurance schemes as follows:

- Products should be easy to understand
- Premiums should be low
- Frequent payment plans should be available

– The insured population should be aggregated

– Distribution channels should be cost effective.

Distribution channels are one of the most important aspects of designing innovative micro-insurance solutions: they include retail outlets, municipal offices, energy suppliers, existing micro-finance institutions, and NGOs. Instituting an insurance mentality is another challenge, as the requirement for pooling risks requires a high level of buy-in from the insured community and some element of social solidarity.

4.5.6. Risk financing mechanisms

Catastrophe bonds and catastrophe pools are examples of alternative risk financing mechanisms where market insurance is not available. The French and Spanish insurance systems, for example, are based on catastrophe pools: policies delivered by private companies are backed by a state guarantee that is triggered by a national disaster and prevents the insurance companies from insolvency. US flood insurance is also state-backed. As a result, the US Treasury had to find around US$18bn to cover the losses after Hurricane Katrina. Nations which can self-finance the risk from flooding may find this a highly cost effective route to providing cover. But usually the level of cover offered has to be limited and often does not include such attributes as alternative accommodation. Australia is considering a move to such a system after the 2010 Queensland flooding, as seen below.

Case Study 4.7: Australia reviews disaster insurance and considers national disaster fund

As previously discussed, in the three consecutive years beginning with 2009 serious flooding and cyclones affected large parts of the state of Queensland, located in the north-east of Australia. It is estimated that the total cost of the recent floods and cyclones during these three years is around US$ 10.46 billion. One month after the severe floods of 2011, only 10 percent of the total of US$ 2.1 billion worth of private claims had been paid. The significant volume of insurance claims and the costs that insurers and reinsurers are expected to pay have also raised concerns that insurance premiums will rise.

In January 2011 the Government of Australia ordered a review into disaster insurance and the need for a national disaster fund. The report intends to examine all aspects of the response and the aftermath of the 2010 and 2011 flood events. With a focus on the insurance sector, the review reports on:

- The performance of private insurers in meeting their claim responsibilities for floods and other natural disasters
- The possible impact of any national government intervention in disaster insurance, as for example, by subsidizing insurance premiums for individuals and small businesses in high-risk, high-premium areas
- The need for a national disaster fund.

The Queensland Floods Commission held a second round of hearings in September and October 2011 at which questions of insurance matters were heard. The final report with recommendations relating to flood preparedness is due to be delivered by early 2012.

Sources: Queensland Floods Commission of Inquiry 2011; Taylor, R. 2011.

Nations which would struggle to guarantee their probable maximum flood loss may extend the risk to the market via catastrophe pooling across countries, or by moving to market catastrophe bonds. The Mexico case study below (Case Study 4.6) shows how this can be achieved and even how this type of arrangement may be used to support flood mitigation as well as recovery. It is, however, an expensive financing mechanism.

Other potential routes include nations getting together to provide catastrophe pools, thereby spreading the risk and reducing the ratio of Probable Maximum Loss (PML) to the GDP of contributing countries as in the Caribbean risk financing pool. Care must be taken to ensure that the risks are complementary so that the combined PML is not the sum of the individual PMLs. A thorough understanding of the sources and interaction of risks is therefore necessary.

Case Study 4.8: Mexican catastrophe bonds

The Mexican government has an innovative approach to all natural catastrophes which it developed with the World Bank, whereby investors' funds are used at agreed trigger level events. Mexican catastrophe bonds started with earthquake bonds in 2006, followed in 2009 by an issue of US$290 million in a broader bond covering earthquake and hurricane risks. The Goldman Sachs Group and Swiss Re managed the bond sale, which will pay investors unless an earthquake or hurricane triggers a transfer of the funds to the Mexican government. The World Bank program, called MultiCat, cuts the cost of issuing the bonds and allows the countries to lock in funding to meet emergency relief. The bonds are due to mature in 2012.

The bonds are used to protect the capital reserves in the Mexican 'FONDEN' and 'FOPREDEN' schemes, which are, respectively, a catastrophe pool covering all natural disasters and a disaster prevention scheme.

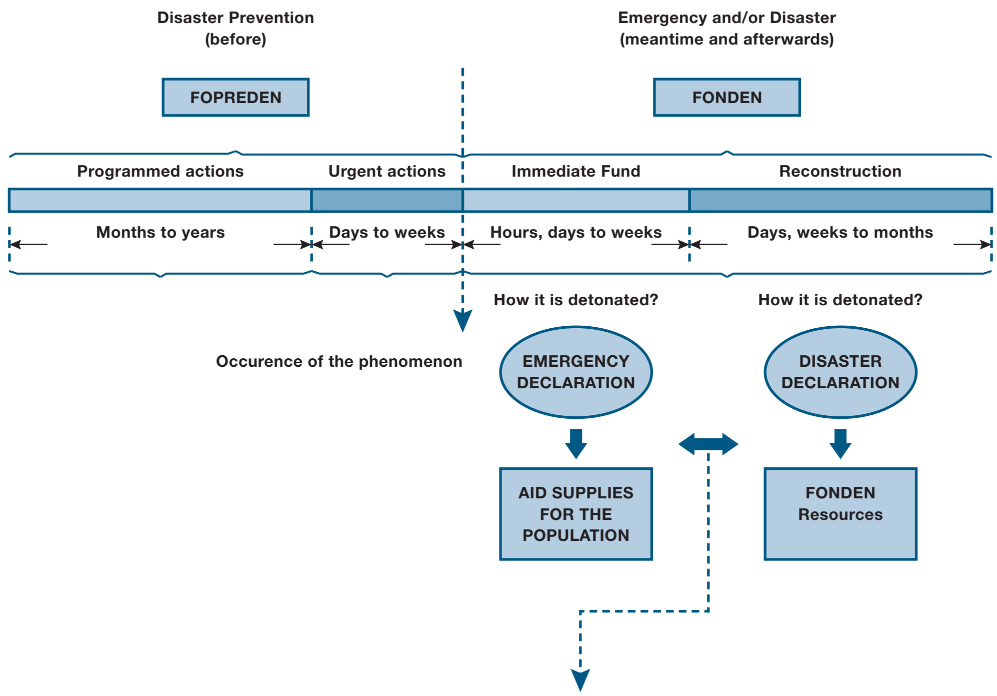

Figure 4.10: Disaster time line SOURCE: Adapted from SEGOB 2009

Preventative actions financed by the FOPREDEN include:

- Actions focused on the identification and evaluation of hazards, vulnerabilities and risks
- Actions focused on risk reduction and the mitigation of the damages caused by the impact of natural phenomena
- Actions to strengthen the preventive capacities of the population and self-protection before risk situations develop.

Buyers of this kind of catastrophe bond, which are most often sold by insurers seeking to reduce their own exposure to catastrophe costs, may be willing to settle for riskier returns after finding dwindling profits elsewhere in the fixed-income bond market. However, at the moment this is a small market, as there are prerequisites in terms of adequate risk assessment information and for the creditworthiness of issuing governments. The involvement of the World Bank helps reduce the cost of issuing the bonds and makes it easier for developing countries to sell them.

This case study illustrates a possible risk transfer mechanism whereby funds set aside for disaster prevention and management can be protected. It has two advantages in that the bond can operate before a catastrophe pool has accumulated sufficient funds to cover probable maximum loss and it can allow expenditure from the pool on a needs basis for smaller events – and provide risk prevention without concern that a larger event will leave the population without resources. It is an expensive alternative though, and may be beyond the capacity of many developing nations.

Source: Swiss Re 2010(a); SEGOB 2009

4.5.7. Compensation and tax relief schemes

The main function of compensation and tax relief schemes is to encourage self-protection activities by individuals. For example, a compensation scheme might incentivize evacuation of the floodplain or other flood-affected areas by buying property at market price, thus allowing individuals to move without financial loss. Such a scheme exists in France, in the form of the "Major Natural Risk Prevention Fund" (a.k.a. the "Barnier Fund" from the name of the Minister who attached his name to the law creating this fund, passed in 1995). The fund is financed through a mandatory contribution on natural disaster insurance premiums paid by property owners. It is used to finance the compulsory purchase of properties ("expropriation") when it is necessary to do so to stave off substantial threat to human lives, by paying the difference between insurance compensation received for property damage from the pre-flood value, thereby compensating the property owner for the full value. In rare instances, the Barnier Fund can also be used to provide incentives to displace homes or finance transactional (rather than compulsory) sales of properties. Owners can therefore buy an equivalent property elsewhere. (Darling et al 2006).

These mechanisms can also be used to relieve the financial pressure on flooded households. Although there is no official fund for private households to gain financial support, after severe flooding in the UK in 2007, many residents were granted tax relief from local council tax. In the US, residents without flood insurance who live outside designated floodplains can claim some of their post-flood property losses back against taxes. Another example, from Brazil, is described in Box 4.4.

Box 4.4

"In Estrela … a study was prepared for the city together with the Urban Master Plan and implemented in the municipal regulation. After the legislation was implemented the risk areas were preserved and gradually the remaining population was removed to safe areas using tax incentives. The tax incentives were the exchange of building construction area permits downtown with flood risk areas. Flood damage losses and population affected have decreased over the years since 1979."

Source: Tucci 2004.

Tax relief for the purchase of flood mitigation products such as door guards and toilet bungs has also often been advocated as a cost-neutral incentive to encourage self-protection, as for example in the British Property Federation response to the Thames Estuary 2100 (TE2100) Plan Consultation Document.

4.5.8. Essential considerations to support the introduction of effective flood insurance

An effective flood insurance regime can provide the necessary financial resources to effect a fast recovery and reinstatement after a flood. Insurance can form part of individual and collective strategies to handle residual risk, high impact but low probability events, and events with impacts which are high with respect to national GDP. Effective insurance regimes can also encourage prevention and mitigation.

Identify those at risk	First identify areas at risk Identify assets and receptors at risk Identify individuals, companies, owners of public assets and infrastructure who could be responsible for reinstatement.
Quantify Risks	As it is described above, the assessment of expected damage is part of a wider FRM agenda. Insurance risks may be different to economic losses due to policy terms and exclusions from cover.
Map distribution of risk	If risk is diverse then it is more insurable. Risk concentrated in just one area will be more difficult to insure. Insurers will require this information to price policies.
Explore level of solidarity	This may have legal, constitutional, regulatory or cultural aspects.
Choose appropriate pooling categories	Risk can be pooled to reduce transaction costs, increase affordability, cross-subsidise premiums or to diversify risk. Consider diversification options such as international pooling or combination with other perils.
Identify/support primary insurer	Primary insurer can be market insurer, state or Public Private Partnership. Market-based insurance may need an initial incentive to develop the market.
Identify/support cost effective distribution channel	Options are to use existing insurance channels, but where insurance penetration is low other more creative schemes may be needed through channels collecting other revenues. Intervention to support set up of new channels may be needed.
Explore reinsurance and securitisation of risk	State-backed insurance schemes may need to be reinsured or backed up with secure finance. Nations may spread risk temporally using future tax revenues or rely on the markets.
Communicate risk	To encourage the take up of insurance, risk reduction should be part of a wider FRM agenda.
Communicate benefits of insurance	To increase take up and ensure continued insurability.

4.6. Solid and liquid waste management

4.6.1. Introduction

The inadequate collection and disposal of waste is often a significant contributor to flooding. An understanding of the role of waste management in the context of flooding is therefore important for the following reasons:

- Existing waste disposal practices may cause or exacerbate flooding, by impeding the flow in drains and watercourses, or by filling low-lying areas which may otherwise act as temporary storage lagoons during floods.
- Debris will be created by the flood and by the clearance of flood debris.
- The waste generated by the existing population will be augmented by that generated by the relief agencies and the flood.
- The existing equipment and waste management practices will form the basis of the post-flood emergency measures.
- There may be opportunities, as part of flood risk management planning, to improve waste management practices.

Poor waste collection is endemic in cities and towns in the developing world and has the following adverse impacts:

- It is an impediment to drainage, often blocking drains and causing flooding.
- It is a source of disease (for example, providing material on which flies can lay their eggs or food for rats, both of which are disease vectors).
- It is a source of infection, especially from clinical waste and sewage.
- It is a source of chemical toxicity, especially from discarded medicines along with commercial and industrial waste.
- It acts as a contaminant of surface and groundwater, which may be used for human activities including consumption.
- It is a contaminant of surface water which, through bioaccumulation by aquatic plants, animals and fish may then enter the human food chain.

The principal concern in being prepared for flood events in urban environments is the blockage of drainage, and also the infilling of storage areas and ponds which may provide temporary storage for flood waters. Uncollected solid waste blocks drains, and causes flooding and subsequent spread of waterborne diseases. This was the cause of a major flood in Surat in India in 1994, which resulted in an outbreak of a plague-like disease, affecting 1000 people and killing 56 (UN-HABITAT, 2010). This section covers this wider aspect of both solid and liquid waste management in the pre-emptive capacity of reducing flood risk. The impact of and disposal of debris (the significant quantity of solid material generated by flood events) is covered in Section 4.11.

4.6.2. Solid waste

Solid waste may be categorized broadly according to its source of generation as follows:

- Municipal waste or household waste is likely to be the greatest quantity of waste generated in urban areas. It consist of general wastes discarded by households and will include food items (both vegetable and meat), paper, plastics, household sweepings and broken domestic items. The annual floods in Kampala, Uganda, and other East African cities are blamed, at least in part, on plastic bags, known as 'buveera' in Uganda, which block sewers and drains (UN-HABITAT, 2010).
- Commercial waste is generated by any commercial activities including offices, shops small manufacturing businesses and is composed of any material relating to the commercial activities
- Industrial waste. This is waste generated by industry and may range from solids liquids and sludges, inert, reactive (substances which are not inert but may react with each other or with water) and hazardous waste depending the type of industry.
- Clinical waste. The majority of urban areas will have doctor's surgeries and clinics with dedicated hospital in the larger towns. They generate household types waste, commercial waste, pharmaceutical waste and organic waste (such as body parts). It may also be the site of the local mortuary. Some clinical waste is highly infectious.
- Animal waste. In many developing countries large herds are retained in urban areas to provide milk. These will often be in the poorer areas and the manure may or may not be removed as field fertilizer and or fuel.
- Other, such as dust and construction materials generated by the sweeping of streets, for example; this is often the responsibility of the municipal authorities together with waste collection.

The type and quantity of waste differs significantly between countries and within urban areas. Industrialized countries and urban areas will tend to generate greater quantities of waste compared to developing countries and rural areas.

The composition will also vary according to season when particular crops are harvested and also factors such as religious festivals when, for example, animal slaughtering may reach a peak.

There may also be significant geographical variations relating not only to the size of the urban population, but also the location within the urban area. There are also differences in the composition of waste between low and high income countries' gross national product (GNP). As might be expected, low income countries generate less waste per capita than higher income countries. In Asia the amount ranges from 0.5 kilogram per person per day in Nepal, whilst in Hong Kong this increases to more than 5 kilograms per person per day (World Bank 1999).

Due to the rapid urban expansion and unplanned development in urban areas the amount of solid waste is increasing day by day and the disposal capacity is diminishing thus providing fewer people with collection services. For instance in cities like La Paz in Bolivia, and Brasilia in Brazil the total collection of solid waste is up to 90%, while on the other hand in Santiago, Chile, the total collection is less than 57% (USAID, 2006). The situation is worse in other countries. In most of the cases treatment plants are non-existent or non-operational due to lack of maintenance. This results in large-scale dumping of waste in open landfills, water bodies and river courses.

Table 4.3: Waste composition related to scale of urban area

Sources of waste	Small Town	Medium Town	Larger town	Informal settlement
Household waste	Predominantly food processing and dust.	Wider range of wastes and greater quantity.	Wider range of wastes and greater quantity.	Predominantly food processing and dust
Commercial	Limited range of waste mixed with household wastes.	Wider range of wastes may be collected separately collected from commercial area housing.	Wider range of wastes and more likely to be separately collected from commercial area housing.	Very limited range probably only form small neighborhood shops.
Industry	Limited range.	Limited range often related to agriculture i.e. crop processing or equipment manufacture.	More specialist manufacture grouped into identifiable areas	Industry unlikely limited as the informal settlements act as commuter areas.

Clinical	Very limited as few clinics. More serious cases are sent to local towns if finances allow.	Very limited as few clinics. More serious cases are sent to local towns if finances allow.	A range of doctors' surgeries, local clinics and potentially a number of specialist hospitals depending on the size of the population.	Clinics unlikely as population have insufficient funds.
Animals	Household animals only.	Household animals and perhaps herds on the perimeter because travel distances are short so that proximity does not confer an advantage.	Potentially large herds in the poorer areas.	Animals unlikely as population have insufficient funds.
Dust from roads	Mostly dirt roads	Mostly dirt roads some paved roads.	Main roads, those in the city center and in expensive residential areas are hard surfaced.	Always dirt roads.
Liquid waste drainage and sewerage	Open drainage channels.	Open drainage channels	Open drainage with enclosed drainage	Open drainage channels

4.6.3. Management of solid waste

The management of solid waste in developing countries is generally the responsibility of the relevant municipal government and may not be considered a priority for the following reasons:

- Lack of public education in the health implications of poor waste management;
- Absence of pressure from civil society to improve waste management practices;
- A lack of expertise in waste management within municipal authorities: employment in managing waste is generally considered menial and of low status;
- Lack of training facilities for waste managers;
- Lack of finance to purchase plant and equipment;
- Poor wages encourage absenteeism;
- Diversion of resources to non-waste management activities;

– The generation of waste owing to population growth exceeds the financial resources available for managing it.

These factors will often result in inadequate collection and disposal of the waste, as well as the concentration of resources in high profile areas (for example, city centers) and the absence of any service in informal settlements.

Waste management comprises a series of steps from the household to a collection point (primary collection); from there it is taken to a larger collection point (secondary collection); from this location it is then taken to its final disposal point. The waste hierarchy can be applied to minimize waste both before and after flooding.

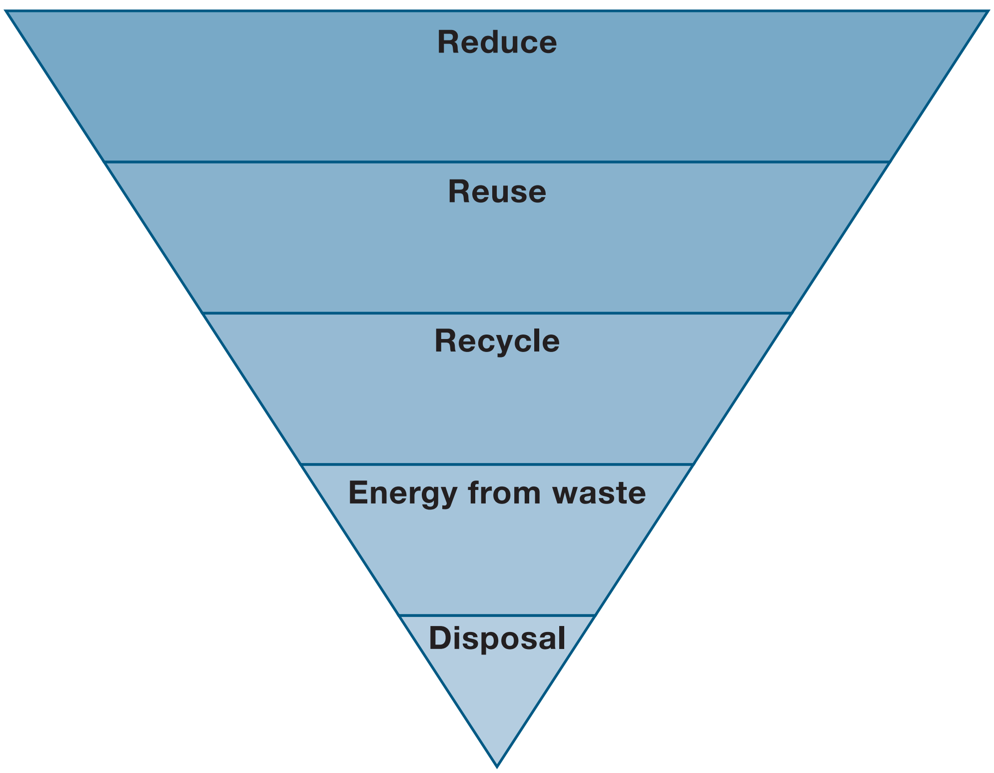

Figure 4.11: The waste hierarchy is applicable to waste management before and after flooding

Reduction of waste is often dependent on a culture of awareness of the importance of solid waste management and conservation of resources. Plastic bags and other plastic products such as drinking bottles are seen as prime culprits in the clogging of drainage and are seen as a relatively simple target in the drive to reduce the amount of waste produced. Simple alternatives such as reusable bags and drinks containers are available. After frequent floods in Mumbai, the state of Maharashtra in India banned the manufacture, sale and use of plastic bags in 2005; unfortunately, poor enforcement means that the ban has so far been less effective than hoped (UN-HABITAT, 2010).

Reuse of waste is seen as a method to remove items from the waste stream and also to generate income and employment from resale of usable items. Reuse strategies include the donation to charity of unwanted items, reuse within the home, and repairing rather than replacing defective household goods. Municipalities can encourage such practices through instituting schemes to collect and distribute unwanted furniture, clothing and other useful commodities, or by local tax incentives for reuse. Reuse can also be implemented once items have entered the waste stream via waste sorting as discussed below.

Recycling involves removing items from the waste stream by transforming items into other useful products. Composting, textile reprocessing and wood recycling are examples of activities that households commonly undertake spontaneously. Municipalities can institute sorting schemes which collect recyclable goods separately from the main waste or can undertake sorting post-collection.

Energy from waste can be a household based activity if paper, wood and other easily combustible products are removed from the waste and used for domestic heating purposes. On a city wide scale, post collection, energy can be generated from waste via incineration or the collection and use of landfill gases.

Finally disposal should be seen as the final alternative for unwanted and unusable items and will still represent a significant challenge for urban authorities to manage.

The improvement of municipal waste services can also benefit from market-based activities such as those listed in the box below (Cointreau 2003).

Box 4.5: Improving municipal waste services

- Tax credits and tax relief, allowances on property taxes, customs duties, or sales taxes to motivate investments in waste management improvements
- Charge reduction, based on proof of recycling or reuse in reducing wastes or requiring collection or disposal
- Tax rebates for pollution savings or energy efficiencies
- Environmental improvement funds, established to support pollution

reduction, resource protection and energy efficiency

- Research grants to stimulate technology development
- Host community compensation, incentives given by host communities to allow waste transfer or disposal facilities to be built there
- Development rights, long-term leases of land and development rights provided to private companies building waste treatment and disposal facilities, or to those remediating and reclaiming old disposal sites
- Tipping fees, changes to generators based on volumes of waste disposed
- Waste exchanges, facilitated exchanges or waste materials
- Trade Associations encouraging industries to join together to provide common inputs to waste management issues
- Product life cycle assessments predicting the overall environmental burden of products which can be used in certification programs
- Deposit-refund, deposit paid and refund given upon product return for reuse, e.g. beverage containers
- Take-back systems whereby manufacturers take back used products or packaging
- Tradable permits allow trading of emissions among various polluters
- Bans on materials or wastes causing disposal problems, e.g. mercury batteries
- Procurement preferences, with evaluation criteria adding points for products with recycled content or reduced resource demand
- Eco-labeling noting a product's recyclable content and whether a product is recyclable
- Recycled content requirements, laws and procurement specifications noting the precise recycled content required
- Product stewardship encouraging product designs that reduce pollution, including the full cost of solid waste recycling and disposal, the reduction of wastes and recycling
- Disclosure requirements: waste generators are required to disclose their pollution
- Manifest systems, precise cradle-to-grave tracking of hazardous wastes
- Environmental rating of industries: published lists enable consumers to consider whether to buy from polluting companies, e.g. Indonesia's PROPER program

- Liability insurance, liability assurances by contractors and private operators
- Bonds and sureties: guarantees for performance by contractors and private operators
- Liability legislation: laws defining environmental restoration settlements
- Insurance pools restructuring insured parties to enable pollution risks to be covered
- Liens placed on land where government remediation is required
- Procurement transparency and competition to encourage bidding on a level playing field
- Performance-based management contracting: oversight contractors commit to overall service improvements
- Clean city competitions rewarding neighborhoods and cities that have improved cleanliness.

4.6.3.1. Collection

Waste collection is the primary step of an integrated waste management system. Municipal authorities rarely, if ever, have capacity to collect all the municipal waste generated. Although targets are set and claims are made that up to 80 percent of waste is collected and recycled (World Bank, 1999) this is often based on inappropriate and invalidated assumptions: 50 percent may be a more accurate estimate. The volume of uncollected waste will increase with expanding populations and migration into urban areas

In many parts of Africa, Latin America and the Caribbean a significant proportion of the population do not have access to regular waste collection. However in many parts of Asia, waste collection has been given priority and regular collection is organized by the local municipalities. Initiatives have also been taken in both Latin America (USAID, 2006) and Africa (UN-HABITAT, 2008).

Considerations for city, climate and local culture should be taken into account in planning adequate collection. For example, in Delhi, India, the city wished to contract out waste collection to a single private company but encountered opposition from the many micro- collection enterprises already existing. Integration of the informal sector can also be very helpful (UN-Habitat 2010). The case study below of Bamako, Mali, shows how efficient community-based collection systems can help in the mitigation of the impacts of flash flooding.

Sometimes in smaller communities, primary and secondary collection may be combined. With increased urban populations and distance to the disposal point, secondary collections become essential and tertiary systems may also be required.

Case Study 4.9: Solid waste disposal in Bamako, Mali

Bamako is the capital of Mali and has a population of approximately two million. The city is located on an alluvial plain between the Niger River and the Mandingo Plateau. Some 45 percent of the population lives in informal, unplanned settlements in the peri-urban areas of the city. Some of the most important environmental problems that Bamako faces are inadequate or non-existent wastewater collection and treatment, inadequate solid waste management, unhygienic individual behavior, and poor urban management;

Due to the success of locally-based initiatives and the setting up of profit-seeking bodies called Groupement d'Intérêt Economique (GIEs) in the 1990s, coverage for primary collection of waste is stronger. GIEs started with sensitizing the community, making clear what their task was and the fee they expected from each household. GIEs have to be entitled by the communes of Bamako, which have institutional responsibility for waste collection, to operate within specific collection zones. Furthermore, they have to make individual contractual arrangements with households within the perimeter then put under their responsibility for collection and transportation of waste to transit sites. Other informal arrangements also exist. Much of the waste is used by farmers (up to 60% of that collected during the rainy season).

The District of Bamako is in charge of final disposal of waste through transportation from transit sites to landfills and further management of landfills. Currently, there is no land filling as such in Bamako. Rather, some dumping sites exist within the city but do not work as planned. This situation has resulting in unauthorized dumping sites and small piles of waste all over the city. The World Bank supported the preparation of a solid waste management strategy for the city of Bamako in the early 2000s. The strategy was approved but has not produced tangible outcomes because of the District having failed to put in place the appropriate staffing and adequate financial resources in support of its implementation.

In 1999 flash flooding throughout Bamako caused death and destruction. Analysis showed that the poor disposal of waste was a significant contributory factor in the scale of the impact of the severe weather event and a four year project to improve stormwater management and solid waste management was undertaken in one of the most flood-affected areas of the city.

The District of Bamako sought to establish partnerships with civil society for environmental management. An NGO known as ALPHALOG supported the creation of a partnership between the city administration and a set of NGOs, CBOs and informal sector groups, to conduct a study to determine why the District had been suffering from a lack of sanitation. This was the basis for initiating an Environmental Planning and Management (EPM) process. The project focused on the following five objectives:

- Watershed management, including retention strategies (such as slip trenches and diversion efforts) and waterway bank restoration
- Refuse removal, collection, and disposal, including removal of backlogged refuse in waterways, and the establishment of a refuse collection system and landfill operation
- Livelihood generation related to drainage and retention improvements, refuse collection and disposal, and the initiation of a composting operation
- Public health and sanitation improvement, through enhanced water management, training and awareness raising
- Decentralization support, to promote democratic governance, by engaging local government authorities and project area residents in a process of identifying needs and priorities.

Stakeholder participation, combined with a comprehensive planning framework, was used for the first time in the city. This helped to build consensus at the action planning workshop. The capacity of NGOs, CBOs and informal sector groups involved in the process has also been enhanced. The institutions are now capable of preparing terms of reference and undertaking their own studies, and they also developed capacity to conduct public information campaigns through their involvement in the process.

In addition to promoting decentralization, other project outcomes included:

- Restoring channel volume in key project area waterways through the removal of several hundred tons of accumulated refuse and debris, which improved drainage capacity and reduced flood risk;
- Improving water retention capacity in selected sites throughout the project area by constructing slip trenches (a.k.a., soak pits), thereby reducing both runoff volume and flood vulnerability;

– Establishing a refuse collection and disposal service through the creation of eight collection routes, each served by a collection team using tractor-trailers, with disposal at a nearby dumping site established by ACF.

Bamako has not experienced a similar flood disaster since 1999, partly as a result of these measures. The main challenge the City of Bamako still faces for waste disposal is the lack of a designated landfill for waste final disposal. There is a site designated for controlled land filling about 30km outside the city limits in Noumoubougou. The construction of the landfill was launched some time ago but has not been completed yet. Two important issues still need to be resolved in terms of which authority will be responsible for paying for the operation and maintenance of the landfill and which will be paying for transportation of the waste to the landfill. The situation is further compounded by the perspective of the creation, in a next future, of a new decentralized entity as result of merging of the District and the six communes of Bamako as well as many other local governments within the Bamako conurbation.

Source: UN-HABITAT n.d.; UN-HABITAT 2010; AfDB 2002; Jha 2010 ; Setchell 2008.

4.6.3.2. Disposal

Current disposal practices in most developing countries leave much to be desired. The result is that as little as 10 percent of the collected waste may be deposited at an official disposal site there being much greater incentives to dispose of the load before reaching the site. Table 4.4 indicates typical following disposal practices.

Table 4.4: Disposal practices

Households	Municipal authorities
Removal by a sweeper who scavenges useful items Dumping on empty land Dumping in watercourses and river valleys.	Dumping in streams On land that requires raising prior to construction Infilling of holes in the road Spreading as a soil improver on agricultural land Land reclamation Infilling of the sides of river valleys Unofficial dumps with no legal entitlement Official dumps Properly operated landfills (rare).

Clinical waste from small industries and hazardous waste are rarely collected separately, but are usually mixed with municipal waste. Large industries, often located outside of the urban area may have dedicated disposal, often incorporating energy recovery as part of the process.

Inappropriate disposal practices may result in visual, chemical and biological contamination of surface and groundwater water resources, typically downstream of the origin of the waste, and are also a significant contributor to flooding, through the blockage of natural and human-made drainage channels. Municipal waste should not be deposited in flood prone areas as this may result in water contamination and the spreading of diseases (Diagne 2007).

4.6.3.3. Waste treatment

More technical treatment processes (such as incineration and composting) require capital resources, which are often beyond the technical and financial capability of municipal authorities to provide and operate. Industrial processes are often far more efficient, frequently incorporating energy recovery from the waste generated.

Treatment for different types of wastes is different and therefore a comprehensive program is required for proper waste treatment after collection. If waste collection is not facilitated with separate collection bins, then sorting should be done. Sometimes composting might not be the best option with mixed waste products. Similarly hazardous wastes should be removed and disposed of as soon as possible so that it does not affect the health of the surrounding areas. Proper training is required for such purpose.

4.6.3.4. Waste Reuse and Recycling

The removal of reusable and recyclable materials reduces the bulk of waste and can provide employment and revenue to offset the cost of the recycling process. In many developing countries, an efficient and structured scavenging system already operates, which provides a basic level of employment for minorities and migrants. Any formal recycling schemes, especially removing the most valuable waste from high income households and from hospitals, would need to seriously consider the impact on the income of existing scavengers.

4.6.4. Pre-emptive actions to minimize the effects of flooding on waste collection

Flooding may quickly render an existing waste collection system ineffective, by destroying vehicles, restricting vehicular access, making existing working routines redundant and though the absence of personnel whilst they see to their own domestic affairs. An effective waste management is critical after a flood; an already well-managed waste collection and disposal system can be modified, however, by considering the following options:

- Locating depots and garaging and equipment on higher ground away from flooding so that they remain accessible.
- Maintaining fuel reserves to be used when commercial fuel supplies are unavailable.
- Identifying a number of disposal sites in different parts of the urban area that can continue to be used if access is restricted by flooding.
- Operating a recycling and hazardous waste collection system that can be easily adapted to take an emergency into account.
- Avoiding the disposal of non-inert waste in flood prone areas.
- Avoiding infilling of low-lying areas, which may act as temporary storage areas during flooding.
- Regular clearing and dredging of drainage channels and waterways.

One example of such practice is in the megacity of Dhaka, Bangladesh, where over a period of two years, the main landfill site, Matuail, was transformed. What was once and open dump subjected to closure during flooding is now a controlled landfill, with perimeter drainage, site roads, leachate management, landfill gas venting, site control offices and an electronic weighbridge (UN-HABITAT 2010).

4.6.5. The management of liquid waste and drainage

4.6.5.1. Sources of liquid waste

In most developing countries, liquid waste is generated by:

- Run off, especially during heavy rainfall events such as monsoons
- Human sources
- Industry, such as textiles and tannery processing.

Sewage is also a significant contributor, as it often provides a significant proportion of the base flow in rivers and drains.

The majority of drainage systems are combined, receiving both sewage and drainage water. The waste is often discharged into open unlined roadside drains, passing into enclosed drains and in larger cites into sewers, before being discharged (untreated) into the nearest water course. In many countries the open drainage water is diverted to irrigate crop fields, even in urban areas.

Drains can become blocked for a variety of reasons:

- Accumulation of sediment from runoff and sewage.
- Encroachment by vegetation.
- Disposal of household waste.
- The construction of unofficial encroachments and the poor design of civil engineering works
- Disposal of household sweepings, road sweeping.
- The disposal of waste by municipal employees.
- The disposal of industrial and commercial waste.
- Inaccessibility because of new development (for example, the construction of new roads).

Larger urban areas are likely to have well developed enclosed drainage systems in both the higher income areas and in the central commercial district. The drains through the outer suburbs and informal settlements are unlikely to be covered, however, and will typically discharge directly into the nearest watercourse. In developing countries, sewage treatment is often both rare and inefficient. The enclosed systems in the higher income and commercial areas are most susceptible to drain flooding because blockages are less noticeable and less easy to clear. The drains in poorer areas are the most susceptible to blockage because these areas are less well served by collection and drain cleaning systems, sometimes as a result of their remoteness or because narrow streets restrict access.

4.6.5.2. Treatment and disposal

Sewage in developing countries is often untreated and is discharged to the nearest water course; the water may be subsequently used downstream for irrigation or for domestic use, leading to further problems in these areas.

4.6.5.3. Drain cleaning

Cleaning and clearing of drains and other urban waterways is often undertaken by the same department responsible for street sweeping. The two functions, because of the lack of resources, tend to be concentrated in the central commercial district, with other less important areas having to provide for themselves. Such tasks are labor intensive and, typically, will only have rudimentary equipment. Perversely, the greatest contributors to blocked drains may be the same departments responsible for clearing them, because of improper sweeping and waste disposal practices.

An example of an innovative approach to the problem is seen in the city of Managua, the capital of Nicaragua. The city is sited on steep rugged terrain and formed of dispersed urban centers with areas of lower population in between. The recent accelerated growth led to deficits in basic facilities and services. In particular, the city identified that weak urban governance led to shortcomings in the refuse collection service. Since 1980 a system of micro-dams has been established with the dual purpose of attenuating floods and retaining refuse. Over 16 dams have been constructed, and research shows that these dams extract in excess of 500 cubic meters of sediment from the river system (Tucci 2007). However, the micro dams are poorly maintained, and there is no effective ordinance for land use planning to regulate new urban development as well as a lack of a Drainage Master Plan. This means that flooding problems continue to be a yearly event in several neighborhoods of Managua.

The reduced flood risk resulting from practices to both reduce the waste accumulating in waterways and to remove the waste already in a river is shown below in a case study drawn from a metropolitan Manila example.

Case Study 4.10: Save the Marikina River Project, Marikana, the Philippines

The Marikina River is a tributary of the Pasig River. It is one of the most important natural water systems in Metro Manila, and serves as the city of Marikina's main waterway. For decades the river was subject to uncontrolled encroachment, and also served as a disposal site for both domestic and industrial waste, causing significant environmental degradation and increasing flood risk.

In 1993, the 'Save the Marikina River' project was launched, with the aims of rehabilitating the watercourse and developing the city's largest recreational area. The project consisted of the following components:

1. Removal of informal settlements, commercial buildings and other industries from the riverside;

2. 109 hectares of land and a community mortgage program were provided for the resettlement of 10,500 families;

3. A strict disposal collection policy was introduced, which forbade solid waste being put out of houses at days and times other than that of collection; with a penalty for non-compliance, and;

4. Regular river dredging.

With regards to flood risk, areas that are prone to flooding have been reduced and floodwaters recede faster now. In 1992, before the implementation of the project, land exposed to flooding was assessed to be 6.36 km^2. By 2004 it was reduced to 4.4 km^2. In addition, property values have risen around tenfold in areas previously vulnerable to flooding with indirect benefits for the Local Government Units (LGU) in the form of higher property tax revenues. Although the project was successful in removing and relocating informal settlements in areas with improved access to basic service and infrastructure provision, water quality and the inflow of garbage from upstream areas still remain to be resolved.

The Marikina case provides a useful illustration of the effects of urban rehabilitation on urban flood risk management. Urban rehabilitation can form part of urban flood risk management schemes and help cities adapt to long term changes, to correct past mistakes and to increase flood resilience.

Sources: World Bank 2005; ADPC 2008.

4.6.6. Pre-emptive actions to minimize the effects of flooding on liquid waste systems

Sewage and drainage systems may exacerbate any flooding through:

- Insufficient capacity of the drainage design
- Blockages
- Contributing to water pollution.

Pre-emptive operations may include the following:

- Appropriate design capacity, especially of trunk drains
- Avoiding overloading existing drains with sewage and industrial discharges.
- Regular clearance of sediment and bank maintenance
- The use of open drains where appropriate. Whilst perhaps not always desirable on health grounds, blockages in open drains are more easily detected and easier to remove.
- Raising the ingress points of wells above predicted flood levels
- Raising pit latrines above the predicted flood levels, or fitting them with liners or concrete rings to minimize the ‘flushing’ of sewage into groundwater
- Constructing embankments around any treatment plants and fitting flap valves to sewer discharge pipes to prevent flood water accessing the sewers and causing secondary flooding.

4.6.7. Flood Waste

The principal objectives of managing waste deposited during a flood are as follows:

- To create or restore access to and within the flooded area.
- To facilitate reconstruction.
- To access buildings needed for flood emergency activities, such as hospitals and schools.
- To avoid obstructing later development because of poor disposal practices.
- To provide materials for post flood development.

In order to prevent waste from disasters rapidly consuming available landfill volume, practical diversion is a high priority. The waste hierarchy (Figure 4.11 above) provides a useful framework that may be applied to flood material, if segregation can be implemented at the point of clearance. Failure to do so will result in a waste of resource and considerably increase the volume of material for disposal. This topic is covered further in Section 4.11.

4.6.8. Solid waste management in informal settlements

Informal settlements are particularly prone to the general lack of solid waste services by the community and local government. These areas are also neglected when waste management plans are implemented, as municipal authorities may not see them as their responsibility or even as falling within their jurisdiction. Situations like this are aggravated further by the prevailing conditions in informal settlements such as a lack of access to dustbins; irregular collection from the dustbins which exist, resulting in overflowing; massive continuous dumping of daily wastes in nearby water bodies and drains; and low-lying and vacant lands and narrow roads and passages making the areas unsuitable for healthy living. There are many instances when, due to rain and overflowing of drains, wastes spread and cause diseases which give rise to health problems and render informal settlements uninhabitable. This problem requires a long-term solution. It is therefore important to know how such situations can be managed with the help and support of the local community and municipal government.

As seen above, municipal solid waste management incorporates planning, engineering, organization, administration, and financial and legal activities associated with the generation, collection, growth, storage, processing and disposal of waste materials, this occurring usually in medium to high income areas. However the same procedures are often not followed in informal settlements. Even when government has accepted the importance of solid waste management in informal settlement areas and provided community bins, their number is often insufficient, with up to 10 to 25 households sometimes sharing one bin (Chowdhury, 2007). There are also occasions when these bins are stolen.

Some of the proven methods for solid waste management in informal conditions are as follows:

Low-cost methods for solid waste collection from informal settlements

Many regular waste disposal systems are expensive and require regular payments for service providers. The effect of operational cost recovery for such systems and lower incomes in informal settlements are partly responsible for the lack of initiative towards paid waste disposal programs. Some low-cost methods have proven to be effective in many informal settlement areas:

- Door to door collection using hand carts, donkeys, and tricycle carts
- Take away bins in narrow lanes, shared and community bio-bins,
- Collection by lorry at the settlement entrance
- The setting up of collection centers outside shops and supermarkets

Door to door collection is easier in areas where roads are wide enough for movement. In other areas, community collection points are effective. Such systems are prevalent in Mumbai and Calcutta in India and Dhaka in Bangladesh. It is however important that the pickup timing, frequency and regularity should be maintained for the success of such processes.

Participation of informal settlement dwellers

Research shows that the majority of informal settlement dwellers has knowledge of waste management and is willing to pay for a cleaner, healthier environment.

Community members' willingness to pay generally increases when collection methods are flexible and inexpensive. These features are best delivered by the informal sector. Engaging informal settlement dwellers in the management of their own waste is a way to capitalize on this willingness to contribute – and also to design schemes suitable for the conditions. For example, the routine of waste collectors often does not match with the working schedule of residents. Establishing the best collection time or allowing waste disposal at the most convenient time is helpful. This solution requires adequate number of bins and frequent cleaning and restoration of the bins in case of theft or destruction. Giving responsibility to the local people for the safety and security of the dustbins can also be useful. Providing large waste bins can also stop theft and encourage community ownership.

Incentives can be offered for responsible waste disposal or recycling, as seen for example in Curitaba, Brazil, where fresh vegetables were offered in return for waste brought to disposal centers. Such practices can yield double benefits in also increasing the nutritional intake of informal settlement residents.

Incorporating informal rag pickers can be another way of motivating residents by generating income and increasing collection efficiency. The local municipality can encourage this activity by making such practices feature as a source of extra income. The sustainability of proper waste management systems depends on the maintenance arrangement of the authorities.

Reuse and recycling of wastes and generation of income

It is essential that waste materials collected from any source are converted to usable products: and this principle is no different in informal settlements to other areas. Collected wastes should be sorted and recycled based on their value. Sorting points should not be at the collection points as this increases littering and contamination (Jha, 2011). It is preferable to have separate collection systems or disposal points for recyclable and reusable wastes. Degradable and non-degradable wastes should be handled separately and composting should be encouraged. Local informal settlement dwellers should be trained and involved in such activities; payment arrangements can be made so that they can remain motivated.

The social status of waste collectors is generally low. To raise this status and generate awareness of the importance of such activities, cooperation among different governing bodies at the local level and with NGOs is required. Regulated fixed pricing of the collected waste and organized dumping are some of the important aspects that local authorities can consider. While doing so, informal settlements should be included in the system and proper information should be disseminated within the areas so that the residents are fully aware of the system.

Strengthening public private partnership for developing solid waste service delivery

Although the gaps between the problems and their solutions are often recognized, in many cases factors such as the supply of funds, manpower and organization of management bodies become major limitations. Capacity building to allow informal settlements to use their own resources and manpower, and utilizing institutional frameworks like those provided by local municipalities and NGOs can help in reducing these gaps.

Strengthening community services with cooperation from the local government can bring substantial changes to the level of solid waste management. The high density of populations in informal settlements can help in charging lower price for such services.

Cooperatives and micro-enterprises can effectively collect waste from hard-to-reach areas at low cost, using appropriate vehicles (USAID 2006). There are examples of small municipalities in Bolivia, Colombia, Costa Rica, Guatemala, and Peru that use informal arrangements, contracts and concessions to encourage waste collection and recycling activities by microenterprise and cooperative associations. The micro-enterprises or cooperatives can then bring waste to a centralized area for pick up by private or municipal trucks. Although these microenterprises or cooperatives are commonplace throughout the region, the arrangements with the municipalities are still at the incipient stage regionally, with some municipalities implementing them and others contemplating them.

4.6.9. Further reading

Ali, M., Cotton, A., and Westlake, K. 1999. Down to earth: solid waste disposal for low-income countries. WEDEC. http://www.wedc-knowledge.org/wedcopac/opacreq.dll/fullnf?Search_link=AAAA:M:589158920300.

Medecins San Frontieres. 2005. Health care waste management in low income countries.

Oxfam. 2008. Technical guidance on how to handle and store hazardous waste (hospital, industrial, chemical, asbestos, batteries, gas, etc). http://postconflict.unep.ch/humanitarianaction/documents/02_03-04_01-04.pdf.

Rushbrook, P. and Pugh, M. 1999. Solid waste landfill in middle and lower income countries. World Bank Technical Paper 426. World Bank.

World Bank. 1999. Solid Waste Management in Asia. World Bank.

4.7. Emergency planning, rescue, damage avoidance actions and temporary shelter

It is vital to recognize that even after the implementation of non-structural flood mitigation measures – as combined with the structural measures covered in Chapter 3 – residual flood risk will remain. It is of paramount importance to make plans to deal with flood events and their aftermath. This involves multiple activities which can be included as part of a flood emergency plan. In this section there is an overview of the elements central to emergency planning. Further details on other measures that deal with flooding and its consequences follow in Sections 4.8, 4.9, 4.10 and 4.11.

4.7.1. Emergency planning

Flood mapping as described in Section 1.4 will have already identified those areas susceptible to flooding. An appropriate and implementable emergency plan will:

- Facilitate emergency response.
- Minimize the impacts of flooding.
- Allocate resources efficiently.
- Reduce confusion.
- Facilitate recovery.

4.7.1.1. Identifying existing internal organizations

All countries possess existing institutions and organizations that, if coordinated, may be mobilized to meet individual emergencies. The purpose of the emergency plan is to identify these institutions prior to the emergency in order to:

- Identify roles and responsibilities.
- Identify command structures.
- Facilitate inter-agency cooperation.

The following organizations should be considered:

Table 4.5: Organizations involved during an emergency

Government organizations	
Police	To maintain order
Military	For security Evacuation by land, water and air Heavy machinery for the removal of debris
Other rescue services such as Fire, and Search and Rescue (if present)	Rescue Evacuation by land, water and air
Hospital authorities	To provide health facilities
Central or regional government	To manage the emergency relief effort
Municipal government	Local knowledge Waste management
Private sector	
Train companies (if present)	Provision of transport for goods and people into and out of the affected area
Transport companies	Provision of transport for goods and people into and out of the affected area
Bus companies	Provision of transport for people into and out of the affected area
Construction companies	Heavy machinery for the removal of debris
Mining companies (if present)	Heavy machinery for the removal of debris Specialist debris removing knowledge e.g. explosives
Civil Society	
Non-governmental authority structures (e.g. tribal if applicable)	Meeting specific needs Contributing to community cohesion Mobilizing communities Communication route
Civil society	Meeting specific needs Mobilizing communities
Religious groups	Meeting specific needs (although they may be more concerned with debating the theological implications of the disaster than assisting the victims)

The preparation of the emergency plan will help to identify barriers to cooperation, including authority structure and finance, which need to be resolved before flooding occurs.

4.7.1.2. Identifying appropriate external agencies

Some flooding events may be addressed using existing national resources but many countries do not have sufficient physical and human resources to address regional and national emergencies. It would then be appropriate to invite the assistance of external agencies.

There are numerous international agencies which can assist in the emergency phase of a flooding event. These include the following:

Table 4.6: Some international agencies which can assist in an emergency

United Nations (Coordination)	UN High Commission for Refugees (for those displaced in other countries). Office for Humanitarian Affairs and Emergency Relief Coordination of UN agencies for Internally Displaced People (IDPs).
United Nations (Specialist agencies)	World Food Program (WFP). UN Children Fund (UNICEF). UN Development Program (UNDP). Office of the High Commissioner for Human Rights.
International organizations	International Federation of the Red Cross and Red Crescent Societies (IFRC).
International Charities	These are too numerous to list but many may have in-country representatives.

The presence of international agencies may, however, overwhelm the host government with the risk that the latter may lose control of the relief effort. This, in turn, can result in the deskilling of local people who may feel it necessary to defer to the external agencies. It should also be recognized that the objectives of external agencies may conflict with those of internal agencies: for example, to 'showcase' their charity in high profile emergencies. Managing these agencies is both difficult and time consuming and may require considerable diplomacy.

The emergency plan should therefore contain detailed policies, identifying the roles and responsibilities and restrictions on invited agencies.

4.7.2. Damage Avoidance

Actions taken before a flood arrives can significantly reduce the loss of life and the amount of damage suffered. Pre-warning and evacuation planning should therefore be part of an emergency plan. It follows that an early warning system (see Section 4.9) is a central requirement for damage avoidance. Local flood emergency planning could involve, for example, the installation of temporary flood barriers, or the removal of zoo animals (as in the Cologne case study elsewhere in this volume). Deployment of some building design features, as described in Chapter 3, may also be dependent on warnings being issued.

It is necessary to mobilize personnel and machinery, where available, to protect infrastructure (such as dikes, levees and retention basins); to remove individuals from facilities at risk (such as hospitals, schools, industrial sites, bridges, or individual houses); and to prevent landslides and riverbank erosion. Strengthening and rehabilitation of existing structures and flood-proofing measures can also protect critical infrastructure. Such measures may include sandbagging or establishing temporary earth, wooden or other flood barriers, including mobile flood barriers (WMO 2011).

4.7.3. Flood emergency preparedness activities

To coordinate emergency procedures, a flood management unit (FMU) needs to be set up. Representatives from the local community should be included as members. The FMU will be responsible for developing a business and government continuity plan (BGCP) and for coordinating emergency procedures in a secure flood free location, as identified in the evacuation plan (see Section 4.10). The FMU can also be organized to serve as the local representative, focal point or community partner for wider river-basin level planning. Government continuity planning requires the community to effectively participate throughout the planning process. Participatory planning for emergency situations can help build trust and confidence among stakeholders, enhance cooperation, facilitate information sharing and encourage regular communication (WMO 2011).

Table 4.7: Flood emergency preparedness activities at various levels

Individual and household level
Build awareness about the risks: drowning, waterborne diseases, electrocution, poisonous animals
Install protective railings around houses, to protect children from falling into the water and to provide support for the elderly
Identify potential safe areas and potential routes to get there
Know what to do when a warning is received
Know whom to contact in case of emergency
Keep life jackets or buoys or tires
Keep first aid kits
Store clean water and food in a safe place
Listen to daily flood forecasts
Move valuable items to higher ground
Be prepared for evacuation
Protect livestock and other important assets
Community level
Identify and maintain safe havens, safe areas and temporary shelters
Put up signs on routes or alternate routes leading to the temporary shelters
Inform the public of the evacuation plan, and the location of safe areas and the shortest routes leading to them
Keep a list with important contacts such as district or provincial and national emergency lines, and identify a focal point in the community or village
Make arrangements for the set-up of teams in charge of health issues, damage and needs assessment
Set up community volunteer teams for a 24-hour flood watch
Improve or keep communication channels open to disseminate warnings
Distribute information throughout the community

Municipality, district, provincial or regional and national levels
Determine roles and responsibilities of each agency during response, relief and recovery
Prepare maps (flood risk, inundation, vulnerability and resource maps) to provide essential information and data on current situation, and to plan for assistance in those areas
Make sure that critical roads are built up to an appropriate height, to create safe areas for flood-affected communities and to ensure continuous transportation critical for flood relief
Identify safe areas and maintain existing shelters, making sure they have sanitary and other basic necessities
Implement public awareness activities; be pro-active
Educate the public on what to do, and what not to do, to prevent harmful activities in floodplains and other flood-prone areas
Prepare resource inventories, identifying how much is available locally and how much is needed from outside
Plan resource mobilization
Set up emergency teams (for example, health, search and rescue teams)
Conduct drills (exercises) for search and rescue teams
Make sure that communication channels to the community are functioning well
Check flood mitigation infrastructure (e.g., dykes, levees and floodwalls) as well as other key infrastructure (e.g., roads, dams)
Disseminate public safety information through the establishment of early warning systems
Specify the source and actions to be taken immediately after receiving warnings.

Source: Adapted from WMO 2011: 6-7

At a household level a number of strategies can be adopted which will reduce damage as a result of flooding. Including the following:

- The identification of household escape routes
- Installation of temporary flood proofing
- The identification of elevated buildings (or even mature trees) that can be used as safe havens
- The moving of property to higher levels
- The storing of emergency provisions
- The use of non-flood impacted communications such as radios, mobile phones or even prearranged signals in order to share information
- The removal of vehicles from the area: their use in the post-flood situation is invaluable.

4.7.4. Evacuation and Rescue

Before the event, and during the first stages of the emergency, the rescue of those affected by the flood will be dependent on existing resources. The emergency plan should identify those resources, including transportation, fuel supplies, and available high ground not threatened with subsequent flooding on which those rescued may be left, along with the equipment required, and how to store and secure it. Evacuation planning is described in Section 4.10.

4.7.4.1. Flood shelters and refuges

The flooding event is likely to have destroyed the homes and livelihoods of a number of people. An estimate of the number of people requiring shelter should be made, taking into consideration the resilience of the housing in the areas affected, the extent and type of flooding and the likely survival rate. The methodology for updating this estimate immediately after the emergency should also be defined. It should be remembered that, depending on the length of time by which the warnings preceded the event, and on the available resources, many families will have left the area to stay with friends and relatives. The number of survivors is likely, therefore, to be greater than those requiring assistance. In the short to medium term, this number is likely to increase as families may return to protect their property even when conditions may be unsuitable.

Alternative accommodation will be required for the survivors as described in Section 4.10.

4.7.4.2. Emergency food supplies

Flooding is likely to have destroyed existing food supplies and local agricultural produce. Prices are likely to rise locally and even nationally in response to a significant flood event.

The emergency plan should identify:

- The most appropriate types of food considering local tastes, culture and the available equipment and fuel for cooking.
- The likely quantities based on the calculated number of survivors.
- The food suppliers and the likely cost.

The food allocation should seek to meet SPHERE standards (The Sphere Project 2011).

4.7.4.3. Emergency water supplies and sanitation

The flooding will have destroyed existing water supplies and sanitation infrastructure, where applicable; any overflow of sewage will also have polluted water supplies. The emergency plan should therefore identify alternative water supplies, preferably gravity-fed to avoid the need for pumping. The tankering of water is a very short-term solution which uses vehicles and fuel which could be more beneficially employed elsewhere.

Similarly, sanitation should be provided close to the displaced population, away from the source of water supply and on unsaturated permeable strata to allow sufficient drainage. These factors should be taken into account when locating refuges and other areas of residence.

4.7.4.4. Social dislocation

In the disruption following a severe flooding event, many families and communities will be separated, often leading to a lessening of social cohesion. The emergency plan should identify the responsible organization and methodology for families and communities to locate and communicate with each other; all the media available after the flood should be utilized, such as notice boards, mobile phones, land lines, news-sheets and radio as applicable.

4.7.4.5. Access

Flooding may affect both roads leading to the flooded area as well as those within it. This can include blockages of debris and silt, as well as flooding or washing away.

The emergency plan should therefore identify the following:

- Access roads to and within the flood zone, avoiding low bridges over rivers, low-lying areas, roads susceptible to land slippage (in cases of flooding caused by heavy precipitation) and highlighting those not susceptible to crime and insecurity.
- The design and location of permanent signage on principal road routes. The use of symbols avoids the difficulties of literacy and language.
- Suitability of road, railways and airfields, where available, for longer distance transport of supplies.
- Suitability of ports near main shipping lanes, with sufficient depth and with suitable loading and unloading facilities for international vessels.

4.7.4.6. Clearance

Floods deposit large volumes of debris and mud, the clearance of which is essential for the relief effort. The emergency plan should identify how the debris and mud is to be cleared, by whom and where is to be deposited. This is dealt with in greater detail in Section 4.12.

4.7.4.7. Emergency health facilities

Flooding may generate a range of injuries. The emergency plan should identify:

- The suitability of public buildings to act as preliminary treatment centers (such as schools, government offices or similar).
- Existing hospital facilities, away from the likely flood area, that may be developed with specialist services and equipment.
- The method of evacuation for those with more serious injuries.
- A system of vaccination.
- The suitability of public areas (such as parks and schools), for the siting of mobile clinics units, temporary camps and distribution centers.
- The provision of power, as electricity supplies (where these exist) are likely to have been severed.

Photo 4.1: A school is used as an aid center. Haiti 2004. Source: Peter Lingwood

4.7.4.8. Energy

It is likely that the floods will destroy access to energy resources, be they electricity or, in less developed areas, other forms of fuel including wood and animal dung. The emergency plan should identify:

- The local fuel resources and their continued accessibility during and after a flood.
- Alternative sources of energy (for example, generators) and the fuel to run them.
- Key institutions such as hospitals which should be supplied with these alternative sources and the methodology for ensuring their continued availability between floods.

4.7.4.9. Security

Emergency situations, and the breakdown of the normal standards of society and their enforcement, often create opportunities for theft and corruption.

The emergency plan should therefore include:

- The securing of the facilities identified in the emergency plan, between and during flood events.
- The visible deployment of reliable security forces immediately post flood to deter looting.
- External auditing of government functions for efficiency and probity.

4.7.4.10. Preparatory exercises and maintenance

Between flood events both an annual audit, and an exercise to implement the flood emergency plan, should be undertaken. This will help to identify changes since the previous year and assist in institutional preparedness. The problems identified should be rectified and the emergency plan comprehensively revised, at least every five years.

The maintenance of relevant systems is discussed in Chapter 6..

4.7.4.11. Further reading

Corsellis, T. and Vitale, A. 2005. Transitional settlement: displaced populations. Oxford: Oxfam Publications.

The Sphere Project. 2011. Sphere, humanitarian charter and minimum standards in disaster response.

4.8. Business and government continuity planning (BGCP)

After a flood disaster, some organizations, mechanisms and sectors may be able to continue to deliver their most critical services. Others may find it much more difficult to perform effectively under the adverse consequences of a flood disaster. It is important to assess the ability of individuals, government and non-government organizations, mechanisms and sectors to continue to perform critical functions under different flood scenarios. Depending on the result of this assessment, priority should be given to repair public infrastructure or maintain services that would experience a higher degree of operational problems in an emergency.

For example, the 2011 Mississippi floods in the US caused supply chain problems when freight terminals along the Lower Mississippi had stop their operations because of high water. Flooding in 2011 in Brisbane, Australia, left thousands of households without power; the electricity providers had to deploy backup generators in some of the flood-affected areas to respond to power outages. Business continuity is not only important in terms of serving immediate public needs but also to ensuring the continued economic prosperity of a flood affected area and avoiding the long- term economic impacts associated with flood-induced business failure.

BGCP ensures that essential services and critical infrastructure will continue to operate should the impact of the flood become more severe. It is a planning process which provides a framework to ensure the resilience of an organization, mechanism or sector to a disaster, and ensures that, when faced with disruption they can carry on, or resume operations with minimum delay. It is better to plan ahead for a flood disaster which may affect the operational integrity of an organization or sector, rather than having to react to a disaster when it occurs.

The objective of a BGCP is to make an organization or a sector less vulnerable to and reduce the impact of adverse events such as floods. Most importantly, the plan ensures to the maximum extent possible the continuity of critical operations to:

- Provide public safety
- Reduce disruption to essential government functions
- Minimize loss or damage to public and private infrastructure, as well as individual property.

Figure 4.12 illustrates the process for developing a business and government continuity plan.

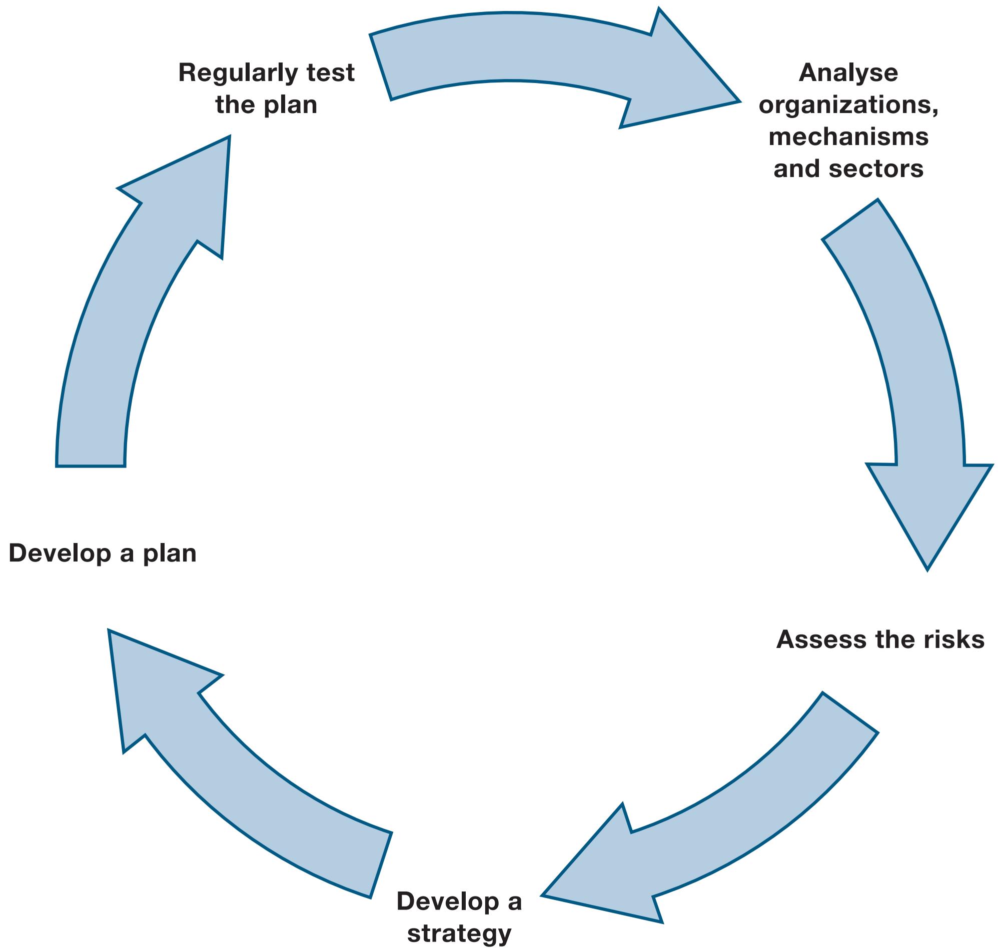

Figure 4.12: Business and government continuity planning process

4.8.1. Relevance to the private sector or the public sector

Emergency action plans are necessary for both the public and the private sectors in order to reduce their exposure to flooding. These plans can increase their resilience to cope with adverse consequences both during and after a disaster.

Government and business continuity plans should be adequately linked to disaster management institutions and mechanisms at the local, district, state and national levels. Local communities should be allowed to be active in developing and enacting flood emergency plans and to implement their own measures to reflect local conditions, real needs and priorities on the ground. Flood emergency preparedness activities vary from the individual to the national level. In addition to government bodies, the private sector and NGOs, as well as other aid organizations, are strongly encouraged to prepare continuity plans and incorporate flood risk components within them.

The initial investment required for flood risk reduction may, however, be considered as a costly and non-profitable activity for many businesses and governments. Investing in contingency planning may require cutting or reducing funding for other routine activities and this often discourages businesses (particularly smaller enterprises) and governments, from putting such plans in place. For this reason, coordination amongst all stakeholders, including between the public and the private sectors, is important in order to develop BGCPs that will effectively reduce the impacts of flooding to their vital assets, and at the same reduce the cost for contingency planning for all individual actors.

Continuity planning, however, should not be considered as an activity that only businesses and governments have to undertake. Individuals and households should also develop their own action plans, and most importantly, they should actively participate in all processes undertaken by other actors to develop such plans. It is also important to bear in mind that different actors exhibit varying levels of vulnerability; action plans will, therefore, be required to appropriately integrate individual needs and priorities in an adequate and effective manner. The factors shown in Figure 4.13 can be used to inform the basic process of action planning, to reduce vulnerability to flooding, and maintain continuity of critical operations.

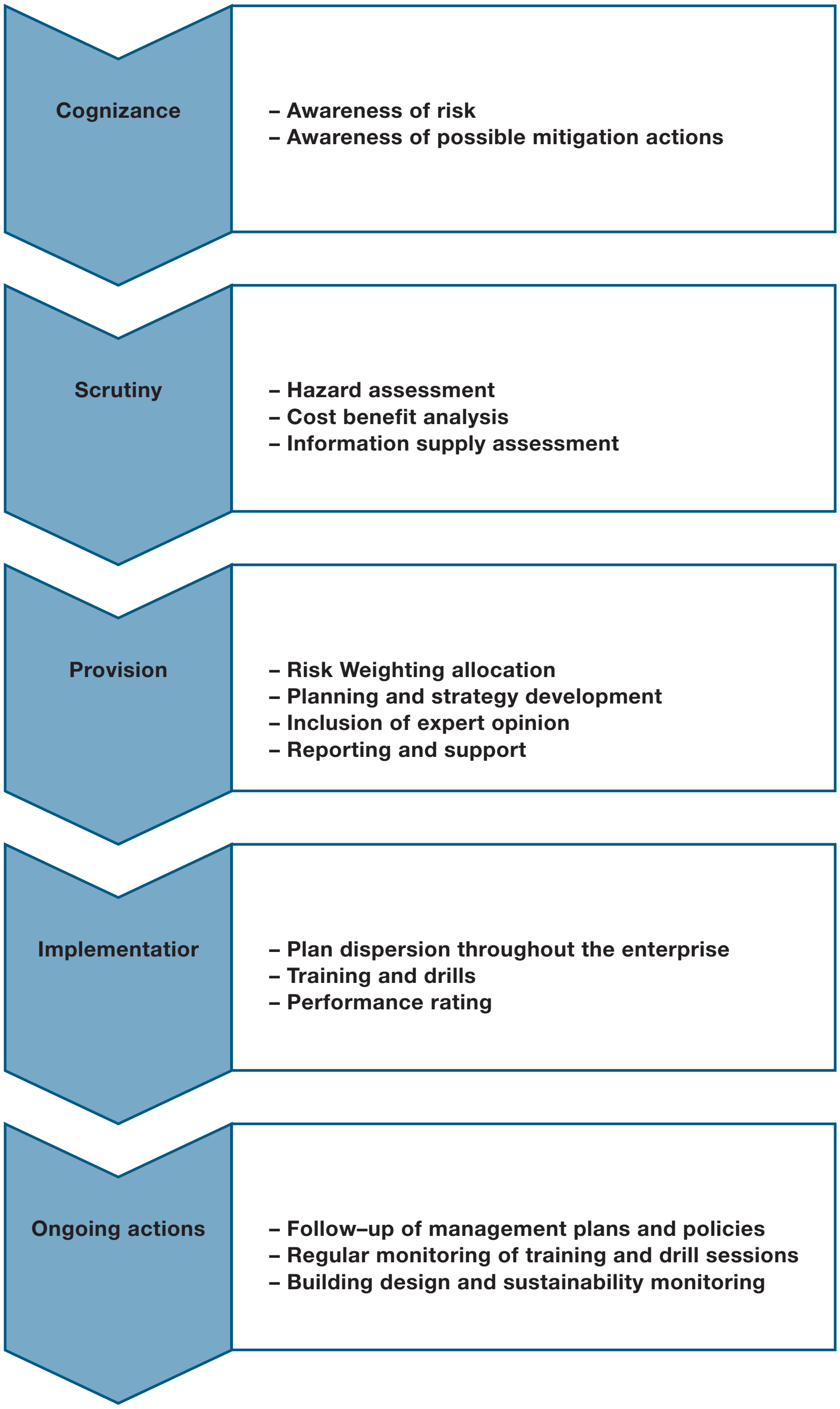

Figure 4.13: Components of an action plan for business and government continuity planning, Source: adapted from Bhattacharya et al. 2011

4.8.2. Minimizing flood damage risks

To minimize the risk of flood damage, public and private infrastructure should adopt appropriate architectural design, as covered in Section 3.9. Moreover, relocation of infrastructure and property built in locations exposed to floods should also be considered. However, decision makers and technical personnel require tools which can help them to consider the costs and benefits of such measures, which is covered in Chapter 5.

Protection of critical infrastructure is likely to be the most important task that businesses and local authorities have to consider. Providers, of essential services that are exposed to flood hazards, whether state-run or private companies, should adopt a range of measures (both structural and non-structural) to manage the risks. In the UK (CLG 2006), use is made of the following hierarchy of flood risk management measures:

- Assess
- Avoid
- Substitute
- Control
- Mitigate

Avoidance is a key non-structural mitigation measure for development of new infrastructure and should be a fundamental part of the land use planning process discussed earlier. Other non-structural measures available to an infrastructure asset manager's toolkit include redundancy reserve capacity, flood forecasting and warning, incident management, and emergency exercises.

Designing infrastructure that is robust to flooding, and can therefore be sited in the floodplain without increasing risk, is a possible approach to reducing damage. It can be seen as robust to the uncertainties of future risk assessments. If such adaptations can be made cost neutral for new infrastructure, this could make a major contribution to reducing future risk. The use of raised construction and services, micro-generation (also raised) and resilient materials may help.

The protection of infrastructure via structural measures in the form of fixed defenses which can include floodwalls or embankments (as covered in Chapter 3) also requires consideration. Design and construction of flood defenses is a specialized field requiring input from hydrologists and geotechnical and civil or structural engineers. Temporary and demountable flood defenses are another form of structural measure that can be used to protect infrastructure, but there are important issues around understanding and minimizing the obstacles to their successful deployment. It must also be recognized that the whole-life costs, including operational and maintenance costs, are likely to be higher for these systems than they are for fixed structures.

Businesses are disrupted not only by the direct physical impact of flooding but by the wider effects of damage caused to infrastructure, inventories, vehicles, equipment, and documentation. In addition, there is disruption of services like electricity, gas, telecommunication and transport facilities. Smaller and often economically more vulnerable enterprises suffer more, the reason being financial incapability to build flood resilient infrastructure, dependency on smaller markets for profitability and the lack of resources and knowledge for capacity building. Sometimes it is possible for certain enterprises to let their employees work from another location, but it is industry specific and not suitable for many businesses. An enterprise with higher efficiency of employee replacement will succeed in such situations.

Businesses having a larger market and higher financial capability are in a better position to recover from disaster than their smaller counterparts. This is because they can disperse their risk factor across multiple locations due to larger market capacity. The resilience factors for large enterprises work well since they are financially capable of building high priced resilient infrastructures for enhanced protection. They are also better able to afford hazard insurance, separate contingency funds and other insurance which are the prerequisites of any business continuity plan to cope during the disruption period and get back to a pre-disaster situation as soon as possible. This attribute is sector-specific in nature and differs largely on the level of exposure and vulnerability of the specific businesses towards flooding.

Insuring those properties that are under-insured, or not insured at all can help speed recovery. Organizations at higher risk may face problems in getting insurance, due to the high rate of premiums; others do not have the option of obtaining insurance at all, especially in developing countries. Receiving early warning of potential flooding lessens dependency on insurance companies for total recovery. Individual reactivity in reducing vulnerability from flooding by adopting resilient measures, together with proactive organizational and governmental help in recovery, are factors that can help with early recovery from business disruption.

4.8.3. Further reading

WMO. 2011. Flood emergency planning: A tool for integrated flood management. Associated Program on Flood Management.

4.9. Early warning systems

The purpose of early warning systems (EWS) is simple. They exist to give advance notice of an impending flood, allowing emergency plans to be put into action. EWS, when used appropriately, can save lives and reduce other adverse impacts. Actions taken after flood warnings which can yield direct benefit are summarized in Table 4.8.

Table 4.8: Actions after warning that yield direct tangible benefit. Source: adapted from USACE 1994

Action	Description
Temporary removal of property from floodplain	Floodplain property owners can move belongings such as televisions, stereos, computers, important documents and personal memorabilia
Moving property to a safe elevation within the floodplain	Residents and businesses occupying multi-storey buildings may have the opportunity to protect moveable property by relocating it from basements and ground floors to higher levels
Temporary flood proofing	Warnings issued with sufficient mitigation time allow property owners to temporarily flood proof property with, for example, temporary closures of windows and doors. These activities can reduce flood damages by preventing inundation.
Opportune maintenance	A warning system can provide officials and individuals with more time to undertake opportune maintenance such as closing a shut off valve on a gas line, halting discharge of certain materials into the sewer system or safeguarding water supplies and sewage treatment plants.
Early notification of emergency services	Increased warning time can reduce the cost of emergency shelter and emergency care as individuals have more time to arrange to stay with relatives, friends or elsewhere. The cost of public assistance and long-term emergency can be reduced if the evacuees have time to secure their property and prepare before evacuation. Communities with limited emergency personnel and other resources will benefit from additional time to ready emergency services.

Orderly disruption of network systems	Warning and response systems offer opportunities for network systems (phone systems, utilities, pipelines, cable TV services, transportation patterns and traffic levels, and local area networks) to prepare for disruption in a more orderly and cost-effective manner. With sufficient warning time, businesses may make alternative plans for their network services.
Suspension of sensitive works	For products that require lengthy production processes, sufficient warning times may provide the opportunity to suspend the production processes to minimize the destruction of the product or minimize the possibility of hazardous materials seeping into the floodwater. Similarly sufficient warning may allow crews to sequence repair work in a way that minimizes disruption to a utility.
Related effects of emergency cost, cleanup cost and business losses	Warning systems may reduce emergency costs and cleanup costs by allowing emergency responders and residents to take preventative actions. Similarly, warning systems may allow for reduced unemployment and income loss, smaller losses in sales, and smaller reduction in taxes collected by increasing the chances of a quick recovery. The costs for flood insurance may be reduced as warnings result in decreases in the amount of coverage required by residents and businesses
Traffic Control	Advance flood warning may provide the opportunity for authorities to decide which roads to close and which to keep open before flooding begins. Traffic can be re-routed in a more efficient manner and personnel can be deployed in a timely manner to block access to potentially dangerous areas as well as to direct traffic onto safe detour routes.

An example of an EWS saving lives and reducing impacts is the Binahaan River Local Flood Early Warning System in the Philippines. Since the system became operational people believe that the low level of damage is due to the warning system (Neussner et al. 2008). The Binahaan River Local Flood Early Warning System Operation Centre (2009) noted that in 2008 there were five uses of the system and three floods, which involved no loss of life due to timely deployment of boats for evacuation.

Another example comes from a teacher, quoted by Gautam and Khanal (2009):

"With the careful use of EWS devices and application of the skills and knowledge we gained through various trainings and exposures, we made sure that no human casualties were reported in our communities although 24 people died in adjoining communities where EWS was not in place. These figures show that if local communities are prepared sufficiently in advance, the impact of flood can be reduced dramatically."

Although it did not involve the use of a meteorological forecast, a successful example of Togo's early warning communication system, which was developed in response to 2008 seasonal forecasts, was demonstrated by the small community of Atiégou Zogbédji located north of Lomé. When river levels were identified as dangerously high, the community leader went through the flood-prone community with a loudspeaker, spreading the message that floods were coming and asking people to evacuate. With just an hour and a half's notice, the population of 2,000 was able to leave. When the floodwaters arrived, physical damage occurred, but not loss of life.

Developments in forecasting and risk assessment which have been discussed in previous chapters have laid the groundwork for developing increasingly timely and accurate warnings with longer lead times. Warning systems can be used to alert relevant authorities or the public or both. The scale of a warning system can be national, based on a river basin, or local and run by volunteers. Most are stand-alone national operations, but warning systems have been developed covering several international rivers, such as the Rhine, Danube, Elbe and Mosel in Europe, the Mekong, Indus and Ganges-Brahmaputra-Meghna basins in Asia and the Zambezi in Southern Africa (United Nations 2006). However, the utility of EWS is crucially dependent on the underlying forecasting system, the quality of emergency plans and the level of preparedness of the community at risk. The quality of forecasting is also dependent on the nature of the hazard. Warning systems related to river flooding have a longer lead time than those for cyclonic events; seismic induced tsunamis may have very short warning periods. Forecasting flash flooding is also very problematic; this has implications for developing nations which are more exposed to such risks, due to the prevalence of monsoon type flooding. Whilst there is general agreement about the desirability of EWS, the implementation of such a system is necessarily subject to local factors.

4.9.1. Essentials for an effective EWS

The four main essentials for any flood warning system are:

- Detection of the conditions likely to lead to potential flooding, such as intense rainfall, prolonged rainfall, storms or snowmelt
- Forecasting how those conditions will translate into flood hazards using modeling systems, pre-prepared scenarios or historical comparisons
- Warning via messages developed to be both locality- and recipient-

relevant and broadcasting these warnings as appropriate

- Response to the actions of those who receive the warnings based on specific instructions or pre-prepared emergency plans

Photo 4.2: Detection and measurement equipment Samoa and India.
Source: Alan Bird

Failure in any one of the four key elements of an EWS will lead to a lack of effectiveness. Inaccurate forecasts may lead to populations ignoring warnings issued subsequently.

The lack of clear warning and instruction may have resulted, for example, in the deaths of people escaping the Big Thompson Canyon flood in the US in the 1970s. Without clear instructions many people were killed trying to drive out of the canyon rather than taking the safer option of abandoning cars and climbing to higher ground.

Finally, the case of Hurricane Katrina demonstrated the scenario where clear advanced warnings failed to protect the population because the evacuation planning was inadequate. .

4.9.1.1. Possible responders to warnings

May stakeholders can influence the way a flood event is handled and the resultant impact. The list of stakeholders usually includes:

- Government (local, regional, national or international depending on the scale of the incident and the catchment). Governments will usually be the first to receive warnings and will put into action their carefully prepared procedures. Often this may involve categorizing the forthcoming emergency and authorizing emergency powers and resources. For example, the decision regarding whether to begin evacuation of an area often rests with local authorities.

- Emergency services and responders. Emergency services and responders will begin to mobilize and relocate their resources and staff.
- Public affected. Where the public is prepared, for example with temporary protection measures or evacuation plans, they will need adequate warning to put these into action.
- Local industry. Businesses can begin to put in place their business continuity plans and warn their staff.
- Voluntary organizations. Such organizations play a very large role in supporting emergency services and will also need to deploy their personnel and resources in the most appropriate and efficient manner.
- Water and drainage authorities. With sufficient notice water authorities may have a role to play in mitigating the speed, severity and duration of inundation. However, they may also need to protect or rearrange their facilities, to ensure the continued supply of essential clean water.
- Utility providers. Where the utility sector has emergency plans to protect and divert services, adequate warning enables such plans to be carried out.

As these and other potential responders will have different information requirements, these needs should be integral to the design of EWS. The most basic and optimal requirements should be understood and the capacity of the detection and forecasting systems be adequate to supply the information assessed.

4.9.2. Needs of responders

It is not possible to generalize regarding the needs of responders or warning messages as the information requirements will be entirely dependent on the specific plans and actions which the warnings will trigger. However, some illustrative examples will show typical lead times and the information that is required.

Local flood warning systems in Fiji are in the process of being upgraded. The Navua system was installed in 2007, initially to provide up to three hours warning of flash floods. It is hoped that this can be extended to six hours in the future. The benefits of the Navua system are predicted to be almost quadruple the costs of installation and maintenance (Woodruff and Holland 2008).

The time taken to evacuate will naturally depend on the number of evacuees and the distance they must travel. Evacuation time is divided between preparation, (which may involve installing protection or moving items upstairs, locating family members and pets) and implementation time (travelling from the area at risk area to a place of safety). Places of safety may be a local shelter or a distant evacuation center; for example, in Hurricane Floyd, which struck the US in 1999, departure times varied, as some people left before official warnings while others stayed until the last moment. Once in transit, average time to the safe destination was nine hours.

Installation of flood protection can take less than half an hour but some systems take longer. The time required to move different items was estimated within the Philippine manual (Neussner 2009) and is shown in Table 4.9.

Table 4.9: Time estimations for moving different types of items

<30 minutes	<2 hours	<4 hours	>4 hours
Television	Karaoke	Large appliances such as a refrigerator	Big oven, freezer
Stereo equipment	Microwave, small stove, toaster	Bookcases, dining furniture	Kitchen utensils
Small electrical appliances	Items in cupboards	Carpets	Beds
Personal effects	Expensive clothing	Additional clothing and personal effects	
	Vehicles	Chickens, pigs	

Source: Neussner 2009

4.9.3. Organizational aspects of flood warning dissemination

It has been noted that there are often multiple sources of flood warnings (ADPC 2006) and that this can be confusing or misleading. For example, separate weather reports and flood alerts may generate confusion. The most desirable situation is that all official warnings, however disseminated, should come from the same source and therefore be consistent. For this to occur there needs to be a clear chain of authority for warnings whereby the necessary information is collated at the appropriate spatial scale and a clear decision process authorizes the release of warnings to potential responders.

There are multiple communication channels by which a flood warning may be broadcast and the choice of media will vary depending on the intended recipients. It is also essential to consider the use of media that will be robust to the impacts of a flood. Formal protocols may exist, via secure dedicated servers or emergency radio frequencies, to allow for exchange of warnings between professional responders.

For the public the number and variety of possible outlets are vast. For example:

- Telephone; text; fax ;pager; email warning service
- Local and national television, press and radio
- Sirens
- Loudhailers
- Drums
- Flags
- Flood warden service
- Internet
- Telephone information service
- Road signs
- Posters
- Word of mouth

The most successful warning services use a combination of media, ideally with consistent messages and timescales, as well as the response the message hopes to initiate. For example, an individuals whose home is likely to be flooded will probably react best to a personal message either via phone, fax or in person; people who should avoid travelling to or through an affected area may prefer a news bulletin backed up by an internet or press map of the affected area.

4.9.4. Appropriate message content

Message content must be appropriate to the context and understanding of the responder. In general, the general public has difficulty in interpreting flood warning messages which are technical in nature.

For a public message the essentials should include

- Clear initial opening line
- Specific local context of where it is going to flood
- Severity of the impact of flood
- Actions people should take
- Timing of the expected flood; how long people have to act
- Language that conveys the appropriate urgency
- Where to get further information
- Repetition of the most important points (if orally delivered).

The clear opening line is essential to catch the attention and alert the listener to the importance of the following information. Repetition is always helpful as this allows for maximum comprehension.

Local context must be comprehensible to the population affected. Recent research in the UK showed that the language used by technical staff about river catchments is not meaningful to local populations (Pitt 2008).

Severity may be indicated by depth, velocity or by reference to a past flood of known or recognized severity. Alternatively, a system of codes may be appropriate: for cyclones in the Bay of Bengal, for example, there is a standardized warning system using numbers and flags.

The most important aspect of the warning is that the message should detail specific actions to take or trigger action in some other way. For example, specify the precise time available to implement a personal flood action plan, if they are common in the population, or refer the individual to the agency which can give emergency instructions. The instructions should be clear and not contradictory. For example, an instruction to: "Listen to your radio or look on the Internet for more information" included in the same message as "Turn off your electricity" can lead to confusion.

Timing aspects are crucial and the message should change in the run up to the event to recognize that actions appropriate well in advance should be abandoned as the water arrives.

Urgency should be conveyed in language that is precise and clearly understood. For example, early in an alert less certain warnings should use words such as "Flooding is possible" and "You should keep an eye on the situation". Later on it will be necessary to use more certain or hazardous flood warnings and should use words such as “Flooding is expected” or “You must prepare to evacuate”. Another example of different warning levels is shown in Figure 4.14 (Neussner 2009).

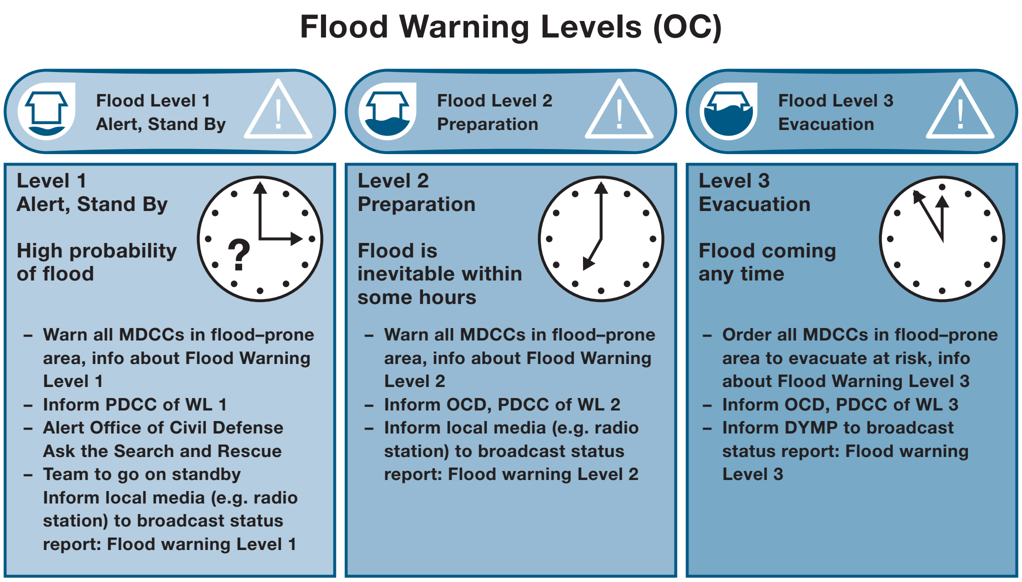

Figure 4.14: Flood warning levels, Source: Adapted from Neussner 2009

4.9.4.1. How to develop an EWS

Early warning systems should be designed in consultation with responders and forecasters to allow assessment of responders’ information needs and the capability of the detection and forecasting models to meet those needs. Where the warning system would not be capable of supplying sufficient warning (which may well be the case, for example, in flash flood situations) it will be necessary to reconsider whether a different measure would be more cost effective.

Method

1. Needs and Applicability analysis

2. Definition of stakeholder group

3. Establishment of stakeholder needs

4. Define warning levels for responders

5. Establish warning center

6. Determine communication media

7. Purchase and distribute equipment (if necessary)

8. Set up warning service

9. Train staff in warning communication

10. Register users of warning services

11. Carry out drills

1. Needs and applicability analysis

Need is determined by the frequency and severity of flooding, the vulnerability of the population at risk and the adequacy of the current or indigenous practices. Applicability is dependent on the type of flood, particularly the predictability and speed of onset, lead times will differ for different causes. Are the indigenous or current practices sufficient or not and do they have specific features which would be useful to adopt in any new system. Capacity to provide warnings consistently over time and to respond to warnings is also a factor to take into account.

2. Define stakeholder group

Stakeholders may include Government, Forecasting groups, Responders, Community groups, Householders and businesses. Representatives of these groups need to be engaged from the start of the process to ensure that all views, needs and capabilities are accounted for.

3. Establish responders' needs

Different responders' needs are related to their mobilization and evacuation lead times as a warning that comes too late to be acted on is of no use. Some responders may be more tolerant of false alarms. Consultation either on a one to one oras part of participatory emergency planning exercise can establish responders needs. Thereby objectives and performance indicators can be developed and the feasibility of developing a suitable system be established in advance of major investment.

4. Define warning levels for responders

Pre-defined warning levels add to the clarity of communication. Clarity of message is necessary for responders to judge the appropriate action level. The definition of warning levels can be part of the consultation or planning exercises used to establish needs. Ideally there should be a single system which conveys likelihood, severity and urgency. Things to consider are: Appropriate language, will everyone understand the message, the use of graphical information or color coding, whether actions are voluntary or compulsory, are there other warning systems which could share the same warning levels or be confused.

5. Establish warning center

The scale and scope of the warning center could be national or at a local level. Available funding, forecasting capacity, spread of risk, vulnerability and cultural or historical factors will influence the choice of local or national warning systems. The center must be seen as a trusted source of information which may require it to be situated in an established ministry or other command structure. Importantly the physical location should not be in an area at risk from flooding and there should be good access and infrastructure with emergency back up facilities.

6. Determine communication media

Identifying responsible authorities with defined roles increases the capacity to disseminate warning information on a well organized manner. While the message should be consistent for all communities the media for communication will be different for different communities. There may be oral or visual methods of communication, for example flags of different colors, sirens, media broadcasts. Consultation will establish the preferred option for communities at risk and it is vital to include representatives of hard to reach and vulnerable groups. The use of mobile phones is likely to be an increasingly important communication option as their use is prevalent in many otherwise isolated areas. It is vital to have at least one communication route which is resilient to the impact of serious flooding on infrastructure such as power distribution and telephone cables.

7. Purchase and distribute equipment if necessary

Responders to warnings have a vested interest in obtaining the best equipment to receive and process warnings. Sometimes this may involve some investment in new equipment. Systems should be designed to use low cost easily sourced equipment wherever possible and the cost of equipment carefully balanced against the effectiveness. Other considerations in the choice of equipment are: the expertise of the operators; locally available resources and local knowledge; the ability of responders to provide a resource base in a collaborative manner.

8. Operationalize warning service

Operationalizing the service involves linking all the elements of forecasting and warning described in order to technically provide a warning service. A parallel programme of publicity for the presence, objectives and warning practice should result in responder and wider community engagement with the system. Awareness of the system and the need to respond to warnings must be generated.

9. Train staff in warning communication

Large numbers of trained staff are needed and regular reviews of trained numbers should be undertaken. Staff will need to be available around the clock and to work at short notice should an incident threaten. Involvement of local volunteers can be effective if these individuals are well trained. Alternatively staff with back office roles can be diverted to warning services in the event of a flood.

10. Register users of warning services

Responders to or users of the system need to be registered and their communication preferences recorded. Registration may be voluntary or compulsory, it may be appropriate to levy a charge for commercial users but the cost for domestic and vulnerable populations should be negligible. An opt out system can be useful in maximizing participation but will not guarantee action as engagement may be lacking.

11. Carry out drills

To test the system, that all the elements such as lead time and communication equipment are appropriate some drills or dummy exercises are needed. It is important to strike a balance between preparedness and not being accused of ‘crying wolf’. Training and drills keeps the system prepared for the actual event. Therefore it is of immense importance that regular drills are managed and monitored.

Costs and resources

Setting up a warning system may be a low cost option for countries and is often seen as the first line of defense for that reason. The cost will be lowest in nations with existing and adequate forecasting and monitoring services. In this case the setting up of a warning center can be a very low cost process and this can be quickly established during consultation and stakeholder identification.

Setting up adequate forecasting and monitoring serviced can require much larger investments in expertise, software and hardware for modeling and monitoring equipment. The lead time to establish forecasts of the required reliability and timeliness may be a deterrent.

Once established the service will require continuous investment in manpower, data and other resources in order to be functionally useful. Recruitment and retention of qualified personnel, continuity of funds and operations and maintenance of monitoring, modeling and dissemination equipment can be key challenges in the long term sustainability of systems. This can be particularly acute for low frequency events.

4.9.5. Further reading

Phaiju, A., Bej, D., Pokharel, S. & Dons, U. 2010. Establishing community based early warning systems: practitioner's handbook. Lalitpur, Napal, Mercy Corps and Practical Action.

MRC & ADPC. 2009. Case study 2-improved dissemination of flood forecasts through community-based early warning systems. Building the local capacity in flood-vulnerable communities in Cambodia. MRC/ADPC.

Neussner, O. 2009. Local flood early warning systems - Experiences from the Philippines (Manual). Tacloban, Phillipines, Technische Zusammenarbeit (GTZ) GmbH.

United Nations. 2006. Global survey of early warning systems. UN.

Jacks, E., Davidson, J. and Wai, H. G. 2010. Guidelines on early warning systems and application of nowcasting and warning operations. Geneva, WMO.

4.10. Evacuation planning

To minimize the loss of lives and reduce other flood impacts, an area should be evacuated when the depth of standing water due to flooding is already or is expected to become high. Such floods are defined as those which are expected to cause buildings, including residential houses, to be washed away or seriously damaged by the flooding.

4.10.1. Organizational aspects of evacuation planning

An interdisciplinary planning organization must be set up covering the key institutions that have remits relating to disaster and specifically flood management. This organization can be a Community Flood Management Committee (CFMC). In addition to the CFMC, evacuation centers should also be established in appropriate settlements.

The members of the CFMC should have knowledge of evacuation and rescue operation and emergency, including medical care (if this is not the case, then basic training should be provided to them). Evacuation plans should be prepared after discussion with the community. Participatory planning will increase people's awareness and ability to cope and manage flood risk. The evacuation plan should be available to all members of the community, including the most vulnerable.

Dissemination of information on flood risk and flood preparedness requires the organization of regular community meetings. Such meetings can take place before the onset of the rainy season, or monsoon. It is vital that evacuation drills will be held regularly to test the effectiveness of the evacuation plans.

The evacuation plan should delineate an escape route and also identify small-scale works that may be needed to make the route safer. Such works can be executed in cooperation with the community as well as with external support. The evacuation plan should also determine modes of transport and access routes for evacuation and rescue operations and relief projects. In addition, the evacuation plan should identify open spaces and buildings to be used as evacuation centers. These can function as described by Arnold, Chen, Deichmann et al. (2006: 149).

- Temporary shelters and refuges
- Hospitals, possibly in existing buildings with stored supplies and basic medical equipment
- Information centers, with uninterrupted linkages to

the central communications system

- Supply distribution points for basic survival supplies, such as water, food, and blankets
- Sanitary facilities, including toilets, showers, and waste disposal units.

To develop evacuation plans and carry out the tasks outlined above, maps showing the most exposed areas to flood risk should be available. Chapters 1 and 2 provide guidance on how to prepare a flood hazard map and a vulnerability map. EWS should also be in place to give advance notice of an impending flood allowing evacuation plans to be put into action (as discussed in Section 4.9). Even when a flood is not as severe as predicted, these preparations help test evacuation plans and inform the communities as to the nature of flood risk.

4.10.2. Provision of flood shelters and refuges

As stated in UNDP (2009:36):

"Shelter is likely to be one of the most important determinants of general living conditions and is often one of the largest items of non-recurring expenditure."

Shelters and refuges must, as a minimum:

- Provide protection from the climate conditions
- Provide space to live and store personal belongings
- Ensure dignity, privacy, safety and emotional security.

In most emergencies there is a common basic need for shelters or refuges. However, issues such as the type and the design of the shelter, the required materials, by whom it is constructed, and the duration it is expected to last, will vary significantly according to the situation. Vulnerability analysis can identify the basic needs and priorities of the affected population in relation to shelters. Safe areas for flood shelters or refuges may include:

- Schools
- Religious meeting places (such as temples, churches, mosques)
- Community centers
- Higher ground (such as roofs, upper floors, embankments)
- Military installations
- Barracks.

4.10.3. Location and size of shelters and refuges

The need for the location and size of shelters and refuges needs to be decided in consultation with the communities. Transportation between the shelters and social and work locations for the displaced population should be considered. Existing social practices, and the provision and maintenance of shared resources (such as water, sanitation facilities and cooking) should be taken into consideration in the design of shelters and also in the allocation of space within shelters and plots. The plot layout in the evacuation centers must preserve the privacy and dignity of individual households.

The use of materials and the type of shelter that are most commonly used among refugees or the local population is to be preferred for the construction of shelters. The design of the shelter must follow the simplest principles and structures. The provision of a solid and robust roof is the main requirement, and even when a complete shelter cannot be provided, adequate roofing should always be the priority.

Plastic tarpaulins can be easily found in most cases. Tents are not always the best type of shelter because it is not easy to live in them and also they cannot provide adequate protection against extreme climate conditions. Nevertheless, in certain cases, tents may be used as storage facilities, or to set up hospitals, schools and other facilities. The success of the evacuation centers highly depends on these facilities.

Table 4.10 outlines the specific requirements regarding flood shelters and refuges, as recommended in the Humanitarian Charter and Minimum Standards in Disaster Response (The Sphere Project 2004).

Table 4.10: Specific requirements for flood shelters and refuges

Surface area	45 square meters per person is indicated as the adequate surface area for a temporary evacuation center. This includes the shelter plots and areas necessary for roads, footpaths, educational facilities, sanitation, firebreaks, administration, water storage, distribution areas, markets and storage, plus limited kitchens for individual households.
Topography and ground conditions	The site gradient should not exceed six percent,, unless extensive drainage and erosion control measures are taken, or be less than one percent to provide for adequate drainage. Drainage channels may still be required to minimize flooding or ponding. The lowest point of the site should be not less than three meters above the estimated level of the water table in the rainy season.

Access to shelter locations	Existing or new access routes should avoid proximity to any hazards. Where possible, such routes should also avoid creating isolated or screened areas that could pose a threat to the personal safety of users. Erosion as a result of the regular use of access routes should be minimized where possible through considered planning.
Access and emergency escape	Steps or changes of level close to exits to collective shelters should be avoided. Where possible, occupants with walking difficulties or those unable to walk without assistance should be allocated space near to exits or along access routes free from changes of level. All occupants should be within a reasonable distance of a minimum of two exits, providing a choice in the direction of escape in case of fire, and these exits should be clearly visible.

Source: The Sphere Project 2004: 217-218.

4.10.4. Water supply and sanitation facilities for flood shelters and refuges

Access to water supply and sanitation facilities are two of the most important components in flood preparedness and relief; these are necessary to prevent the spread of diseases, create a safe environment and provide minimum personal hygiene. Health protection is always one of the major concerns when disaster occurs and creation of a healthy environment, therefore, becomes essential.

Excreta and other waste must be disposed of properly. In addition, general disinfestation measures must be taken. It is important that all sanitation measures are carried out in close coordination with those responsible for water supply and health services.

The identification of a water source is the most important task for the water supply system. Natural water can be sourced from groundwater, rainwater, and surface water. In most areas groundwater is the safest, followed by rainwater and then surface water. However in some areas, such as in India and Bangladesh, this is not suitable as groundwater may be naturally contaminated by arsenic, a poison.

Access to sanitary facilities, including toilets, showers, and waste disposal units, should be planned taking into consideration their adverse effects on any neighboring population. Evacuation planning should also reflect the gender roles, and the local social practices of the affected population, and particularly the needs of the most vulnerable (The Sphere Project 2004).

4.10.5. Stockpiles of required materials

The evacuation plan should include provision for the materials, equipment and tools that will be necessary during an evacuation. The CFMC should assess the need of such provisions in consultation with the community. Moreover, individual households should be asked to maintain some of the provisions, whilst the remainder should be maintained by the CFMC at easily accessible locations. Stockpiles of required materials may include:

- Ropes, harnesses or both
- Ladders
- Floating rescue devices
- Life jackets
- Inflatable boats
- Torches
- Loudspeakers
- Blankets
- Tents
- Food and clean water
- Dry food
- Tools (such as axes, metal cutters, crowbars, rescue knives)
- Radios or other reliable communications equipment.

4.10.6. Communications between shelters and refuges

The success of an evacuation plan is highly dependent on the efficacy of the communication systems. Established communication systems must ensure that the relevant authorities are promptly informed, for example by radio or telephone. Given that during the flood emergency situation the public telecommunications infrastructure may have been damaged and be out of order, the communications systems must be based on equipment that can operate independently. Standby electrical power sources may be required.

The sharing of information is essential to achieve a better understanding of the problems. Coordination among all those involved in an evacuation operation is necessary to assure that the evacuation plan is being implemented successfully. It is also important to establish communication mechanisms to allow the affected population to comment on the process of the evacuation operation. This can be done by organizing public meetings and through community-based organizations. Specific provision should be taken into consideration for individuals who are confined to their shelter, for example, the disabled.

Adequate access to information is a fundamental requirement for any communication system. A way to avoid anxiety and distress is to accurately inform the local population about all the aspects of a disaster. Information about the nature and scale of the flood, as well as the emergency operations undertaken by the local government and authorities, and other aid and relief organizations should be shared. Information should be uncomplicated and empathic with the difficult situation of the affected population.

Finally, national governments should designate certain radio frequencies (for in-country and for international communications) to facilitate disaster communications. These frequencies should be available to relief organizations and be known to the local communities prior to the disaster.

A case of an evacuation plan in Pakistan is now detailed in the case study below.

Case Study 4.11: The Lai Nullah Evacuation Plan, Pakistan

In order to mitigate the losses caused by floods, and particularly the loss of life, an evacuation plan was developed by the Japan International Cooperation Agency (JICA) in collaboration with the City District Government Rawalpindi (CDGR). The plan was accompanied by the implementation of a forecasting and warning system.

The Lai Nullah Basin has a large catchment area which extends to the twin cities of Islamabad and Rawalpindi. Floods in the region are caused by heavy rainfall during the monsoon season. In 2001, floods caused 74 deaths and damaged or completely destroyed a thousand houses.

The main purpose of this project was to establish an adequate evacuation system. As a result the project aimed to:

- Utilize the flood early warning system effectively
- Develop the capacity of local authorities and promote people's awareness and preparedness on floods.
- Strengthen the capacity of other related organizations to mitigate flood losses.

Before implementation, a field survey was conducted in the targeted area in order to build an understanding about the social and cultural context and better inform the evacuation plan. In particular, the survey aimed to investigate the ways in which individuals and local communities respond to flood events and how their behaviour might positively or negatively contribute to flood risk.

During the implementation of the program evacuation drills for residents will be taking place and hazard maps will be evaluated and improved. The case illustrates that evacuation planning along with flood forecasting and warning systems should be part of any emergency plan. Evacuation plans minimize the risks and impacts of flooding for the population of cities and towns.

Source: JICA Pakistan; JICA 2007.

4.10.7. Further Reading

ADPC. 2005. Primer for disaster risk management in Asia. Asian Disaster Preparedness Center and United Nations Development Program.

The Sphere Project. 2004. Humanitarian charter and minimum standards in disaster response. Geneva: The Sphere Project.

UNDP. 2009. Emergency Relief Items, Compendium of Generic Specifications. UNDP.

UNHCR. 1999. Handbook for emergencies. 2nd Edition. Geneva: UNHCR.

UN. 2004. Guidelines for Reducing Flood Losses. UN Department of Economic and Social Affairs (DESA), UN Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN ISDR), and National Oceanic and Atmosphere Administration (USA NOAA). Geneva: United Nations.

WMO. 2011. Flood Emergency Planning: A tool for Integrated Flood Management. Associated Program on Flood Management.

FEMA. n.d. Evacuation plans. http://www.fema.gov/plan/prepare/evacuation.shtm.

4.11. Flood recovery and reconstruction

Not all floods can be defended against: the planned recovery from a flood event is a valuable tool in flood risk management, and forms a part of a flood resilient mentality. As discussed above, emergency warning and evacuation together with the construction of the most resilient critical infrastructure and buildings is a planned way of ensuring in advance that the need for recovery and reconstruction is minimized. However, there will inevitably be some damage necessitating reconstruction. This section covers this process.

As full reconstruction can take many years, it is important to do two things: firstly, to ensure that normal life can be resumed despite the on-going reconstruction work; and secondly, to shorten the time taken for reconstruction as much as possible. Gaining access to flooded areas is the first stage, as discussed below. Next, a rapid assessment of the state of critical infrastructure will help to establish the extent and scale of damage and inform plans for getting the critical infrastructure up and running again at a national level. Coordination of recovery efforts throughout all sectors can then be most easily achieved.

4.11.1. Access and solid waste clearance

Recovery agencies and those affected will need access to the affected areas. After the floodwaters have receded, access difficulties are likely to continue because of the destruction of roads and other transport routes. Furthermore, there will be blockages formed by large amount of debris which has been carried out from its place of origin and deposited elsewhere, as well as from collapse of structures in situ. Clearance of the waste is, therefore, a high priority during recovery to enable access and for reconstruction work to commence.

4.11.1.1. Types of flood-generated waste

Solid waste generated by flooding will include:

- Eroded soils and rocks, depending on the local topography
- Building materials such as concrete and wood
- Uprooted and washed out vegetation
- Corpses, both human and animals

- Vehicles, and in the case of a tsunami, boats.

The type of material deposited is dependent on factors unrelated to the waste normally generated, including the following:

- The dynamics or destructive power of the flood
- The source of the flood, whether from the hinterland of a town, or from the sea for a tsunami or tidal surge
- The topography of the town and surrounding area, including if it is flat or mountainous and also the size of the urban area affected.

4.11.1.2.Types of flood-related wastes

- Mud and rocks. The upstream erosion of land will generate significant volumes of mud and rock debris which is likely to be deposited in the urban areas as a result of the slowing of the floodwater as it passes through urban areas.
- Household debris. Household goods will stay mostly within the surviving buildings but some possessions and furniture may be lifted and carried by fast flowing water. Vehicles will be easily washed way and may form a significant component of the debris in the larger urban areas.
- Construction materials. The majority of the debris from a high energy flood will reflect the predominant building material of the area, such as concrete and stone in the more affluent areas, wood in earthquake prone areas and sheeting (including corrugated iron) in the low income areas.
- Corpses (human and animal): The decomposition of corpses poses a significant health risk, especially in hot climates where biodegradation and disintegration will occur rapidly. Wherever possible human remains should be identified and recorded by listing in public places for relatives to consult. Where there are insufficient facilities to retain bodies, these should be buried in marked mass graves with the appropriate cultural and religious traditions. Animal carcasses should be buried in separate mass graves. It is unlikely that the size of existing burial sites will be sufficient, and new sites should be selected with regard to land ownership and distance from ground and surface water supplies.

4.11.1.3.Clearance of flood-generated waste

The purpose of flood waste management, in order of priority, is as follows:

- Clearance of waste to allow access to important locations within the impacted urban area

- Clearance of waste that is preventing drainage of flood water
- Clearance of domestic waste from the new centers of population
- Clearance of waste from hospitals
- Clearance of corpses
- Re-establishment of regular collections to surviving areas.

In the event that the pre-flood waste management system is no longer operational and the equipment has been destroyed, a completely new system will have to be established, preferably under a single temporary agency to maximize the use of scarce equipment and manpower. If the pre-flood waste management system is still operational it is unlikely that the existing equipment would be sufficient or that the personnel would be able to adjust to the significant change in operational practices required.

The clearance equipment required would include:

- Mechanical diggers, preferably wheeled, because unlike tracked vehicles they are able to access sites without the need for a low loader.
- Large capacity dumper trucks.
- Tractor trailers may also be used for local unspecialized collections.

Manpower may be recruited from amongst the internally displaced persons (IDPs); although waste collection is not the most attractive of operations, it provides employment as well as a sense of contributing to the restoration of their town and often confers status amongst the community.

The different types of material that may be segregated for reuse, their potential uses and the processing required are shown in Table 4.11.

Table 4.11: Types of material that may be segregated

Material	Potential use	Potential processing
Soil (contaminated)	Replacement of eroded soil. Flood defenses. Landscaping of subsequently abandoned areas to form public open spaces. Replacing soil eroded from agricultural areas	Segregation, mixing with uncontaminated organic material

Trees and vegetation	Sawing into building material. Chipping as fuel. Export for manufacture of building board.	Segregation, cutting and chipping
Wood (construction)	Construction of temporary shelters and fuel.	Segregation, cutting and chipping
Sheeting (metal)	Reuse for temporary shelters. Bailing and export for recycling	Segregation, sorting and bailing for export
Bricks, concrete, stones and sand	Size selection and crushing for use as hard core for infrastructure (e.g. replacing or raising roads, replacing wharfs, replacing or repairing railway embankments and flood defenses).	Segregation, sorting and crushing
Steel	Export for reuse.	Segregation and storage for future-use
Household goods	Repair and reuse depending on condition.	Segregation
Industrial equipment	Repair and reuse depending on condition	Segregation
Vessels and vehicles	Re-floating vessels, salvaging useable items, breaking for timber or steel	Segregation, disassembly and export

4.11.1.4. Management of the waste of Internally Displaced Persons (IDP)

Floods, like other emergency situations, result in a considerable displacement of people elsewhere in the country, to unoccupied buildings unaffected by the flood and open areas or to refugee camps. Many IDPs, by preference, are likely to move out of the area to stay with relatives where they will add to the quantity of household waste being produced. This may strain existing waste management facilities. Other IDPs will wish to stay near their properties and communities, occupying any available space, including buildings and open ground. These will be at best only equipped with rudimentary facilities.

- Those people who have no other opportunities will often be temporarily housed in refugee camps run by external organizations. The camp design should incorporate waste collection and sanitation facilities, and allow the collection and transportation of waste from the camps to the disposal site.
- After the flood emergency had passed, the closure of buildings and land previously occupied by camps and emergency facilities will generate large quantities of a wide range of waste material redundant household goods

(blankets, cooking materials); shelter facilities (such as tents and plastic sheeting); infrastructure (fencing, lighting and latrines); and much of this will not be reusable and will, therefore, require collection and disposal. Departing Agencies should not be relied on to clear the sites and remove and dispose of their waste.

4.11.1.5. Management of non-flood waste after a flood

After a flood, waste will continue to be generated by the resident population but where the pre-flood waste collection system has not recommenced, this will be disposed of wherever possible, including those areas which have already been cleared. The type and quantity of waste is also likely to change significantly in the following ways:

- Municipal waste or household waste: there will be a reduced volume where it is normally collected, because of the reduction in the number of inhabitants. However, this will be replaced by that generated by the camps and emergency facilities.
- Commercial and industrial waste: following any occupation of commercial and industrial premises by IDPS, owners and occupiers will want to regain access to their buildings, clear waste (including silt, debris, damaged goods and equipment), refugees' household materials and sewage, where relevant.

4.11.2. Mitigating damage

There are steps that can be taken after a flood, by both governments and individuals, which may reduce the level of damage suffered. As discussed in Chapter 2, the damage suffered during flooding is made worse by factors such as the duration of the inundation. Where floods are prolonged, the potential for water-borne disease is greater, materials in contact with floodwater will degrade and the potential for scour, erosion and undermining increases. Draining floodwaters from the affected area can therefore be a crucial first step in recovery and lead to a faster restoration process. One of the disadvantages of hard engineered flood defenses is that, if overtopped, they stand in the way of water regaining its normal course and lead to more prolonged flooding. In these cases, either pumping out the water or, possibly, destruction of portions of defenses is warranted.

Within buildings and enclosed areas, underground spaces may allow water to accumulate and take time to disperse. In some instances this can increase structural damage, if the water outside has receded: careful pumping out of water from such areas is advisable.

Secondary damage is also possible, either from wet and damaged contents, or from ill-advised attempts to dry buildings and contents. It is advisable to remove wet and damaged contents from buildings as soon as possible, as this will enhance drying and reduce damage. In temperate conditions, the access of air to wet buildings and contents will enhance drying and speed up recovery.

4.11.2.1. Identify and prioritize key items of reconstruction

The most important component of continuity planning is to prioritize the repair of public infrastructure, especially roads, railways and embankments. A prioritization process should consider the provision of services at the regional, city and community levels, so as to ensure the continuation of minimum functions. For example, if suppliers of food, fuel, telecommunications, or transport services have not developed plans covering continued delivery of their services in the context of a flood disaster, then the economic, social, humanitarian and governance consequences of a disaster can be significantly intensified.

Critical infrastructure can be defined as those facilities, systems, sites and networks necessary for the functioning of the country. Typically this might include any or all of:

- Roads including bridges and tunnels
- Railways
- Canals and rivers
- Airports
- Ports
- Electricity generation and supply
- Water treatment and supply
- Wastewater removal and treatment
- Fuel supply domestic and industrial and to transport networks
- Telecommunications
- Computer networks
- Hospitals and health facilities

– Government buildings

– Food distribution network.

The order of priority of restoration of the infrastructure will be to some extent specific to the country and settlement size concerned and will also depend on the scale and severity of the flood event. Planning for resilience in the critical infrastructure makes the restoration more straightforward, for example, careful placement of infrastructure sites will cause them to suffer less damage. Increasingly the dependence of all other systems on power means that the restoration of power, or provision of emergency power supplies, may be the most important need. However, the provision of clean drinking water, either through emergency distribution or rapid restoration of clean water infrastructure, can also be seen as a major priority in large disasters, as this can significantly reduce the incidence of waterborne diseases such as cholera.

4.11.2.2. Planned redundancy

The failure of some infrastructure is an inevitable consequence of flooding and where the drive towards efficiency has led to a tightly integrated infrastructure, the failure of one element can lead to a domino effect of further indirect consequences. For example, the failure of electricity systems can leading to pumping station failures, which could worsen both the depth and impact of a flood event. Similarly, road failure leads to the inability of emergency responders to reach affected populations. The notion of planned redundancy is to increase the capacity of systems, such that a reasonable proportion of the infrastructure can be affected but the extra demand can still be absorbed elsewhere. In power generation grids this could be achieved by having reserve capacity in the system (operational capacity over and above that required to meet demand).

4.11.3. Assessment and prioritization of needs

There are many different types of assessment which may be carried out in the aftermath of a flood as shown in Table 4.12. These assessments have different purposes and can be carried out with varying degrees of accuracy depending upon the purpose of the evaluation. A rapid assessment is required at the outset of recovery, to assess the level of damage and the priority areas for direction of recovery effort. Such an assessment will be achievable more rapidly, with greater accuracy and, therefore, be more effective if it builds upon pre-event vulnerability and risk assessments. Ideally, a database of vulnerable assets and likely damage levels should be created in preparation for severe flooding.

Rapid assessments may be based on remote sensing equipment, satellite or airborne survey, eye witness reports or reports from emergency responders. Co-ordination of such evidence sources can also be planned in advance.

Table 4.12: Types of assessments

Type	Definition
Damage Assessment	An assessment of the total or partial destruction of physical assets, both physical units and replacements costs
Loss Assessment	An analysis of the changes in economic flows that occur after a flood and over time, valued at current prices
Needs Assessment	An assessment of the financial, technical and human resources needed to implement recovery, reconstruction and risk management. Usually 'nets out' resources available to respond to disaster.
Rights-based assessment	An assessment that evaluates whether people's basic rights are being met. Has its origins in the United Nations Universal Declaration of Human Rights
Rapid Assessment	An assessment conducted soon after a major flood event, usually within the first two weeks. May be preceded by an initial assessment. May be multi-sectoral or sector-specific. Provides immediate information on needs, possible intervention types and resource requirements
Detailed Assessment	An assessment undertaken after the first month to gather more reliable information for project planning. Often takes about a month to conduct and is usually sector-specific.
Housing Damage Assessment	A damage assessment that analyzes the impact of the flood on residential communities, living quarters and land used for housing.
Housing sector assessment	An assessment of the policy framework for housing, the post flood housing assistance strategy and the capability of the housing sectors to carry it out
Community-based assessment (CBA)	An assessment that analyses how the context will affect reconstruction and the way in which communication with the affected community can support the reconstruction effort. It includes government and political risk analysis, stakeholder analysis; media communication environment and local capacity analysis and social and participatory communication analysis

Source: Jha 2010

In any assessment and priority setting exercise it is important to consider the needs of the vulnerable. Good practice includes including members of vulnerable groups in assessments and collecting information on their needs. Vulnerable groups may be based on gender, age, and health, economic, racial, religious and marital status. Views on the needs and relevant groupings and even contact details can be collected in advance of flooding and this will make post-disaster consultation less onerous.

4.11.4. Post-disaster reconstruction and resettlement

4.11.4.1. Assessment of resettlement needs

In situations where flood damage has been extensive and the risk of further flooding of the area remains, then there may be little option but to relocate the affected population. People may have been temporarily relocated to evacuation facilities, but it is in everyone's interest that IDPs should be re-housed and that the temporary camps are closed as quickly as practicable after the ending of the emergency phase of the flood. The closing of evacuation facilities (often public buildings, such as schools) will need to be done as soon as possible to allow them to be returned to their normal role. The closing of the emergency shelters will not only contribute to the restoration of communities, by focusing on the way forward to rebuilding livelihoods, but will also provide a focus for agencies who may wish to withdraw their assistance at the end of the emergency phase, especially if resources are required to meet a disaster elsewhere in the world.

4.11.4.2. Resettlement planning

It is imperative that there should be an appropriate institution with the mandate and resources to address the need for resettlement after a serious flood event where people have been displaced. A fundamental and far reaching decision will need to be made, regarding the need to resettle IDPs in their original location or the extension of an existing urban area for the development of a new town. In formulating that decision the following factors should be considered:

- The susceptibility of the flooded area to further flooding and the cost of the engineering work to reduce that risk.
- The susceptibility of the proposed host area and the cost of the engineering works required.
- The willingness of IDPs to return to their home town, or the

willingness for the new host population to receive an influx of people whom they may regard with suspicion, if not open hostility.

- The extent of the restoration of the services in the flooded area, particularly potable water supply, wastewater collection and treatment, surface water drainage, electricity and other forms of energy. This needs to be compared to the cost and technical ease of supplying such services to a new area.
- The suitability of the proposed host area to provide the facilities for IDPs to continue their pre-flood livelihoods (for example, fishing households that need to live on the coast, as is often the case with tsunami and cyclone affected areas).
- Transport facilities to previous work and social areas, for those unable to find work locally, or with responsibilities for an extended family.
- The ownership of the host land and the arrangements for acquisition and financial compensation to the existing owners, whether private or public.
- The resolution of land ownership in the flooded area, when ownership documents may not exist or have been destroyed in the flood.
- Development plans for the abandoned urban area, that render it safe but which do not preclude further development. The silt cleared from the town may be stored and beneficially used to cover and seal the urban area for subsequent use for farming or a memorial park.
- Financial and institutional resources to implement a formulated detailed resettlement plan.

The planning and implementation of such a resettlement plan will need to be a highly participative process, including all of the affected people, both the flood displaced people and also those people living at the locations being considered as appropriate sites for relocation. In order to facilitate rapid implementation, resettlement plans should start to be developed during the emergency phase of the flood relief effort. Early decisions may then be incorporated in the clearance of debris in order not to preclude future development.

Case Study 4.12 illustrates good practice in this area.

Case Study 4.12: The case of the tsunami-damaged village of Xaafuun, Somalia

Disaster affected areas can be improved considerably by taking advantage of the opportunities that might arise after a disaster. In Xaafuun, a remote village located in the northeastern coast of Somalia, post-disaster reconstruction after the Indian Ocean Tsunami in December 2004 provided an opportunity to tackle multifaceted problems in the Somali coastal region.

Owing to a lack of formal institutional arrangements, and insufficient expertise in planning and coordination, the initial interventions that were implemented by numerous organizations were located within the sensitive and unstable dune ecosystem near the old village. In particular, houses were built at sea level near the coast, destabilizing the very fragile ecosystem of the area.

In response to this, UNICEF, in partnership with UN-HABITAT, investigated the ways in which the village could be relocated to a more appropriate site. A multi-disciplinary team, comprised of urban planners, a local economic development expert and an environmental expert were given the task of identifying a safe and environmentally sustainable site.

The final decision for the new location of the village was agreed upon with the district authorities, the village elders and the women's representatives. A new and more appropriate layout for the houses was agreed, after the preparatory sketch plan was discussed with all local actors. The village plan (shown in Figure 4.15) was based on the following principles:

- Compact settlement to mitigate the impact of strong winds on living spaces and housing units, which also ensures the cost-efficient development and operation of basic services
- A public zone comprising both public spaces and public buildings that faces the sea, is acting as a buffer between the residential area and the dunes
- The main road links the main public facilities and aligns with the access road to the village and previously built structures
- A small-scale fishing industry and spaces for spontaneous economic activities and social gatherings were created next to the formal market
- The plan considered the need for expansion of the village over time.

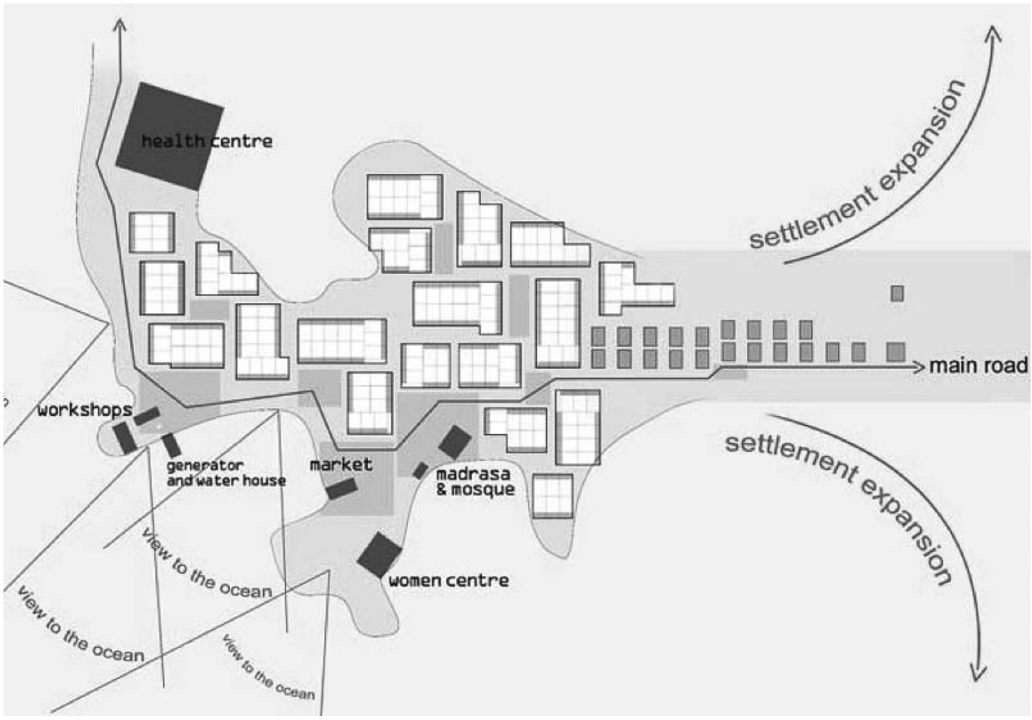

Figure 4.15: Village plan, Source: UN-HABITAT 2006

Relocation of the settlement allowed the dismantling of the original village and the environmental rehabilitation of the dunes. Local authorities demonstrated clear environmental awareness, for example, by forbidding cutting of live wood and re-using construction materials from the old village, while youth and women's groups showed interest in re-planting the dunes to facilitate the natural rehabilitation of the disrupted ecosystem. Since the completion of the project, Xaafuun attracted substantial investments that can further contribute to economic development objectives over the longer-term. Good practice in this case was demonstrated in the way in which long-term development perspectives were introduced in a post disaster situation.

Source: UN-HABITAT 2006.

Many former residents may not wish to return to a flooded location and may individually make the decision to move elsewhere in, or away from the urban area. This is often the case where there are family links to locations elsewhere: this has been a significant factor for large numbers of people who did not return to New Orleans after Hurricane Katrina. Significant migration away from the flooded urban area will reduce the number of people that have to be formally resettled. However, it is often the case that it is the least able people (typically the poor, the elderly and the economically challenged) who will have little choice but to remain in the flood affected area. It may be the case that these people are concentrated in a particular area (in a specific section of an urban area, as was the case in New Orleans) and this may place additional burdens on the land and services there, which may already be fragile. A significant challenge will be the establishment of an adequately resourced and technically capable authority with the remit and commitment to direct, oversee and co-ordinate the resettlement program.

4.11.4.3. Implementation of resettlement and reconstruction programs

It is unlikely that the resettlement plan will be implemented until sometime after the emergency. Some possible major barriers to its effective implementation include the following:

- Land availability
- Local hostility
- Availability of resources
- Political interference
- Corruption

The flood victims and the host community should be involved at every stage, but it should be recognized that the former may be so traumatized, and their lives so disrupted by the flood, that they are unable to make long term decisions. Failure to involve communities may result in violence motivated by land issues, jealousy that IDPs are receiving preferential treatment, significant corruption by individuals and the lack of clarity in the plans and the speed in carrying the plans forward.

4.11.4.4. Resettlement of flooded areas

Once cleared and drained the urban area may be resettled; many damaged buildings may be reinstated and repaired to a habitable condition, sometimes to a better standard than their pre-incident condition. Before any reinstatement works commence, it is very important to ensure that building components and materials are sufficiently dry. Failure to adequately dry buildings can lead to latent defects, mould growth and the need for further remedial works. A useful practical guide to drying water-damaged dwellings can be found in Lakin and Proverbs (2011) and is detailed in the How To section below. The drying of a flood damaged property is a complex process that is best undertaken by a competent and well trained technical person, such as a qualified damage management technician. The following outline provides a succinct guide:

- Stop the flow of water. No drying process can be successfully completed until the flow or ingress of water is stopped.
- Assess and address health and safety issues. Post warning and information notices.
- Survey the whole building inside and out, take pictures of pre-existing damage to the property. Take moisture readings and record on a drying plan. Take control 'dry' readings. Check outside relative humidity and temperature readings to facilitate flushing the building.
- Access and extract pooled and reservoired water.
- Install correct drying equipment and erect containment to create a balanced controlled drying system.
- Use the target drying method to efficiently achieve aims.
- Visit the property regularly to record moisture readings and adjust until completion.

Each stage of this process involves considerable care and attention requiring a detailed knowledge and understanding of the many technical issues involved.

In other cases, resettlement may be difficult to implement, because of the occupation of any remaining buildings, proving land ownership and inappropriate clearance that may prevent development. Improvement in urban planning and infrastructure may be difficult to achieve for similar reasons. There may also be an understandable fear of settlement in the area due its perceived continuing flood risk.

4.11.4.5.New development

Key elements in the design of the new habitation areas include the following considerations:

- The layout of the development and population density

- The facilities normally available to a typical family (for example the number of rooms in a house). A well proven strategy is to design a basic core house that can then be modified by individual households to meet their requirements
- The availability and suitability of appropriate materials (for example wood in earthquake prone areas)
- The availability of skilled workers for the reconstruction works.

There should be elements of improvement – or building back better, as the phrase goes – which include the following:

- Reduction in population density
- The widening of roads to accept modern vehicles
- Improved water supply, sewerage and surface water drainage. In places where it has not already been carried out it may be prudent to consider the separation of sewerage from the surface drainage network and to construct the drains to reduce the risk of flooding from blockages
- Improved foundations to improve building stability, especially in earthquake prone areas
- Wider distribution of electricity
- Provision of neighborhood waste disposal points to encourage proper disposal of waste.

4.11.5. How to restore flood damaged buildings

Buildings which are flooded but which remain structurally sound will nevertheless need to be cleaned, dried and restored before reoccupation. Facilitating this quickly has been shown to reduce stress for homeowners and disruption for business and public service providers. The process for responsive restoration has several phases, including drying.

Method

1. Assess damage

2. Clear and remove standing water and decontaminate

3. Determine appropriate treatment

4. Drying phase

5. Repair phase

1. Damage assessment

As discussed in Chapter 2, damage and loss assessments can be required for different purposes. The purpose of damage assessment here is to assess the level of damage, likely cost of repair and any structural or health and safety issues which will affect the integrity of the restored building and may render restoration impractical or dangerous. Before entering any building to make a detailed assessment, it is essential to ensure that the structure is made safe. In cases of doubt expert assistance should be sought.

The involvement of structural engineers may be necessary, particularly if the flood was of a depth and/or velocity likely to cause structural damage. In some recent events of large magnitude the use of "building triage" was used whereby a rapid assessment was undertaken by trained personnel to identify which buildings needed a more in-depth expert evaluation. Insured properties may well need to be formally assessed by an agent of the insurance company prior to commencement of any restoration (a full estimation of repair costs can be made at this stage).

At damage assessment stage it is important to consider older and historic buildings as a separate case as they will require specialist input and potentially should observe requirements relating to relevant conservation orders. Report of the assessment should ideally include details of all building elements damaged and an inventory of damaged contents. Details of the flood characteristics, including its depth, velocity and contaminants,are also very useful.

2. Clear and remove standing water

Once it is safe to do so, standing, pooled and trapped water can be extracted to facilitate drying. The use of pumps, bailing or absorbent materials are suitable. It is important to wait until the water has subsided before pumping out water, and also until groundwater has receded before pumping out basements. To avoid structural stress on the building after deep flooding it is advisable to phase pumping to ensure equalisation of levels throughout the internal space. It is advised to limit basement pumping to one meter of water in any one day and to place generators outside of closed spaces (Ciria 2005). Vacuum pumps can be fitted to a variety of delivery mechanisms. These include mats and wheeled devices which will extract moisture from floor coverings. Mud should be removed while still wet, with shovels and can involve the use of scrubbing and high pressure hoses, if appropriate to the building type and finishes. Cavities should be opened for drying and cleaning. Disposal of mud and silt must be in accordance with controlled waste regulations with particular attention to any hazardous substances.

3. Determine appropriate treatment and strip out

The choice of drying and repair method is usually dependant on a variety of factors such as the building type, tolerance to further building damage, resources available and building occupancy (Soetanto and Proverbs 2004). Usually the choice will be based on an assessment that involves a thorough building survey, assessment of the risk of future flooding and consultation with property owners and occupiers. This survey must cover all areas of the property, whether apparently affected or not, as moisture can pool and wick through materials and evaporation within closed spaces can result in damaged areas that were not in contact with the water. If areas are neglected, there is a real possibility that the drying process will be incomplete. This can lead to rot, mold, and degradation of the building fabric. Inadequate drying can lead to health issues in the longer term.

A drying standard can be set at this stage using the information collected on site. Drying standards use the normal equilibrium conditions in a building to set a benchmark. Targeted moisture levels for the affected areas are determined based on a combination of established principles and criteria for the particular material balanced with moisture readings taken in an unaffected area. Attempts to dry buildings to theoretical standards that do not take account of pre-existing conditions and ambient factors may never reach expected completion readings.

Natural drying of buildings can take months (Ciria 2005), and the desire to dry quickly usually means some form of assisted drying is preferred. Experience suggests that drying using traditional techniques can take place in three weeks under ideal conditions. Ideal conditions include a combination of reasonable ambient temperatures, low humidity and adequate air circulation. Therefore even in high temperature zones drying can be delayed if humidity levels are high or the air is still. Internal conditions can become saturated quite quickly and cause further damage if adequate ventilation is not ensured.

Assisted drying can simply involve the use of fans to increase circulation and keeping all windows open. However, it is also possible to dry multiple properties very quickly and simultaneously using “speed drying” techniques although there is still some doubt as to the possibility of damage to building contents and they may not be suitable for historic or heat-sensitive buildings or building components.

Building elements may be dried in situ, removed for drying, or stripped out and replaced. Stripping out of materials which cannot be dried should occur before drying is attempted. However guidance is divided as to whether it is preferable to remove and replace other elements rather than undertake time consuming and expensive restoration. Removal of wet materials can assist the drying out of the building fabric. A decision on which elements to strip out and which dry will form part of the drying and restoration plan.

The cost of drying methods will need to be balanced with the required speed of drying and other factors such as the balance of energy used during drying against embedded energy in building materials stripped out and replaced (Tagg et al.2009). Security concerns can weigh against the desire to keep buildings open; in this case dehumidifiers may be employed in closed conditions. Historic features may need to be conserved despite the high cost of drying and restoration. Drying methods may also be varied during the drying process as different phases are reached (Soetanto and Proverbs 2004)

4. Drying phase

Once the water is extracted and wet materials stripped out, the drying of the building and remaining in situ fixtures and fittings can begin. Drying is fundamentally a process which involves evaporation from the surface of wet materials into air which is at a lower relative humidity than the material itself. Differences in relative humidity determine the speed of evaporation. It is vital that on completion of the drying process, the structural materials are checked to ensure they will not enable or support mould or mildew growth. There are three basic methods available:

Naturally with ventilation and possibly fan-assisted. This is the slowest method of drying a building and can be severely affected by the prevailing ambient conditions. An ideal initial approach is to allow natural ventilation and evaporation to "flush" the wet air from the building. This is achieved by correct placement of air movers to draw out damp air, thus replacing it with drier air from outside. It is much better for the structure if climatic conditions allow and enables the process to be kick started to aid efficient drying. The specific humidity differential of the introduced air needs to be 5 to 10 percent lower between outside and inside, with a temperature of 20 centigrade as an ideal.

Convection drying using heat and ventilation. This method includes high temperature "speed drying" methods and traditional fan heaters but could also encompass use of the in situ heating system, if one exists, and open windows. Great care must be taken when using high heat forced-air or air conditioning systems. Rapid drying out of historic buildings using hot air power drying systems could cause irreparable harm to significant features of the building. Knowledgeable use of a psychrometric chart, thermometer and hygrometer will greatly aid this process and illustrate the effectiveness of the drying plan for future reference. Expert assistance is usually advisable.

Use of dehumidifiers. There are two main types of dehumidifier namely refrigerant and desiccant. Refrigerant dehumidifiers operates best between 15-28oC and at 60-98% relative humidity as they cool down the air and extract water through condensation. Desiccant dehumidifiers have a wider range of operating conditions as they use chemicals which can attract water (desiccants) to draw water from the air. Desiccant dehumidifiers can be used to push dry air into closed spaces. Dehumidifiers should be used in a closed environment as they rely on creating an unnaturally dry atmosphere; the speed of drying is largely dependent on the capacity of the equipment relative to the space to be dried.

It is important to ensure that all drying equipment is working well and to select the optimum number of dryers or humidifiers. The capacity of a dehumidifier relates to the figures for water removal over a twenty four hour period at a given temperature. To calculate the number of dehumidifiers that will be initially required to be deployed, the first step is to decide how many air changes per hour will be required to use the drying equipment efficiently.

Monitoring of the drying process is also crucial to ensure controlled drying. The initial survey shows the state of the building on the day of the incident and target moisture levels for completion. As drying proceeds, regular monitoring will provide the information needed to target the drying effort, adjust the containment areas and to place equipment accordingly.

5. Repair Process

Once drying targets are reached, the reinstatement of the building can commence. The drying target for commencing repair may take account of the fact that wet processes such as re-plastering may be tolerant to high levels of moisture. Reinstatement may involve further stripping out of elements which did not dry satisfactorily or were damaged during the drying process. Repair should follow existing construction regulations, and observe health and safety standards. Recommended repair processes can be found in Proverbs and Soetanto (2004).

The repair process should, if finances allow, be designed to minimize the risk of future flood damage and may include the replacement of water-sensitive materials with more resilient alternatives (Proverbs and Soetanto, 2004). Characteristics of resilient materials include:

- Low permeability
- High integrity
- Ease of cleaning
- Less susceptibility to contamination
- Fast drying

Further guidance for specific building elements can be found in Soetanto et al (2008). Research shows that such installations are less disruptive and costly when undertaken as part of the repair process than as a discretionary retrofit (Joseph et al., 2011).

4.11.6. Further guidance

Butcher, D. 1971. *An operational manual for resettlement*. Rome: FAO.

CARE International, ProAct, emergency shelter cluster. 2009. *Post-disaster debris guidance*. http://postconflict.unep.ch/humanitarianaction/documents/02_05-04_01-03.pdf.

CIRIA 2005 – Standards for the repair of buildings following flooding, CIRIA, London

Cernea, M. M. 1988. *Involuntary resettlement in development projects*. World Bank Technical Paper No.80, Washington, DC.

Colson, E. 1971. *The social consequences of resettlement*. Manchester: Manchester University Press.

Environmental Protection Agency. 2008. *Planning for natural disaster debris*. http://www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/pndd.pdf.

FEMA (Federal Emergency Management Agency). 2007. *Debris management guide, public assistance, FEMA-325*. http://www.fema.gov/government/grant/pa/demagde.shtm.

Jha, A. K. 2010. *Safer homes, stronger communities: A handbook for reconstructing after natural disasters*. Washington, DC: World Bank, GFDRR. http://www.housingreconstruction.org/files/saferHomesStrongerCommunities.

Oxfam. n.d. *Guidelines for solid waste management in emergencies. Oxfam* *technical manual*. http://www.oxfam.org.uk/resources/.../TBN15_domestic_refugee_waste.pdf.

Proverbs, D. & Soetanto, R. 2004 Flood damaged property: A guide to repair. Blackwell Publishing Ltd, ISBN 1-4051-1616-1.

USEPA. 2008. *Planning for Natural Disaster Debris EPA530-K-08-001, Office of Solid Waste and Emergency Response & Office of Solid Waste*. http://www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/pndd.pdf.

4.12. References

Abarquez, I. and Murshed, Z. 2004. *Community-based disaster risk management: Field Practitioners' Handbook* ADPC.

AFRICAN DEVELOPMENT BANK (2002) Study on solid waste management options for Africa. Abidjan, ADB.

ADPC (2005) *Primer for disaster risk management in Asia*. Asian Disaster Preparedness Center and United Nations Development Program.

ADPC (Asian Disaster Preparedness Center). 2006. *Integrated flood risk management in Asia*.

ADPC (Asian Disaster Prevention Center). 2008. *Flood disaster mitigation and river rehabilitation by Marikina City, Philippines. Safer Cities 22: Case studies on mitigating disasters in Asia and the Pacific*.

Alam, K. 2008. *Flood disasters: Learning from previous relief and recovery operations. ALNAP Lessons Paper*. ALNAP/Provention Consortium.

Ali, M., Cotton, A., and Westlake, K. 1999. *Down to earth: solid waste disposal for low-income countries*. WEDEC. http://www.wedc-knowledge.org/wedcopac/opacreq.dll/fullnf?Search_link=AAAA:M:589158920300.

Arnold, M., Chen, R.S., Deichmann, U., Dilley, M., Lerner-Lam, A.L., Pullen, R.E. and Trohanis, Z. ed. 2006. *Natural Disaster Hotspot Case Studies*. Washington, DC: World Bank Hazard Management Unit.

Bhatt, M. and Aysan, Y. 2008. "Evaluation of the DIPECHO Action Plans in South

Asia." ALNAP, European Commission Humanitarian Office. http://www.alnap.org/pool/files/erd-3671-full.pdf.

Bhattacharya, N., Lamond, J., Proverbs, D. 2011. "Flood vulnerability and hazard adjustment for UK commercial sector."Paper presented at "International Conference on Disaster Resilience," Sri Lanka.

Binahaan River Local Flood Early Warning System Operation Centre. 2009. *Binahaan River Local Flood Early Warning System. Annual Report 2007-2008*. BRLFEW System Operation Centre.

Burby, R. J. 2001. "Flood insurance and floodplain management: The US experience Global Environmental Change Part B." *Environmental Hazards* 3: 111-22.

Butcher, D. 1971. *An operational manual for resettlement*.Rome: FAO.

CARE International, ProAct, emergency shelter cluster. 2009. *Post-disaster debris guidance*. http://postconflict.unep.ch/humanitarianaction/documents/02_05-04_01-03.pdf.

CDC. 2008. *Re-entering your flooded home (Emergency Preparedness & Response)*. http://www.bt.cdc.gov/disasters/mold/reenter.asp.

Cernea, M. M. 1988. *Involuntary resettlement in development projects, World Bank Technical Paper No 80*. Washington, DC: World Bank.

Chowdhury, M.H.I. (2007) Solid waste service delivery fort informal settlement areas through strengthening partnership between local government and NGO's, PhD thesis, University of Technology, Berlin

CLG (Department of Communities and Local Government). 2006. *Planning Policy Statement 25: Development and flood risk – Practice Guide*. London: CLG.

Cointreau, S. 2003 Economic Instruments for Solid Waste Management. Washington: IADB/World Bank.

Colson, E. 1971. *The social consequences of resettlement*. Manchester: Manchester University Press.

Corsellis, T. and Vitale, A. 2005. *Transitional settlement: displaced populations*. Oxford: Oxfam Publications.

Creighton, J. 2004. *The public participation handbook: making better decisions through citizen involvement*. San Francisco: Wiley.

Cummins, J. D. & Mahul, O. 2009. *Catastrophe Risk Financing in Developing*

Countries. Washington, DC: World Bank.

Dale N., Nyirongo J., Anderson C., Baker L., Dilloway S., Faleiro F., van den Ende P., Bercilla J., and Beesley J. 2009. Local voices, *Global choices: For successful disaster risk reduction*. Christian Aid, Oxfam, Practical Action, Save the Children and Tearfund.

Darling, E., Skillen, L. and Wu, M. 2006. "Just Compensation Valuation Schemes After A Flood Disaster in France, California, and Louisiana." Paper presented at seminar "Disasters and the Law," Boalt School of Law, UC Berkeley, April 28. http://www.law.berkeley.edu/library/disasters/Darling_Skillen_Wu.pdf.

Diagne, K. 2007. "Governance and natural disasters: addressing flooding in Saint Louis, Senegal." *Environment and Urbanization* 19: 552-62.

Delica-Willison, Z. n.d. "Community-based Disaster Risk Management — Gaining Ground in Hazard-Prone Communities in Asia." Special unit for south-south cooperation. UNDP.

ECHO. 2005. *Model guidelines for mainstreaming water and sanitation in emergencies, protracted crises, linking relief, rehabilitation & development and disaster preparedness operations*. European Commission.

Emergency Management Australia. 2000. *The Good Practice Guide*. Commonwealth of Australia.

Environmental Protection Agency. 2008. Planning for natural disaster debris. http://www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/pndd.pdf.

FEMA (Federal Emergency Management Agency). 2007. *Debris management guide, public assistance, FEMA-325*. http://www.fema.gov/government/grant/pa/demagde.shtm.

—— . n.d. *Evacuation plans*. http://www.fema.gov/plan/prepare/evacuation.shtm.

Garrelts, H. and Lange, H. 2011. "Path Dependencies and Path Change in Complex Fields of Action: Climate Adaptation Policies in Germany in the Realm of Flood Risk Management." *AMBIO* 40: 200-9.

Gaschen, S., Hausmann, P., Menzinger, I. & Schaad, W. 1998. Floods - an insurable risk? A market survey. Zurich: Swiss Re.

Gautam, D.R. and Khanal, S. 2009. *Community Based Disaster Reduction – Contribution to Hyogo Framework of Action Kailali Disaster Risk Reduction Initiatives Case Study*. Lalitpur: Mercy Corps Nepal. http://ndrcnepal.tripod.

com/nepal_disaster_risk_case_study.pdf.

Global WASH Cluster. 2009(a). "Technical briefing for emergency response: Water Supply in Urban Flood Settings." http://www.humanitarianreform.org/humanitarianreform/Portals/1/cluster %20approach%20page/clusters%20pages/WASH/Urban_Floods_Water_Supply_Briefing.pdf.

Global WASH Cluster. 2009(b) "Technical Briefing for emergency response: Hygiene Promotion in Flood Settings." http://www.humanitarianre form.org/humanitarianreform/Portals/1/cluster%20approach%20page/clusters%20pages/WASH/Hygiene_Promotion.pdf.

Global WASH Cluster. 2009(c). "Technical briefing for emergency response: Sanitation in urban flood settings." http://www. humanitarianreform.org/humanitarianreform/Portals/1/cluster%20approach%20page/clusters%20pages/WASH/Urban_Floods_Sanitation_Briefing.pdf.

Global WASH Cluster. 2009(d.) "WASH Visual Aids Library (French, Spanish or English)." http://ceecis.org/washtraining/index.html.

Global WASH Cluster. 2009(e). "Hygiene Promotion in Emergencies, Lessons Learned from Koshi Flood Response." http://www.un.org.np/reports/UNICEF/2009/2009-05-01-Hygine-Promotion.pdf.

Godfrey, S. and Reed, B. 2011. *Cleaning and disinfecting wells. WHO/WEDC Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies*. Geneva: WHO/WEDC. http://wedc.lboro.ac.uk/resources/who_notes/WHO_TN_01_Cleaning_and_disinfecting_wells.pdf.

Government of Germany. 2005. *Act to Improve Preventive Flood Control of 3 May 2005. Federal Law Gazette I of 9 May 2005, 1224*. http://www.bmu.de/english/water_management/downloads/doc/35456.php.

Ibrekk, A. S., Krasovskaia, I., Gottschalk, L. & Berg, H. 2005. "Perception and communication of flood risk - preliminary results from the FLOWS project." Paper presented at "International conference on innovation advances and implementation of flood forecasting technology," Tromsø: Norway. (no date).

IASC. 2008. *Human rights and Natural Disasters, Operational Guidelines and Field Manual on Human Rights Protection in Situations of Natural Disaster*. http://www.reliefweb.int/rw/lib.nsf/ db900sid/KHII-7EE9KM/$file/brookings_HR_mar08.pdf?openelement.

ICDO (International Civil Defence Organisation). 2009. International Civil Defence Journal Vol. XIX N° 2 ISSN: 1022-3908, Pg. 27.

IFRC (International Federation Of Red Cross And Red Crescent Societies). 2007. *World Disaster Report: Focus on Discrimination*. IFRC. http://www.ifrc.org/Global/Publications/disasters/WDR/WDR2007-English.pdf.

—— . 2010. *World disasters report: focus on urban risk*. IFRC.

ISDR. 2004. "Reducing Disaster Risk: A challenge for development, ISDR informs: Latin America and Caribbean, Issue 9 web publication." http://www.eird.org/eng/revista/No9_2004/art12.htm.

—— . 2008. "Indigenous knowledge for disaster risk reduction: good practices and lessons learned from experiences in the Asia-Pacific region," UNISDR, Bangkok.

Jabeen, H, Johnson, C., and Allen, A. 2010. "Built-in resilience: learning from grassroots coping strategies to climate variability." *Environment and Urbanization* 22 (2): 415-432.

Jha, A. K. 2010. *Safer Homes, Stronger Communities A Handbook for Reconstructing after Natural Disasters*. Washington, DC: World Bank, GFDRR. http://www.housingreconstruction.org/files/saferHomesStrongerCommunities.

Jha, A.K., Singh, S.K., Singh, G.P., Gupta, P.K. 2011. Sustainable municipal solid waste management in low income group of cities: a review, *Tropical Ecology* 52(1): 123-131

JICA Pakistan Office. n.d. *The Project for the Improvement of the Flood Forecasting and Warning System for Lai Nullah Basin*. Under Japan's Grant Aid Program.

Joseph, R., Lamond, J., Proverbs, D. 2011. An analysis of the costs of resilient reinstatement of flood affected properties: a case study of the 2009 flood event in Cockermouth. *Structural Survey* 29: 279-293.

Kunreuther, H. 2002. "The role of insurance in managing extreme events: implications for terrorism coverage." *Risk Analysis 22* (3): 427–37.

Lakin, B. and Proverbs, D.G. 2011. "A practical guide to drying a water-damaged dwelling." In *Flood Hazards: Impacts and Responses for the Built Environment*, ed. Lamond, J., Booth, C., Hammond, F. and Proverbs, D.G. Florida: CRC Press.

Lamond, J. & Proverbs, D. 2009. "Resilience to flooding: learning the lessons from an international comparison of the barriers to implementation." *Urban Design and Planning* 162: 63-70.

Lamond, J., Proverbs, D. & Hammond, F. 2009. "Accessibility of flood risk insurance in the UK - confusion, competition and complacency." *Journal of Risk Research* 12: 825-40.

Lave, T. R. & Lave, L. B. 1991. "Public Perception of the Risks of Floods: Implications for Communication." Risk Analysis 11: 255-67.

Madamombe, E. K. 2004. *Zimbabwe: Flood management practices - selected flood prone areas zambezi basin. The associated program on flood management: Integrated flood management case study*. WMO/GWP.

Medecins San Frontieres. 2005. "Health care waste management in low income countries."

MoGA 2002. Ministry of General Administration, Govt of Nepal

MRC & ADPC 2007. *Case Study 3-Reaching out to the Public. Raising Community Awareness to Flood Risk Reduction in Cambodia*. MRC/ADPC.

Neussner, O. 2009. *Local Flood Early Warning Systems - Experiences from the Philippines (Manual)*. Tacloban, Phillipines: Technische Zusammenarbeit (GTZ) GmbH.

Neussner, O., Molen, A. & Fischer, T. 2008. "Using Geoinformation Technology for the Establishment of a Local Flood Early Warning System." Paper presented at Second International Conference of Geoinformation Technology for Natural Disaster Management and Rehablitation. Bangkok, Thailand (no date).

O'Donnell, I and Smart, K. 2009. *Responding to urban disasters: Learning from previous relief and recovery operations. ALNAP lessons*. Provention Consortium. http://www.alnap.org/pool/files/alnap-provention-lessons-urban.pdf.

Office of Climate Change. 2010. *Increasing Queensland's resilience to inland flooding in a changing climate*. Queensland: Dept. of Environment and Resource Management, Local Govt. Association.

Oxfam. n.d. "Guidelines for solid waste management in emergencies. Oxfam technical manual." Available from http://www oxfam.org.uk/resources/…/TBN15_domestic_refugee_waste.pdf.

—— . 2001. "Guidelines for public health promotion in emergencies." Oxford: Oxfam. http://www.oxfam.org.uk/resources/downloads/emerg_ manuals/public_health.pdf.

—— . 2008. *Technical guidance on how to handle and store hazardous waste* *(hospital, industrial, chemical, asbestos, batteries, gas, etc)*. http://postconflict.unep.ch/humanitarianaction/documents/02_03-04_01-04.pdf.

—— . 2009. *TBN 7-UD Toilets and Composting Toilets in Emergency Settings*. http://www.oxfam.org.uk/resources/learning/humanitarian/tbn_drafts.html#eco.

—— . 2011. "Six months into the floods, Resetting Pakistan's priorities through reconstruction." 144 Oxfam Briefing Paper, January 2011, Oxfam, Oxford. http://www.scribd.com/doc/52830168/Six-Months-Into-the-Floods-Resetting-Pakistan-s-priorities-through-reconstruction.

Phaiju, A., Bej, D., Pokharel, S. & Dons, U. 2010. *Establishing Community Based Early Warning System Practitioner's Handbook*. Lalitpur, Napal: Mercy Corps and Practical Action.

Pitt, M. 2008. *The Pitt Review: Learning lessons from the 2007 floods*. London: Cabinet Office.

Prasad, K. 2005. *Manual on community approach to flood management in India, Associated Program on Flood Management*. WMO/GWP.

Proverbs, D. & Soetanto, R. 2004 Flood damaged property: A guide to repair. Blackwell Publishing Ltd, ISBN 1-4051-1616-1.

Queensland Floods Commission of Inquiry. 2011. Homepage. http://www.floodcommission.qld.gov.au/home.

Rheinhard, D. n.d. *Invest to prevent disaster: A Re-Insurer's Foundation Perspective on Microfinance*. Munich: Munich Re.

Rouse, J.R. 2005. "Solid waste management in emergencies. WHO Technical Notes for Emergencies, N° 7." Prepared by WEDC. http:// www.who.int/water_sanitation_health/hygiene/emergencies/solidwaste.pdf.

Rushbrook, P. and Pugh, M. 1999. *Solid waste landfill in middle and lower income countries World Bank Technical Paper 426*. Washington, DC: World Bank.

SEGOB (Secretaria de Gobernacion). 2009. "Mexican experience in the creation and implementation of financial instruments to prevent and attend natural disasters." http://siteresources.worldbank.org/INTLACREGTOPURBDEV/Resources/presentFONDEN-FOPREWB140611.pptx. (Slides 2-5).

Setchell, C. A., 2008. Multi-sector disaster risk reduction as a sustainable development template, the Bamako flood hazard mitigation project. Monday Developments, Interaction.

Shaw, R. and Okazaki, K. ed. 2003. *Sustainability in grass roots initiatives: Focus on community based disaster management*. Hyogo, UNCRD. http://www.hyogo.uncrd.or.jp/publication/pdf/GrassRoots.pdf.

Siegrist, M. & Gutscher, H. 2006. "Flooding risks: a comparion of lay people's and expert's assessments in Switzerland." *Risk Analysis* 26: 972-9.

Spranger, M. 2008. *Natural Catastrophe Risk Insurance Mechanisms for Asia and the Pacific. Special Nature Of Disaster Risk In Megacities*. Tokyo, Japan.

Swiss Re. 2010(a). *The essential guide to reinsurance*. Geneva, Swiss Re.

Swiss Re. 2010(b). *Microinsurance - risk protection for 4 billion people*. Sigma 6. Zurich: Swiss Re.

Taylor, R. 2011. "Australia reviews disaster insurance, considers fund." *Reuters Canberra*, March 4 (Thu Mar 3, 2011 9:29pm EST). http://www.reuters.com/article/2011/03/04/australia-insurance-idUSL3E7E401C20110304?feedType=RSS&feedName=everything&virtualBrandChannel=11563.

Tearfund. n.d. "Disaster Risk Reduction - Raising Awareness of Risk Through Radio in Afghanistan: A Case Study." http://tilz.tearfund.org/webdocs/Tilz/Topics/DRR/Raising%20Awareness%20of%20Risk%20Through%20Radio%20in%20Afghanistan.pdf.

The Sphere Project. 2004. *Humanitarian charter and minimum standards in disaster response*. Geneva: The Sphere Project. http://www.sphereproject.org/content/view/27/84.

The Sphere Project. 2011. *Sphere, humanitarian charter and minimum standards in disaster response*.

Tucci, C. E. M. 2004. *Brazil: Flood management in Curitiba metropolitan area. The associated program on flood management: Integrated flood management case study*. WMO/GWP. http://www.apfm.info/pdf/case_studies/cs_brazil.pdf.

Twigg, J. 2007. "Characteristics of a disaster-resilient community, a guidance note." DFID Disaster Risk Reduction Interagency Coordination Group, DFID, London. http://www.benfieldhrc.org/ disaster_studies/projects/communitydrrindicators/community_drr_indicators_index.htm.

UNDP (United Nations Development Program). 2009. *Emergency Relief Items, Compendium of Generic Specifications*. Geneva: UNDP.

UNEP. 2008. *Disaster waste management mechanism: practical guide for* *construction and demolition wastes in Indonesia*. UNEP

UN-HABITAT. 2002. *Understanding Informal settlements: Case Studies for the Global Report 2003*. Produced by the Development Planning Unit (DPU), University College London (UCL).

UN-HABITAT. 2006. *Paving the way for sustainable development in a post disaster situation. The case of the tsunami-damaged village of Xaafuun. North Eastern Somalia*. UN-HABITAT. http://www.unhabitat.org/pmss/getElectronicVersion.asp?nr=2295&alt=1.

UN-HABITAT. 2008. *UN-HABITAT and the Kenya Informal settlement upgrading programme Report*. UN-HABITAT KENSUP team, Nairobi

—— . n.d. "Bamako - Using Partnerships to Support Environmental Management." http://ww2.unhabitat.org/programs/uef/cities/summary/bamako.htm.

UN HABITAT (2010) Solid Waste Management in the Worlds Cities. London/Washington, United Nations Human Settlements Programme/Earthscan.

UNHCR. 1999. *Handbook for emergencies*. 2nd Edition. Geneva: UNHCR.

UNICEF. 2006. "Behaviour change communication in emergencies. A tool kit." UNICEF, Regional Office for South Asia. http://www.unicef.org/ceecis/BCC_full_pdf.pdf.

UNISDR. 2007. *Building disaster resilient communities: good practices and lessons learned*.

United Nations. 2001. *Report of the Executive Director of the United Nations Centre for Human Settlements on the review and appraisal of progress made in the implementation of the Habitat Agenda*. UN General Assembly 25th Special Session.

—— . 2004. *Guidelines for Reducing Flood Losses*. UN Department of Economic and Social Affairs (DESA), UN Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN ISDR), and National Oceanic and Atmosphere Administration (USA NOAA). Geneva: United Nations.

—— . 2006. *Global Survey of Early Warning Systems*. UN.

—— . 2007. *Building Disaster Resilient Communities - Good Practices and Lessons Learned*. Geneva: "Global Network of NGOs" for Disaster Risk Reduction UN/ISDR.

—— . 2009. *Disaster Risk Reduction in Nepal Flagship Programmes*. UN: Kathmandu.

USACE (US Army Corps of Engineers). 1994. *Framework for estimating national economic development benefits and other beneficial effects of flood warning and preparedness systems*. Institute for Water Resources, Alexandria, VA.

USAID. 2006. Environmental Issues and Best practices for solid waste management, Environmental Guideline for USAID Latin American and Carribean Bureau.

USEPA. 2008. *Planning for Natural Disaster Debris EPA530-K-08-001, Office of Solid Waste and Emergency Response & Office of Solid Waste*.,http://www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/pndd.pdf.

Waterstone, M. 1978. *Hazard mitigation behaviour of urban flood plain residents. Working Papers*. Boulder Colorado: Institute of Behavioral Sciences.

WFP (World Food Program). 2002. "Urban Food Insecurity: Strategies for WFP – Assistance to Urban Areas." http://www.wfp.org/policies/introduction/policy.

WHO. 2006. "Guidelines for drinking-water quality, third edition, incorporating first and second addenda." http://www.who.int/water_sanitation_health/dwq/wsh0207/en/.

—— . n.d. "Technical Notes for Emergencies, N° 6." Prepared by WEDC. http://www.searo.who.int/LinkFiles/ List_of_Guidelines_for_Health_Emergency_Rehabilitating_water_treatment_works.pdf.

WHO/WEDC. n.d. "WHO Technical Notes On Drinking-Water, Sanitation And Hygiene In Emergencies: Technical Note no. 10." http://wedc.lboro.ac.uk/resources/who_notes/WHO_TN_10_Hygiene_promotion_in_emergencies.pdf.

WMO. 2011. *Flood Emergency Planning: A tool for Integrated Flood Management. Associated Program on Flood Management*.

Woodruff, A. & Holland, P. 2008. "Economic Tools for Flood Risk Reduction: Bridging the Gap between Science and Policy in Pacific Island Countries." Paper presented at 2nd Australasian Natural Hazards Management Conference Wellington, New Zealand.

World Bank. 1999. *What a Waste: Solid Waste Management in Asia*. Washington, DC: World Bank.

—— . 2005. *Natural Disaster Risk Management in the Philippines: Enhancing Poverty Alleviation Through Disaster Reduction*. The World Bank East Asia and Pacific Region and National Disaster Coordinating Council Republic of the Philippines.

Pumping out floodwater, gradually bringing down water levels in the high street, Yorkshire, UK (2007). Source: Gideon Mendel

Chapter 5

Evaluating Alternative Flood Risk Management Options: Tools For Decision Makers

Chapter 5. Evaluating Alternative Flood Risk Management Options: Tools For Descision Makers

5.1. Introduction

Chapter Summary

This chapter outlines, within a flood risk management context, the uses, benefits and, where appropriate, the limitations of existing tools and methods that can provide information to decision makers, illustrate the impacts of decisions to multiple stakeholders, and make the decision making process more transparent and accountable.

The key messages from this chapter are:

- While pros and cons of measures can be defined in purely economic terms, the judgments made by city managers, urban planners and flood risk professionals must consider broader issues, such as the vulnerabilities of inhabitants, the impact of measures, equity considerations, environmental degradation, biodiversity, sources of funding, social capital, capacity and the potential to obtain financing from third parties.
- Decisions regarding flood risk management are complex and require wide participation from technical specialists and non-specialists alike. There is clearly a role for tools which can predict the outcome of decisions, communicate risk and create linkages between stakeholders.

The impacts of flooding on cities and towns can be devastating and deadly, resulting in the need to manage the risks of flooding by governments, communities and individuals. The various measures or solutions which are available to manage flood risk in urban settings were described in Chapters 2 and 3. These methods have been successful in limiting the impact of flooding, particularly in the developed world. Urbanization, together with the observed and predicted changes in the climate, means that the solutions may need to be employed more widely to prevent the future impacts of flooding from becoming an even more destructive problem. However, despite this concern, it is not always possible or desirable to defend every urban settlement against flood risk to the highest possible technical standards. Government decisions about management of flood risk need to be balanced against competing and often more pressing claims on scarce resources as well as other priorities in terms of land use and economic development.

Decision makers and technical personnel therefore require a clear vision of the alternatives. There are now many methods and tools available to assist them in making choices. This chapter examines some of the more important of these, outlining their uses and benefits as well as their limitations in the flood risk management context.

Section 5.2 focuses on evaluating costs and benefits in monetary terms using Cost Benefit Analysis (CBA). However, city managers, urban planners and flood risk professionals must take a broader view and consider multiple aspects – some of which cannot be quantified. This need can be addressed by the use of Multi-Criteria Analysis (MCA).

Section 5.3 describes ways in which to determine the acceptable level of flood risk and to decide between alternatives, while taking account of wider policy, equity, and social issues and uncertainties.

Section 5.4 describes a variety of techniques and support systems which can be used in visualizing, assessing and communicating risk and its consequences.

5.2. Evaluating costs and benefits

Thorough assessment of flood risk should lead to more informed decision making and the selection of more appropriate flood risk reduction measures. The flood risk reduction solutions in the previous chapters provide an overview of different ways to reduce both exposure to flooding (the likelihood of being flooded) and the impacts of flooding (damage to property, for example).

The selection of the most appropriate solution (or series of solutions) is typically based on a combination of the effectiveness, cost and benefit that the solution or solutions may provide. This section will examine the methods of assessing the costs and benefits.

In conceptual terms, the reduction of risk by investment in risk reduction measures can be summed up by the term “buying down risk”. As illustrated in Figure 5.1 there is a cumulative impact of investment in each measure, which results in a residual risk of flooding lower than the original risk.

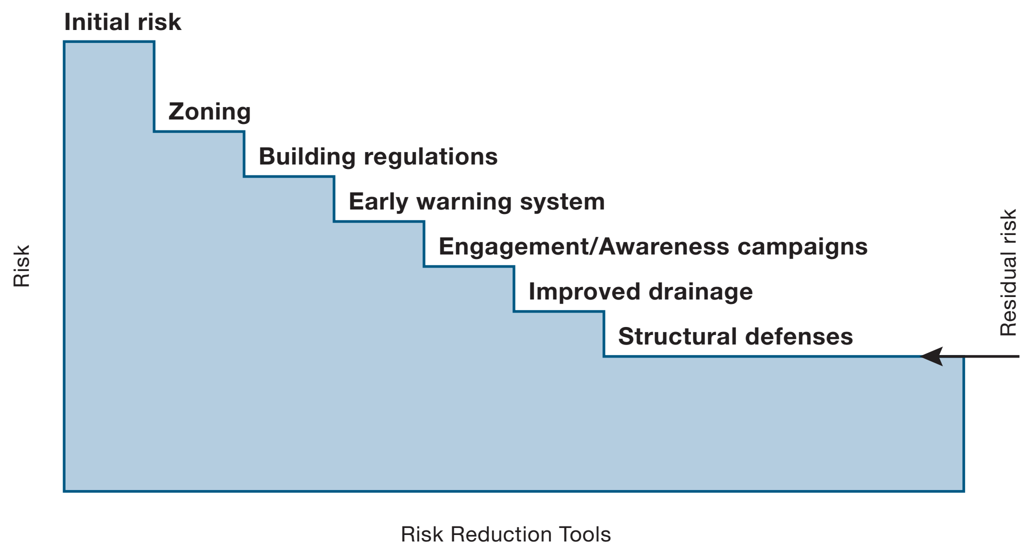

Figure 5.1: Buying down the risk. Source: Adapted from Manous 2011

It is important to recognize here that residual risk never reduces to zero; that the cost of reducing the risk may exceed the benefits of doing so; and that funds may not be available to invest in measures. Evaluation of the costs and benefits of each measure, or combination of measures, can form part of a wider strategy, which sets future targets for investment in measures and prioritizes spending on the most cost beneficial activities.

5.2.1. Cost Benefit Analysis

Cost Benefit Analysis (CBA) is the industry standard analysis tool for flood risk management measures. The purpose of CBA is to assess, over its lifetime, the monetary value of all of the costs involved in the development, construction and maintenance, and the monetary value of all of the benefits to be gained from a flood risk solution, in order to determine whether its benefits outweigh its costs. This is the main form of assessment used by decision makers to determine whether a project is worth proceeding with, and if so, when it should be started. Despite its acknowledged limitations it can be a powerful aid to decision making as illustrated in Case Study 5.1.

Case Study 5.1: Vaisigano Catchment Cost Benefit Analysis: Samoa

In 2008, a series of structural and non-structural measures proposed by the Pacific Islands Applied Geo-science Commission (SOPAC) for the lower Vaisigano catchment in Samoa, were compared using CBA.

Proposed solutions included floodwalls, a diversion channel, flood forecasting, development control and elevated construction. Avoided damages (benefits) were compared with costs including non-market costs. Data used included public records and surveys of businesses and households. Flood maps from previous events were combined with stage damage curves, and expert opinion on construction costs was obtained. The non-monetary and indirect benefits were, however, not well-captured. A 50 year life span for structural measures and 30 years for non-structural measures was assumed.

Results indicated that the most economically viable option was raised construction with a Benefit-to-Cost Ratio (BCR) ranging from 2 to 44. Flood forecasting was also found to have a BCR greater than 1. Structural measures, however, proved not to be cost beneficial. This conclusion was unlikely to be changed even if better quantification of indirect benefits was achieved.

The recommendations were that investment in flood forecasting, mapping and zoning, accompanied by zoning regulation on floor heights, should be considered, along with the possibility of grants or tax rebates to households in order to flood proof new homes. A key lesson learned was that Cost Benefit Analysis is capable of ranking both structural and non-structural solutions. Even if all benefits cannot be quantified, the differences between solutions may be large enough to give confidence in the robustness of the result.

Source: UNISDR 2009.

Table 5.1 below shows a simple example of CBA, as suggested by DFID, for use in deciding whether or not to retrofit buildings with flood proof features.

Table 5.1: Retrofitting buildings to prevent damage from floods

Potential Benefits	Methods to quantify benefits
Avoided damage to property	Value of damaged property
Avoided loss of household possessions	Compare damage to goods with and without retrofitted buildings
Avoided injury and illness	Medical expenses Loss in wages for time spent out of work
Avoided reduction in economic activity (for commercial buildings)	Loss in earnings, for example from estimated drop in customers
Avoided clean-up	Estimate the cost of labor and material for clean-up
Avoided emergency services costs	Necessary provision of equipment and people Incident specific costs (staffing, fuel, materials)

Source: Adapted from DFID 2005

The list of possible benefits and costs that might be considered for an urban flood risk management project, including direct and indirect benefits, could be very lengthy. Costs are usually easier to identify and evaluate – and it is important here to consider lifetime costs including maintenance and upgrading. Depending on the project, these might include:

- Assessment of risk and potential measures
- Design of measure
- Implementation and capital cost
- Resettlement costs where large land use changes are involved
- Maintenance including the setting up of systems and institutions to handle maintenance
- Cost of secondary measures, e.g. meteorological forecasts required to enable an early warning system or necessary measures on tributaries when large barrier systems are installed
- Restoration or rehabilitation of surrounding areas
- Disruption of traffic and trade

- Replacement or upgrading costs if the reversal of the measure would not be possible
- Ecological loss for example in large conveyance or storage projects.

For different types of measures, the benefits could be similarly broad and far-reaching, particularly for those non-structural and greening measures that are designed to integrate into urban planning and management. There may be many distributed benefits from flood risk reduction measures, not just a reduction in damages. For example, the provision of a floodwall may provide protection to an area of land, enabling this land to be used for urban development, or for infrastructure, such as a highway. It may also increase safety, reduce insurance premiums, and reduce building code requirements and encourage investment. A flood relief channel may be used for recreation, commerce and environmental management, thereby increasing business and tourism. It could also increase the value of property along the waterfront, and by providing recreational space, improve the quality of life, reduce the urban heat island effect and permit higher density development in adjacent areas. The list of benefits might also include:

- Reduction in loss of life
- Reduction in physical damages
- Reduction in commercial losses due to business interruption
- Reduction in emergency costs such as evacuation and clean up
- Increased development potential of protected areas and potential for inward investment
- Reduction in health effects such as medical expenses and lost work time
- Improved quality of life, lower stress
- Maintenance of biodiversity, ecosystems, carbon sequestration
- Reduced Urban Heat Island impacts leading to lower energy consumption
- Increased leisure amenities, tourism generation
- Increased hydro-power generation
- Increased technical capacity of population and higher levels of education.

No list can be wholly comprehensive, and it is part of the evaluation process to identify the various costs and benefits that are relevant for individual cases. The measurement of benefits is usually much less certain than that of costs for two main reasons. First it involves a measure of expectation of future losses which, given the probabilistic nature of flood forecasts, could be far from the actual avoided loss. Second the wider benefits may not materialize due to unexpected consequences and interactions with urban environments and management practices. For example, the commercial development potential of a newly protected site may not be realized due to economic downturn, non-completion of associated infrastructure, or the sudden availability of other development sites nearby. Given the long lead and life times for flood risk management projects many assumed conditions can change. The relative weighting between direct and indirect benefits varies between flood scenarios. There is some indication that the larger the flood event, the higher the proportion of indirect losses due to massive disruption. Other influencing factors include the level of development and insurance penetration (Mechler. 2005). Therefore for some projects (and some types of benefits in particular) the total benefits will be difficult to quantify. If the anticipated benefits are widely distributed, hard to quantify or uncertain, sensitivity analysis is crucial to assess under which circumstances the decisions would change.

The scale of the CBA is also critical. At the scale of the national economy, and in the long term, it may often be seen that a natural disaster boosts an economy and therefore prevention has a lower payback than at a more local level, where the economy suffers severely in the short term. Therefore, evaluations must be both scale and time relevant; the scope and objective of evaluation must also be defined. Projects and activities funded from city revenues, for example drain clearance, should provide a local benefit. Large catchment storage and conveyance schemes might benefit the whole economy. The benefits to the wider economy are naturally more difficult to quantify, but may make a significant difference to the evaluation of different projects.

Photo 5.1: Recreational use combined with flood relief channel and new dyke, Netherlands, Source: Baca Architects

To fully realize the potential power of CBA it is necessary to represent costs and benefits in monetary terms. A number of analytical mechanisms have been developed to attribute value to environmental and social issues, thereby describing them in economic terms such that they can be incorporated into traditional CBA. Broadly speaking, these can be described as one or the other of two approaches:

1. Valuation – such as assessing economic value based on an associated cost (such as house prices or the cost of travel)
2. Pricing/costing – such as assessing the cost of alternatives (such as the cost of replacing the lost environment, or the cost of an alternative to it).

Both of these approaches are based on 'use value' and 'non-use value' to people, as seen in Figure 5.2. Sometimes it is difficult to attribute a human use value to the environment. The environment, nonetheless, may be considered to have value on the basis that it is attractive to look at; or it is the habitat of rare species; or it has historic importance; or people would be disappointed if it were gone; or it might have a potential benefit in the future, such as undiscovered medicinal plants.

These methods focus on the value of the environment to people. Consideration of non-use value may need to be applied to the value of other components or creatures in the ecosystem, and which in turn may support that ecosystem.

It is worth noting here that our understanding of the value of the environment to people is continually improving: for example, we now know more about how wetlands can reduce storm energy and enhance water quality. Over time, there may be fewer and fewer non-use values, making the analysis of the benefit from the environment clearer.

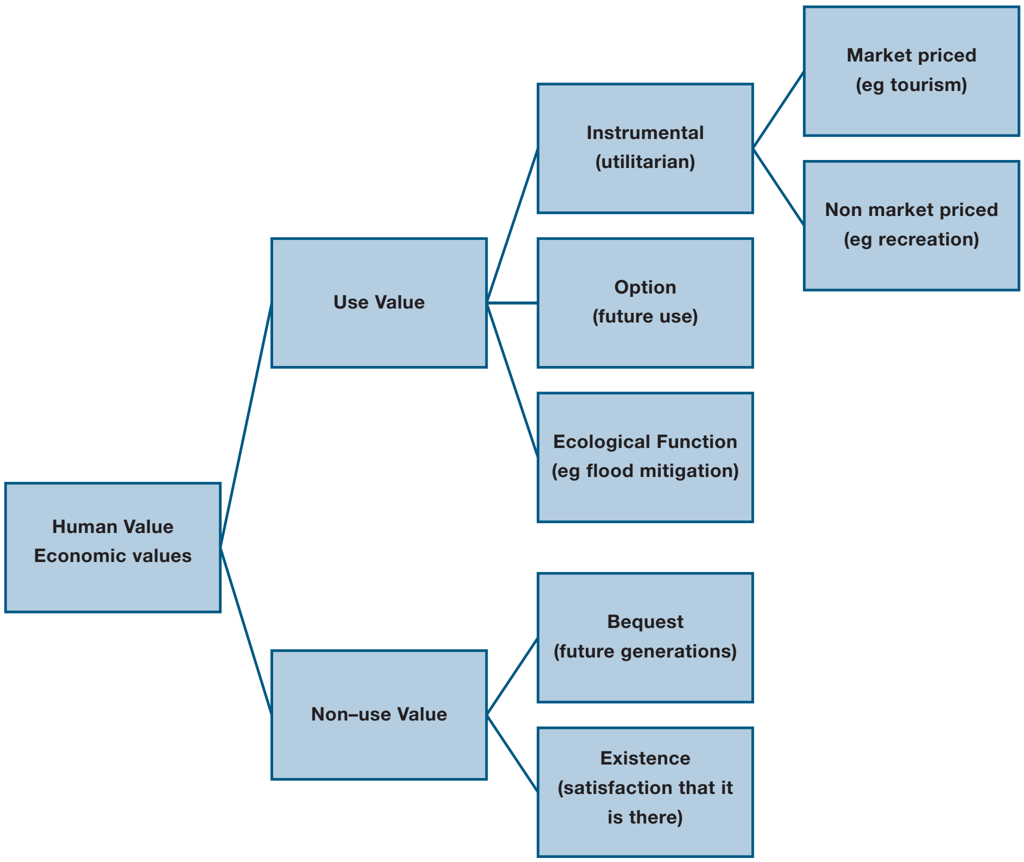

Figure 5.2 : Environnemental values. Source: Adapted from Lamond and Bateman 2012.

The uncertainty of climate change predictions has also begun to influence the assessment approach. There is a need to explore a range of outcomes and solutions to provide robust decision-making, which increases the reliance on 'valuation' assessment (which is based on theory) over 'pricing' assessment (which is based on an understanding of past value or cost).

An alternative or sometimes additional complementary approach to such quantification is to use a supplementary analytical tool such as Multi-Criteria Analysis (MCA), which is discussed below. This may be used to assign formal scoring and weighting to various options, which can then be ranked.

5.2.1.1. Evaluation techniques

Typically, CBA is used to test the economic viability of a specific flood risk measure, using one of the following basically equivalent assessment techniques:

- Net Present Value (NPV);
- Benefit Cost Ratio (BC); or,
- Internal Rate of Return (IRR), effectively the efficiency of the investment.

This method of analysis assumes that the flood risk solution being considered has already been determined. The aim of the CBA is to assess whether or not it merits implementation and at what time it is best to implement. The three evaluation techniques indicated above are now briefly described.

Net Present Value (NPV) is a mechanism for adjusting the simple benefit minus cost calculation to take into account the future value of cash flows over the lifetime of the project. The NPV is the value of the project (benefits less costs) after the ongoing costs and benefits in current money are discounted to present day values. The discount value is often taken to be the 'opportunity cost' of not investing the money in alternative schemes (this could be the cost of borrowing, or the average return rate on capital investment). If the NPV is positive, then the project is considered desirable. NPV is particularly relevant to large structural flood risk solutions, which are likely to incur the majority of the project costs early on, while benefits may only accrue over time. Incremental non-structural measures, on the other hand, may delay costs while still delivering benefits early on. If several options are to be considered, the one with the highest NPV is normally selected.

Benefit Cost Ratio (BCR) is a different way of representing this discounted cash flow picture. Rather than taking the difference between the costs and benefits, the BCR takes the ratio of the discounted value of the benefits to the discounted value of the costs. A BCR of one is equivalent to an NPV of zero (the breakeven point). Some governments and organizations set a minimum BCR ratio for a project to be eligible for funding.

Internal Rate of Return (IRR) is a mechanism for identifying the maximum discount/ interest rate at which the project is still economically viable (that is, the point at which the NPV is zero), which can be viewed as a project yield on investment. If this rate exceeds the government rate of return on capital then the project is seen as desirable. IRR is not considered to be the best method for ranking projects as the interpretation of maximum return rates is complex.

CBA can be used to help assess whether a flood risk measure is cost effective, or which of the flood risk solutions being considered are the most economically efficient. It can also help with ruling out options. CBA is most effective when compared with a 'do nothing' scenario or 'without' the flood risk solution scenario. Table 5.2 illustrates the five initial policies explored in relation to the UK's Thames Estuary 2100 project, the first of which is the 'do nothing' scenario.

Table 5.2: Various policies examined by TE2100 project

Policy P1	No active intervention 'walk away'
Policy P2	Reduce existing flood risk management actions (accepting that flood risk will increase over time)
Policy P3	Continue with existing and alternative actions to manage flood risk at the current level (accepting that flood risk will increase over time from this baseline)
Policy P4	Take further action to sustain the current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change and climate change)
Policy P5	Take further action to reduce flood risk (now, now and in the future, or solely in the future)

The evaluation of the 'do nothing' scenario helps to determine the negative impact of flooding if no flood risk management solution is implemented. When combined with other analytical tools to assess environmental and social benefits such as MCA, CBA can provide clear direction on which flood risk solution should be implemented – and when. This further helps to provide assurance to institutions to facilitate planning, financing and development.

5.2.1.2. Distributional impacts and equity

A limitation of CBA is that traditionally it has been unconcerned with the distribution of costs and benefits: for example, it neither considers who pays for the risk reduction measures, nor who benefits from them. Also, by taking as its basis the economic costs and benefits, it artificially weights the preferences of the wealthy over those of the less well off. Flood defenses will be provided more to the rich because the assets of the rich are greater and therefore the damage prevention potential within wealthy neighborhoods is much greater than that in poorer ones. Similarly in contingent valuation studies, the rich will be, on average, willing to pay more for risk reduction because they are able to. Some methods for valuing a life will rank a high earning individual above a low earner or non-worker.

This aspect of CBA has serious equity implications: The low average economic status of individuals in developing countries will tend to mean that all interventions are less economically beneficial than they are in developed nations. Unless costs are commensurately lower in developing economies, fewer measures will be able to be justified on a cost benefit basis and the population may be less well protected as a result. It may be important therefore to control costs by the use of locally based resources and labor and to consider competing projects within the context of development goals rather than economic return. Within individual countries it is the poor who will struggle most to justify funding to protect themselves and their property. Those who are economically inactive (for example women and children) and also often most vulnerable, will also be disempowered and may have their needs ignored. Decision makers should be made aware of these limitations and of methods to overcome it, such as vulnerability weighting and approaches which look at costs and benefits relative to income.

There is also a density aspect to costs and benefits such that widely distributed assets tend to display a lower CB ratio; the urban and rural poor, whose assets are low level but also sparsely distributed, will rarely qualify for any risk reduction spending if CBA is strictly adhered to. The Mississippi River floods of May 2011, discussed in Chapter 3, provided an illustration of a situation where highly populated urban settlements were protected by the deliberate direction of floodwater on to less populated rural land and settlements. While this may be justified on economic grounds, and planned well in advance, it can still be viewed as unjust.

The source of funding can also have distributional implications. Usually, solutions are paid for by taxpayers out of general taxation, which will have a redistributive impact but may be seen as unfair by those who live in areas which are not at risk. Methods can be employed to adjust for these issues if they are recognised but frequently they are ignored or not explicitly considered.

5.2.1.3. Sensitivity Analysis

Many of the assumptions necessary to perform a CBA such as the discount rate, expected project costs, or future flood probability may be rough estimates, uncertain, or politically motivated. Sensitivity analysis is designed to test the robustness of CBA to changes or inaccuracies in assumptions, or project overruns, amongst others: for example, in a CBA in Peru, the IRR varied from 12 percent to 30 percent when assumptions were changed (such as not taking account of loss of life). In this case, however, the IRR was above the required threshold under all assumptions (ISDR 2009). In another example, sensitivity analysis of a World Bank flood control project in Taiz, Yemen, found that the evaluation is most sensitive to increased construction costs and reduced damage costs (World Bank 2001).

5.2.2. Multi-Criteria Analysis (MCA) of cost benefit and socio-environmental issues

MCA is a complementary approach to incorporate less formal consideration of social and environmental issues into project evaluation. MCA is used to balance the needs of multiple stakeholders and to allow consideration of costs and benefits that do not ordinarily have an economic (market) value, such as biodiversity, well-being or community spirit, as Case Study 5.2 demonstrates. MCA provides a framework for attributing importance to the functions of such items; equally it encourages decision makers to consider these items where they may not otherwise do so.

Case Study 5.2: Cost-Benefit Analysis for Community-Based Disaster Risk Reduction in Nepal

A disaster risk reduction project to help selected communities address the adverse impacts of annual flooding was carried out by Mercy Corps Nepal and the Nepal Red Cross Society between 2007 and 2009 in the Kalali District in western Nepal. Floods and other weather-related hazards in Nepal are a major factor contributing to poverty. This is likely to increase due to climate change and variability.

The Kailali Disaster Risk Reduction Initiative (KDRRI) was implemented in six communities. The aim of the project was to increase the resilience of those communities through DRR. The project which was implemented in collaboration with the communities, the local government and other key actors, included measures such as capacity building and training, early warning systems, small-scale mitigation, education, and facilitation of coordination. At a second phase, the project expanded these activities to 10 additional communities.

The cost effectiveness of the project was assessed by employing social science research methods (such as structured surveys, field visits and interviews) for data collection, in combination with a computerized mathematical model, for data analysis.

The project yielded a B:C ratio of 3.49. This means that for every USD 1 spent, there is USD 3.49 in economic benefits. These benefits represent the prevention of economic losses or the avoidance of otherwise necessary humanitarian assistance. This B:C ratio, however, does not include the qualitative benefits of the project. Qualitative analysis found that the KDRRI project provided significant economic, social, and environmental benefits that were difficult to quantify. These benefits were associated with increased social cohesion, education, empowerment, saved lives, and indirect impacts on economic capital. If the qualitative benefits were included, the final B:C ratio would have been significantly greater. The experience demonstrates that community-based measures are in fact very effective in reducing flood risk and have a high payoff.

Sources: White and Rorick 2010.

MCA aims to establish the goals and objectives of all of the stakeholders that may be affected by both the flood risk and the associated risk reduction measure. Consensual weighting is then determined for various elements, through discussion with stakeholders. Table 5.3 below illustrates how MCA was used to provide weightings to six categories being assessed for a flood warning system in Scotland.

Table 5.3: MCA weightings used in SNIFFER UKCC10B, Source: Halcrow 2009.

Category	Weighting
1) Risk to life and serious injury reduction	30%
2) Social impacts reduction	20%
3) Residential property damage reduction	15%
4) Business and agriculture damage reduction	15%
5) Flood defense operations improvement	15%
6) Infrastructure disruption reduction	5%

This weighting was then used to assess the benefits to different areas within the river catchment for potential flood events, as shown in Figure 5.3.

Benefits

Return period (yr)		☐ 10	☐ 50	☑ 200	Average
Category	Weighting (0–100)	Score (0–100)			
1 **Risk to life/serious injury reduction**	**30**	**15**	**100**	**100**	
2 **Social impact reduction**	**20**	**90**	**100**	**100**	
3 **Residential properties damage reduction**	**15**	**40**	**100**	**100**	
4 **Business/agriculture damage reduction**	**15**	**24**	**48**	**57**	
5 **Flood defence operations improvements**	**15**	**19**	**8**	**0**	
6 **Infrastructure disruption reduction**	**5**	**8**	**100**	**100**	
Total	**100**	**35**	**78**	**79**	**18**

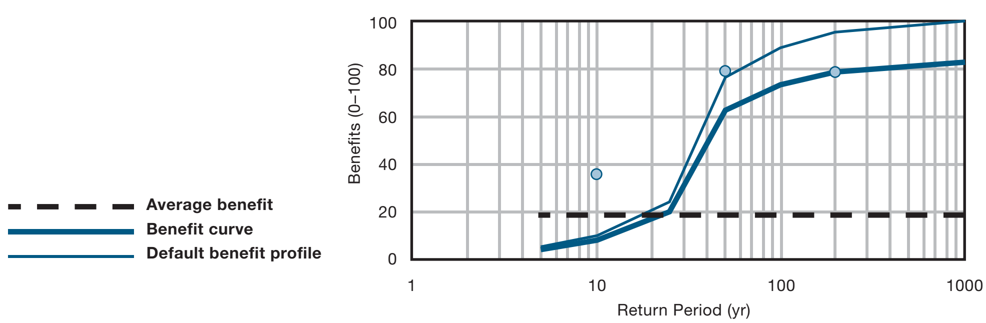

Figure 5.3: Benefit profile for 0.05 percent flood event, Source: Adapted from Halcrow 2009.

The weightings used in MCA are consultative and derived from stakeholders. This implies that the weightings are subjective and anthropocentric, and that they may be based on ill-informed judgments. These weightings would be quite different for a different project, or for one in a different location, or as a result of political or social factors or changes. It is vitally important to gain representation from a sample of all stakeholders and to brief them thoroughly on the purpose and details of the proposed schemes. However, they illustrate a particular weighting that was reached by agreement with the key parties in a particular instance.

The multi-actor participation explicit in MCA, and the need for buy-in to the weighting analysis and results, means that transparency and public involvement from an early stage are essential. Public involvement may also require better communication of issues that are difficult to grasp, together with a clear explanation of the analysis process.

5.2.3. Operation and maintenance cost

One of the most important considerations when evaluating the costs of a project is the cost of operation and maintenance (O&M). If flood risk solutions, particularly those that are structural, are not maintained then it can fail at the time the solution is required to provide protection. This can increase the risk more than if the solution did not exist: not only by giving the residents a perception of protection but also by undermining the need for evacuation planning or other measures.

CBA and MCA can include such costs without difficulty, but estimating the costs of operation and maintenance through the lifetime of the solution may be difficult. Several factors could influence this – inflation, increased wealth, or the shortage of a workforce, amongst others. Often the O&M costs will be underestimated relative to the initial costs. Furthermore, even if the costs are identified it is important to identify the responsibility for and the source of this money. Is it provided upfront and set aside? Will the government provide it? Will private industry, such as the insurance sector, provide it?

There are many reasons why O&M may not be continued after a project is completed. But if there is a serious risk that it will not be continued, then it may be preferable to use non-structural measures.

5.3. Determining the appropriate level of protection (ALARP)

As discussed above, CBA, incorporating MCA as necessary, are very useful tools in ranking alternative solution sets for flood risk. However, such analyses are limited in that they can only rank the alternatives suggested – and that they do not provide a final decision as to whether or not to undertake measures.

Governments have limited resources and will often choose not to implement schemes which may be cost beneficial because of the lack of available funds to do so or because there are other priorities which take precedence. This is true in developed countries, such as the UK, where many more schemes pass the cost benefit threshold than can be immediately funded. It will also apply in developing countries where resources may be much more limited, or may depend on international donors with their own agendas to satisfy.

As discussed above, economic analysis in general will struggle with concepts of equity and distributional effects and with the quantification of environmental and social impacts. For the analysis of flooding, the quantification of the value of a human life may be a key deciding factor. This seemingly simple concept is fraught with emotional difficulties and subject to value judgments, which economic models cannot make. Flood risk reduction solutions will usually benefit some stakeholders and disadvantage others. The decision of what is fair or equitable is not easy to make. Another issue in decision making in the era of climate change, is the huge uncertainty associated with future predictions of flood patterns.

In practice, although governments of the developing world are largely responsible for determining the level of spending on flood risk management as opposed to say, education, they do not do so in isolation. The fact that, in democracies, it can be observed that response to natural disasters is correlated to re-election campaigns is clear evidence that governments are very mindful of public opinion, as well as the views of (or pressure from) the wider international community (World Bank and the United Nations 2010). There is some evidence that both voters and donors are more prepared to accept risks from natural hazards rather than anthropogenic hazards; it seems they also prefer spending on relief to prevention. This could be a result of cynical self-interest, some element of moral hazard, or lack of belief in the ability of government to control nature.

Increasingly, if individuals and nations rely on insurance or risk markets to finance reconstruction, then the demands of insurers and capital lenders may become increasingly important in determining the appropriate level of flood protection. This is the case in the UK where the current informal ‘gentlemen’s agreement’ between the insurance companies and the government provides no guarantee of cover for those with a probability of flooding which is greater than 1.3 percent (or 1 in 75), unless plans are in place to reduce the flood risk below the threshold within five years (although it is still profitable for insurers to provide cover to some households above this risk threshold).

5.3.1. Defining 'target protection'

Target protection levels may be an attractive notion but very few countries have a published target for protection levels of their population. The Netherlands is an interesting case: structural defenses are designed to protect the population within the dykes to against a 0.0001 percent (1 in 10,000 year event). The expected impact of climate change means that the standard is being re-examined. The very notion of target protection is difficult to define in a situation where structural defenses are being replaced by non-structural measures such as land use planning, early warning and evacuation. Protection ceases to be a promise to keep people and assets apart from water and moves towards a language of minimising expected losses.

5.3.1.1. The As Low As Reasonably Practical (ALARP) principle

In deciding on an acceptable level of risk for populations to bear, the concept of 'As Low As Reasonably Practical' can be adopted. With this approach, the acceptance of risk can be expressed as a three tier system which requires definition of:

- An upper band of unacceptable risk
- A lower band of broadly acceptable risk
- An intermediate band of tolerability which is tolerable if risk reduction is impractical or the CB ratio is close to one.

This is illustrated in Figure 5.4.

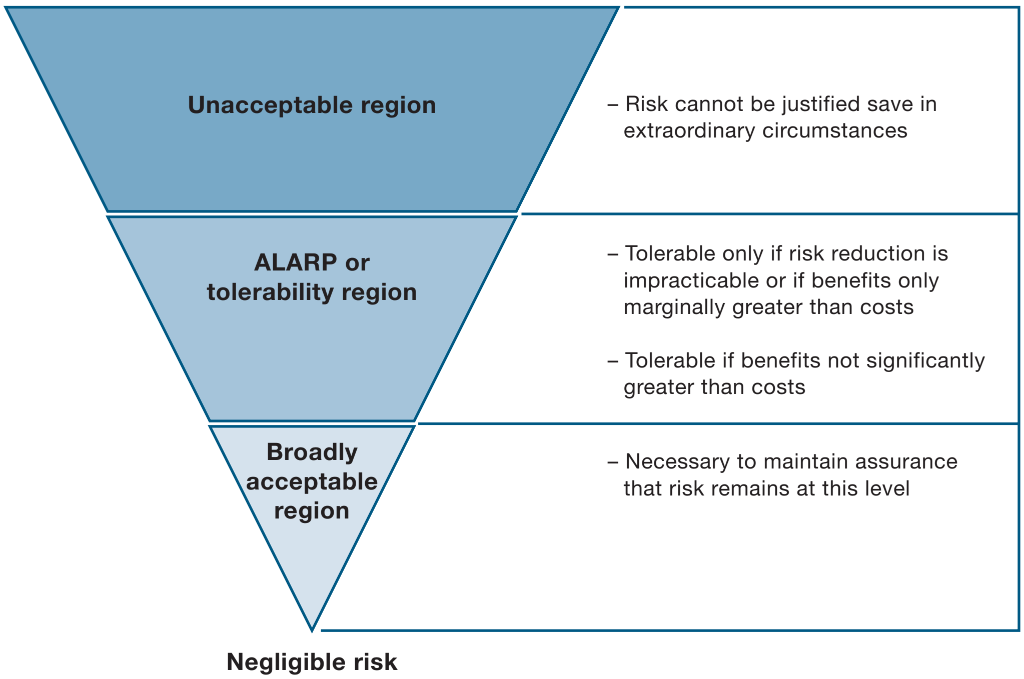

Figure 5.4: Acceptable levels of risk and the ALARP principle, Source: Adapted from FLOODsite 'Language of Risk.'

This conceptual framework is useful as it allows for some fixed decision points, without being completely deterministic. However, in the field of societal risk (rather than the industrial sphere from whence the concept came) defining the bands can be problematic, as consensus between stakeholders is unlikely to be easily reached.

Attitudes and tolerance to risk can be measured via the use of revealed and expressed preference methods; so too can the appetite of populations to pay to reduce the risk. In the context of flood risk management, expressed preference methods may tend to under-estimate risk tolerance due to the game playing of participants. Revealed preference may fail to detect risk aversion due to inertia, low income levels and lack of alternative choices.

5.3.1.2. Opportunity cost

Governments must also consider the 'opportunity cost' of flood risk management spending. Opportunity cost here refers to the cost of not doing something else with the money spent on flood measures. The money might be more usefully spent in protecting against other disasters or in education or health. In theory, governments could evaluate all possible uses of the money allocated to flood risk management and rank them in order of importance. In practice, no government would want to allocate funding on such a basis, or be able to evaluate all the potential spending priorities in enough detail to do this. However, opportunity cost is a useful concept in decision making, such as when using a comparison of average CBA ratios across government departments to inform programs.

5.3.1.3. The value of a life

Difficult as it may be to accept, in order to make cost benefit decisions in flood risk management, a valuation of a human life is often employed. It is a particularly important figure in the benefit analysis of evacuation schemes, which may not provide much damage reduction, but do save lives. The method used is usually referred to as Valuation of a Statistical Life (VSL) (World Bank and the United Nations 2010). Recommended VSL figures range from US$ 4 to 9 million for the US and from US$ 0.8 to 74.1 million for other countries (Wang and He 2010).

There are paradigms available to assist in this valuation, such as the expected future earnings, or the economic contribution of an individual, or the replacement cost of the investment in health care, education and social welfare that the state has provided. Insurance models may also be useful. Under such paradigms, relatively wealthy economies will naturally value a life at a higher rate than less wealthy ones and VSL will be related to average income. This often leads to very low valuations in the thousands of dollars for developing economies. Contingent valuation methods generally yield higher values: a recent Cambodian study for landmine clearance gave an estimate of US$ 0.4 million. Within a nation, regional, gender and ethnic differences may also apply.

It can therefore be seen that the choice of method of value for VSL is a critical issue for project evaluation and that even attempting to rank different solutions may be dominated by the choice made. Sensitivity analysis on this variable is therefore usually warranted.

5.3.1.4. Demands of insurability

Commercial insurance is most available to cover residual risks which conform to insurance principles. In order to diversify their portfolios, reinsurers rely on a range of international businesses with risk profiles that complement each other.

Attractive propositions rely on known risk profiles and simple triggering events. To offer the security that the risks are covered up to a given level of return, either by defenses or by internal funds and practices, and to allow the insurer to pick up the risk for extreme events may involve an externally determined target level of protection.

In the UK the 'gentlemen's agreement' referred to above, also known as the 'statement of principles' (ABI 2008) sets a 1.3 percent (1 in 75 years) target level of protection. Defenses constructed to a lower level of protection will leave the residents and businesses at risk of being uninsurable. This insurance-set standard has the potential to create the minimum and maximum level of protection, with little incentive to exceed this target without further government regulation.

5.3.1.5. Benchmarking and regional cross-cooperation

Governments may benchmark their performance against other similar economies or near neighbors. On a practical level this could be in order to attract inward investment, secure livelihoods and promote economic growth on a par with other countries. Alternatively, if risks are pooled regionally, or there is cross-border cooperation on mitigation or relief operations, then parity in protection levels may be part and parcel of negotiations.

As a simple example, if a river basin crosses national boundaries, it may be incumbent upon nations downstream to protect to at least the level of their upstream neighbors, but possibly not to greater levels.

5.3.1.6. Decisions under uncertainty

Uncertainty can lead to indecision. Where investment in flood defenses and infrastructure is designed to last well into the long-term future, the range of possible future climate scenarios (discussed in Chapter 1 of this volume) is unlikely to be addressed by one optimum solution. Decision makers are nervous of:

– Over-adaptation: where adjustments are proven to be unnecessary given the climatic conditions that actually occur, such as a sea defense built to withstand four meters of sea level rise that never emerges.

– Inaction or under-adaptation: a failure to act, or where adjustments do not achieve the maximum potential reduction in losses for the realized climate, or in some cases actually increase impacts above what they could have been, given improved anticipatory adaptation.

– Incorrect adaptation: where adjustments are made but are later found to be either not adaptive or counter-adaptive.

Robustness, that is finding alternatives that perform well under all scenarios, then becomes a preferred strategy rather than finding the optimal solution. An optimal solution might perform well in most scenarios but be disastrous under some assumptions, bearing in mind that the ALARP concept may ensure that robust solutions do not result in risks in the intolerable band. Figure 5.5 illustrates the trade-off between cost benefit and robustness and shows that some measures (e.g., early warning systems) perform well under both judgment criteria while others (e.g., hard-engineered defenses) may be better on one criterion but perform poorly on others.

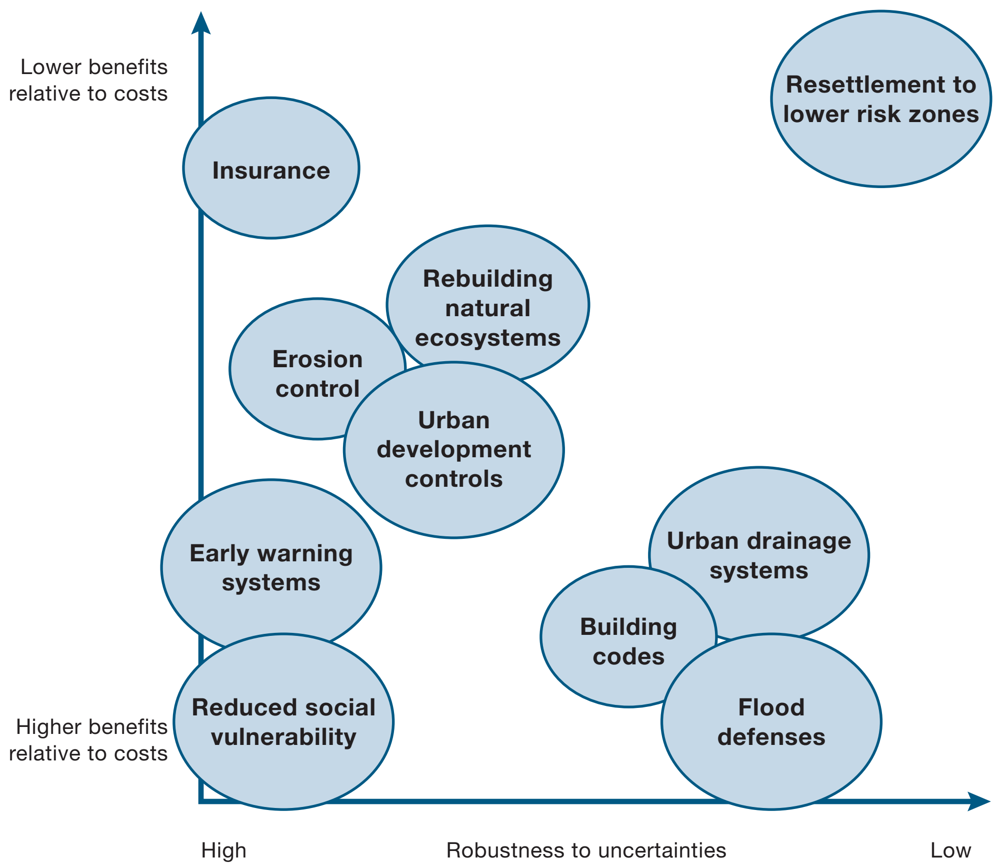

Figure 5.5: Relative costs and benefits of flood management options.Source: Adapted from Ranger and Garbett-Shiels 2011.

Robustness can be achieved by means of a variety of strategies, depending on circumstances and the urgency with which decisions need to be made: flexible solutions; ‘no regret’ solutions; the precautionary principle; planned redundancy (‘just in case’); and ‘wait and see’. In the developing world it has to be recognized that the urgency to make robust decisions is high: as urbanization and urban development proceed, infrastructure needs to be planned and large populations need to be protected. This will lead to a preference for the flexible, ‘no regret’ and ‘just in case’ approaches. In contrast, the developed world may be able to delay making changes to the already existing settlements and infrastructures.

5.3.1.7. No regret solutions

Measures which will be cost-beneficial regardless of changes in future flood risk are often termed ’no regret’ measures. These measures usually have some of the following features:

- Are low cost, and are therefore likely to have a high CBR whatever happens
- Have benefits other than flood risk management
- Are part of a wider program that contributes to development
- Are not sensitive to changes in future flood risk.

Examples of such approaches are forecasting and early warning systems: these are not sensitive to future flood risk and are relatively low in cost to set up. Informal settlement upgrading or clearance by rivers also has many benefits over and above the flood management role; restoring wetlands may also have amenity value.

Box 5.1: Early Warning Systems

Early Warning Systems save lives and can have extremely high payback relative to cost. If people are aware of a risk beforehand, and receive a credible and trusted warning in sufficient time to evacuate to a place of safety, many lives can be saved. Weather forecasts, warnings, and emergency responses associated with hurricanes in the US are valued at US$ 3 billion per year (two-thirds of this from reduced loss of life). The value of public weather forecasts to households in Ontario, Canada, is estimated at US$ 1.26 billion per year (Jha and Brecht 2011). A pilot study in Russia found a payoff of US$ 4–8 for every US$1 invested in modernization of hydro-meteorological services across the country.

After super-cyclone Bhola killed more than 300,000 people in 1970, the Government of Bangladesh in partnership with the Bangladesh Red Crescent

Society established the Cyclone Preparedness Program in 1972. Working with local communities, a system appropriate to the area was developed to transmit hazard warnings based upon radio broadcasts complemented by flags of various colors, hoisted where they would be easily visible.

As part of a comprehensive, end-to-end mitigation, warning, evacuation, and sheltering system this led to a dramatic drop in deaths and property losses from cyclones in that country. Another good example is the China Meteorological Administration's Weather Alert Service via SMS which reaches more than 90 million users.

The urban poor are, however, more likely to take increased risks to secure housing and property during disasters, in spite of functioning early warning systems. Cities are, therefore, likely to require targeted communication strategies to reach out to these communities. A good example is the Jakarta Flood EWS, which has a strong focus on the community capacity building element and ensures the coordination of activities between front-line providers (such as NGOs and community organizations) and local governments.

Source: Jha and Brecht 2011.

5.3.1.8. Flexible solutions

Flexible solutions are those which can be adapted to changing futures. Although changes may be necessary in the future as risks change, flexible solutions allow for that change without major reinvestment or reversal of earlier actions. Many non-structural measures tend to be inherently flexible, for example early warning systems or evacuation plans. Structural measures are seen as less flexible, but flexibility can sometimes be incorporated, as seen for example with the installation of wider foundations for defenses so that they can be raised later without having to strengthen the base. The purchase of temporary flood defense barriers can also be seen as flexible, as they can be deployed when and where necessary as flood risks change.

5.3.1.9. Decision Trees

Decision trees or decision pathways are a commonly used decision- making aid in many fields. The concept works by assessing options against various appraisal criteria at different points in the future and identifying thresholds (or ‘tipping points’) for each option. It is then possible to lay these options out in a temporal sequence, mapping the point in time when each tipping point is expected to be reached. Their advantage, when considering future investment in flood risk reduction in an era of climate change, lies in their ability to reflect probabilistic scenarios in a transparent way. The highly-structured nature of the approach should ensure that all contingencies are considered and that timing and uncertainties in decision parameters are clarified. The use of such methods is illustrated in Case Study 5.3 where the future of the Thames Barrier was assessed against potential sea level rise.

Case Study 5.3: Flexible planning: Thames Estuary 2100

The Thames Estuary 2100 project (TE2100) developed a long-term tidal flood risk management plan for London and the Thames Estuary. Walls, embankments, barriers, gates and other flood defense structures already exist to provide protection against flooding from the sea. Protection against flooding from upstream is provided by walls along the River Thames, and walls, culverts and local flood storage along tributaries. In most areas these structures were designed for a flood level of a 1000-year event, while for some less developed areas, lower standards were adopted.

These flood defense structures will reach the peak of their design lives over the next 20 to 30 years due to gradual deterioration. This, along with the potential increase in frequency and severity of flooding due to climate change and socio-economic change, has led to the development of the TE2100 project. The project identifies adaptation options and pathways under a range of climate and socio-economic scenarios in order to respond to future uncertainties.

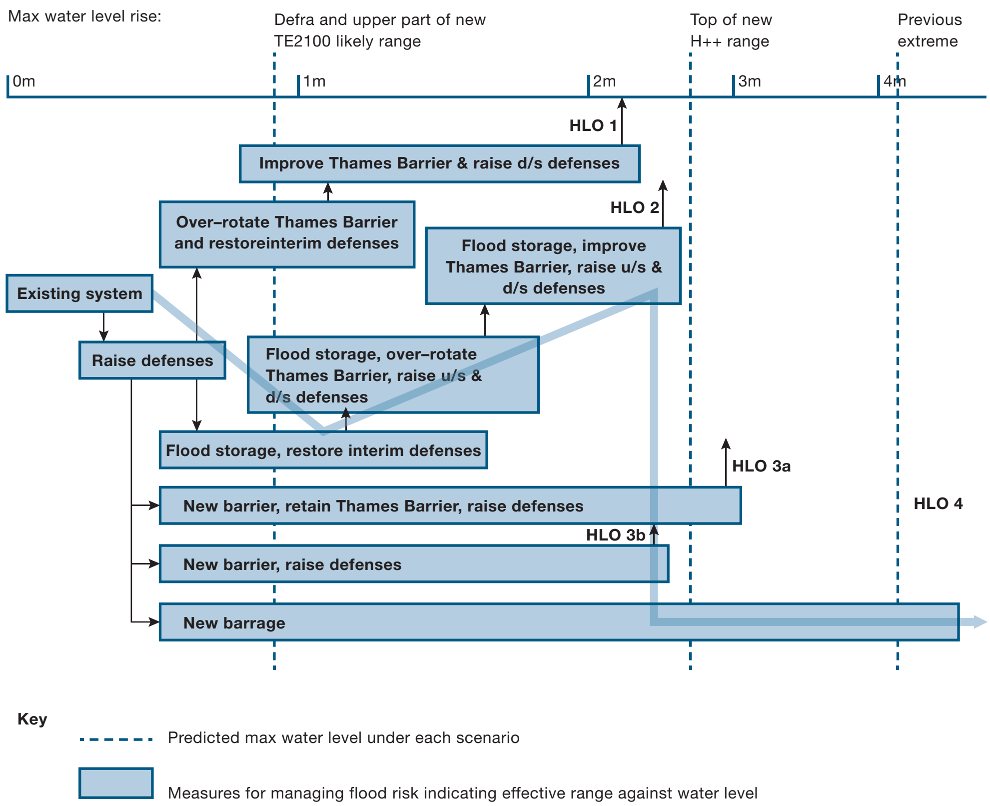

Figure 5.6: Adaptation options and pathways developed by TE2100 (on the y-axis) shown relative to threshold levels increase in extreme water level (on the x-axis). The light grey illustrates a possible 'route' that decision makers would initially follow if sea level was rise faster than predicted. Source: Adapted from Reeder and Ranger 2011.

Uncertainties in future flood risk projections and the high sensitivity of decisions about climate change, all make urban flood management planning a challenging process. The TE2100 project developed and applied a framework for adaptation planning that ensured that adaptation strategies would be cost-effective in reducing risk, while being flexible and adaptable to future uncertainties.

Sources: Ranger et al. 2010; Reeder and Nicola 2011; Defra 2009; Environment Agency 2009.

5.3.2. Consideration of the worst case scenario

For most decision making purposes the standard decision tools focus on the most probable events and plan to deal with scenarios on or around the average expectations. Probability theory and experience both point to the need to also consider the worst case scenario. It is a truism to say that a “one in a million event” is almost certain to happen eventually. While the unthinkable happens rarely, the consequences need to be thought through. Judgment will be required to define the exact worst case scenario to be considered.

Worst case scenarios can also often be triggered by failure of systems, it is not necessary to determine how likely a system is to fail to know what will happen if it does. Systems should be planned to “fail gracefully,” or as gracefully as possible, in order to minimize the damage from the worst case scenario.

Equally worst case scenarios can be generated by extremes of weather well outside the expected patterns. Defining the worst case is more problematic here as the definition of possible weather events is infinitely variable. Often it is only necessary to contemplate a weather event outside the design capacity of the system. Alternatively an event causing total destruction of a settlement could be considered.

Whatever the scenario, the importance of the discipline of considering the worst case is to prevent complacency and over-reliance on solutions.

Benefits might include:

- To plan for failure
- To avoid solutions which might make a man-made disaster worse than the natural event
- To make long term strategic decisions on placement of key infrastructure
- To highlight the importance of integrating a set of structural and non-solutions
- To demonstrate the importance of flood risk management investment as against other priorities.

Visualization and simulation tools such as those described below can be very useful in this regard.

5.3.3. Further reading

ESPACE. 2008. “Climate Change Impacts and Spatial Planning Decision Support Guidance.”

Defra. 2009. "Accounting for the Effects of Climate Change." London: Defra. http://archive.defra.gov.uk/environment/climate/documents/adaptation-guidance.pdf.

Environment Agency. 2009. The Thames Estuary 2100 Environmental Report Summary. London, UK.

5.3.4. Considerations for evaluating appropriate measures

A systematic and organized evaluation protocol is helpful for articulating how a proposed activity can be evaluated to see if its expected outcomes are particularly effective for the area of concern. It is an essential tool for all decision-making bodies as they require a strategic framework for more systematic and consistent processes in order to promote their mission, particularly for risk assessment and for enhancing the quality of the environment.

Actions	Considerations/ operations	Outputs / benefits
Adaptation of a risk based approach	The likelihood of flooding The potential impact of flooding	Incorporates both existing and potential risk
Determination of a proportionate approach	The cost of appraisal should be appropriate to the level of investment required for the project. Information costs should be balanced against greater accuracy	Output is more effective when there is a balance between cost effectiveness and accuracy
Understanding the problem	Define the flood problem carefully and understand the risk and potential solutions	Problem definition helps in identification of the priorities that needs to be aided first
Working within the hierarchy of decision making	Feasibility Plan National priorities and its position within the plan selection Taking account of legal and ethical issues	Output from such planning is generally well-organized and priority-based. Local communities are benefitted the most when work takes place without changing the existing framework of decision making

Stakeholder cooperation	Engaging all stakeholders and canvassing their views, goals and objectives will lead to an evaluation which represents the interests of all	Encourages community engagement, awareness and overall development
Identifying baseline and multiple solutions	The status quo is a useful comparison and also critical in evaluating the NPV of the proposal	Opens multiple windows for problem- solving, provides time for evaluation of products
Integrating environmental assessment	There may be statutory environmental assessment requirements	Environmental assessment identifies opportunities for enhancing the environment

5.4. Tools for decision makers, including simulation and visualization

Decisions regarding flood risk management are complex and require wide participation from technical specialists and non-specialists alike. There is clearly a role for tools which can predict the outcome of decisions, communicate risk and interface between stakeholders. To that end a large range of tools have been developed to aid the decision making process.

The list is long here: for example, a recent European project (ENCORA n.d.) identified the following tools: Planning Kit, Water Manager, IRMA-Sponge DSS Large Rivers, IVB-DOS, STORM Rhine, MDSF, EUROTAS, Flood Ranger, DESIMA, NaFRA, PAMS, HzG, DSS-Havel, WRBM-DSS, Elbe- DSS, INFORM 2.0/.DSS, RISK/RISC, FLIWAS, FLUMAGIS, DSS ñ RAMFLOOD, ANFAS, MIKE 11 DSS and EFAS. New tools are constantly evolving and it is therefore impossible to discuss all of those currently available in this section; furthermore, it is likely that new and better tools will replace them. The aim of this section is to introduce the various types of tool that have been developed in relation to the different aspects of urban flood risk management; no endorsement or recommendation for particular systems is intended.

These tools are sometimes collectively referred to as Decision Support Tools (DST). Flood risk management tools are often quite intricate, due to the complexity of hydrological systems, and the effects that flooding has on so many different aspects of society and the environment. The purpose of these tools is to aid decision makers with information and analysis, education and communication, and ultimately decision making and application. By using visualization, these tools widen the possibilities for participation. A good tool or series of tools can be invaluable in simplifying the assessment, communication and decision making process, and can be particularly useful for the Multi-Criteria Assessment discussed earlier in Section 5.2.

Table 5.4 identifies a range of tools and techniques and indicates their relevant purpose. The following section gives some examples of these tools and their practical application; and finally how these can be combined to form a complete Decision Support System (DSS) is described.

Table 5.4: Decision Support Tools

Tool or technique	Purpose	Description
Geographical Information System (GIS)	Inform, analyze and communicate	Computer aided, geospatial mapping information analysis and presentation tool
2D/3D flood modeling	Inform	Identify flood hazard (extent, depth, velocity, time of onset) for various return periods over time
Evacuation and loss of life models; Evacuation process modeling; Life Safety Models (LSM)	Inform and analyze	2D/3D modeling combined with other parameters such as demographics
Breach Analysis	Inform and analyze	2D/3D modeling combined with time
Simulation games	Educate and communicate and training	2D and 3D computer visualization tools to explain flood risk and various solutions
Planning exercises, games and toolkits	Educate, communicate, train and decide	Physical and computer based tools to agree consensus on solutions, based on set criteria (such as planning regulations)
Checklists	Decide	To assess flood risk development proposals for completeness against industry guidance.
Decision Support Systems	Inform, Educate and Decide	Compilation of tools often linking flood risk modeling issues with socio-economic and other issues.

5.4.1. Geographical Information System (GIS)

A Geographical Information System (GIS) is a computer-aided mapping tool for recording, collating, analyzing and displaying spatial information. The format is readily accessible with the information being linked to a known geographical reference point. GIS permits the user to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, reports, and charts. A GIS helps the user to answer questions and solve problems by looking at the data in a way that is quickly understood and easily shared.

GIS layer combines spatial information with additional database information to provide a query-based data resource. Each object, such as a polygon or line on a plan, can be assigned information about what it is, what area it occupies and other distinguishing facts. A polygon indicating a building, may also state the area, the height of the building, and the construction.

GIS is applicable to all forms of spatial mapping and analysis: archaeological information, census data, flood zones, flora and fauna sightings, land designations, land values, shopping catchment areas and overall urban planning data. It is particularly useful for government and municipalities to enable a wide range of information to be collated, overlaid and thus reviewed simultaneously.

GIS enables flood hazard information, in particular, to be overlaid with other information, such as urban development plans, demographic plans and land value plans. This allows the user to identify the receptors that will be affected by flooding, the vulnerability of those affected, and the value of land and infrastructure affected. This, in turn, can be used to identify the cost impact amongst other issues. Figure 5.7 shows two maps produced using GIS information, one portraying the land ownership and usage type, the other the expected flood depth during a 0.5 percent probability flood.

Figure 5.7: GIS layers indicating land ownership/use (left) and flood depths (right), Source: Baca Architects, Information provided by Environment Agency, West Sussex County Council and Stakeholders.

The above examples are two of a series of GIS layers that have been overlaid to show the main constraints to a potential development site on the edge of a town. This was then used to inform the designs for an integrated urban plan that identified the extent and type of development that could take place over the next 20 years and simultaneously reduce flood risk, contamination and provide environmental enhancements.

Once the information is assembled, GIS software allows the information to be presented and also queries to be carried out from simple information requests through to complex queries, such as identifying the total value of all property within a predicted flood area. More advanced assessment 'plug-ins' can be used to carry out other assessments, such as topographical land changes, or can then be integrated with flood modeling tools to produce new projected flood maps.

5.4.2. 1D, 2D, and 3D flood flows modeling

Computer flood risk modeling can be used to assess the impacts of the various flood hazards described in Chapter 1. Modeling can also be used to test the effectiveness of different flood risk solutions in lesser or greater detail, depending on the development stage within a project.

Any of the types of modeling can be a powerful tool in aiding decision makers to understand flood hazard. However, modeling is only a tool, and can only be as good as the information put into it. Once produced, model outputs must be calibrated against historic flood records and eye witness accounts.

Two-dimensional (2D) modeling or linked 1D/2D modeling is developing as the industry standard for assessing flood risk and flood hazard in various parts of the world. This combines hydrological modeling with GIS information, such as two dimensional land levels, surface roughness (such as the difference between hard landscaping and fields or woodland) and buildings or other obstacles. This type of modeling can also introduce timing information (adding the third dimension), to see how a flood will progress through a site, thereby identifying which areas will be affected first and for how long they will be flooded. It can also be used to assess the impact if a flood defense should be breached. Once a 2D model is produced it can be used to test out various solutions and development proposals. Figure 5.8 shows still photographs taken from an animation of an extreme flood on a proposed new development at two different stages. This type of information can be very helpful for identifying safe routes and planning evacuation procedures.

Figure 5.8: Extracted images from an animation of a 1 in 1000 year flood on a new development plan in Norwich, UK. Source: JBA Consulting and Baca Architects

Breach Analysis is another form of 2D/3D modeling used to explore the potential effects of flooding should a flood defense or dam be breached.

Outputs from computer modeling are typically produced in a GIS compatible format so that they can be integrated with other GIS information and used to produce flood extent mapping, flood hazard mapping and flood zoning information.

5.4.3. Evacuation and loss of life models and evacuation process modeling

Evacuation and Loss of Life Models, or Life Safety Models, are specific types of 2D/3D modeling, which combine 2D modeling with demographic information. This allows identification of the vulnerability and awareness of receptors. This can be used in order to determine the potential loss of life and to assess evacuation times available, potentially aiding with phased evacuation.

Box 5.4: Life Safety Model (LSM)

The Life Safety Model (LSM) developed by HR Wallingford (n.d.) shows the impact of flooding with or without a flood warning. The LSM includes many features such as:

a. The flood wave evolves with time. This evolution has different effects upon people that i. get warned; ii. start evacuating; iii. reach safety; iv. get stuck in traffic or floating cars; and v. are killed.

b. The time-varying flood condition (depth and velocity) encountered by people affects their resilience, survival capacity and their speed. There are people drowning because they are swept away by the flood, but also as a result of exhaustion due to continuous exposure.

c. If people evacuate by car, engines can stop or the car can get swept away.

d. The buildings can collapse after being hit by the flood wave or as consequence of a continuous exposure to the flood.

e. People can be modeled as individuals, or as groups that do not separate during an evacuation. The slowest members would slow down the group and the fastest members would enhance the speed of the slowest.

f. People in the model can receive different types of warning.

g. People can evacuate along roads or along footpaths, toward a set of safe havens predetermined by the user. Vehicular movement is modeled by a traffic algorithm that can represent reduced speeds due to congestion and bottlenecks.

Source: FLOODsite. n.d. (a) and (b); HR Wallingford. n.d.

Evacuation modeling for flood risk events tends to be 2D/3D GIS based, due to the extent of the area that may be affected by flooding. This form of evacuation modeling uses a dynamic traffic model, such as INDY, to determine the time required to evacuate a risk area (FLOODsite n.d. (d)). This can also be combined with flood risk modeling, such as breach analysis, to determine the critical areas requiring evacuation in order to optimize the evacuation system.

Evacuation modeling for fire and earthquakes can be 4D, incorporating all three spatial dimensions and time; it may also be used in combination with agent-based artificial intelligence to include behavioral modeling. More detailed building scale modeling may be used in the future to inform the movement rates and patterns used in city scale evacuation planning, particularly for hurricane or tsunami events.

5.4.4. Simulation Games

Various organizations have produced simulation games, some of which are available online. These are designed to improve awareness of flood risk in an enjoyable manner; for example, 'Stop Disasters', produced by the UNISDR (n.d.) invites users to spend a given budget on development enhancements to reduce the impact of one of five different disasters (flood, hurricane, earthquake, wild fire, and tsunami) around the world. In the case of the flood and tsunami disasters, the short game introduces some of the solutions that need to be considered to reduce flood risk, such as building location, emergency planning and structural and non-structural solutions. The game provides information about the cost and susceptibility of development options, as well as the cost and effectiveness of flood risk 'defenses'.

The FloodRanger game (Discovery Software Ltd. n.d.) was developed with UK Government funding, as part of the UK Foresight initiative (Evans et al. 2004); It enables users to try several different flood solutions (mostly structural) to manage the flood risk to an area in the UK over a 100 year period and simultaneously to provide housing and employment. The game is designed to work with two climate change scenarios derived from the Foresight project and presents 3D visualization. A second version, named 'FloodRanger World' also exists; this allows the user to create a FloodRanger game for non-UK locations.

Levee Patroller (Triadic Game Design n.d.) is a game specifically aimed at improving the awareness of the general public in identifying signs of damage to dykes in the Netherlands. It uses gaming technology developed and provides an immersive visualization from the first person perspective. Currently, the game is integrated into a course offered by Deltares (n.d.) to teach levee inspection; it is also implemented and internally used by six Dutch Water Boards, and is permanently exhibited at the Nemo Science Museum in Amsterdam.

Simulation games can be complicated and costly to produce; they are rarely used as decision-making tools. They are more likely to be produced based on the information produced from other decision-making tools to aid communication or for training purposes.

5.4.5. Planning games and toolkits

Planning and consultation games, such as Planning for Real (n.d.) can be very useful tools for bringing together planners with flood risk engineers to identify mutually acceptable criteria. These games are relevant due to their ability to raise awareness of flood risk and the acceptance of flood risk management solutions in the context of urban growth and development. This form of consultation is focused on place making and community: it does not place a high priority on flood risk management. However, when combined with other assessment tools and planning toolkits, it can improve understanding and can lead to more sophisticated and broadly acceptable solutions, particularly where non-structural flood solutions are being considered. Figure 5.9 shows one such program being used in community consultation to test an integrated planning toolkit with 2D flood hazard mapping to determine the optimum and safe site layout.

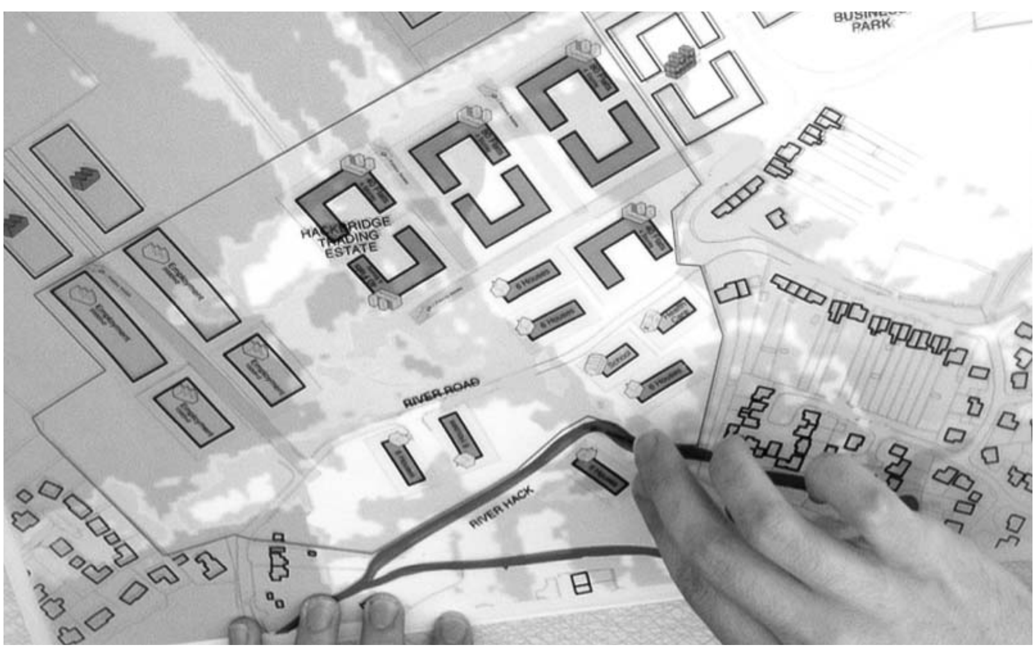

Figure 5.9: Planning for LifE in Hackbridge, U.K. Source: Baca Architects

Physical planning exercises and games can be more effective than computer simulations in engaging with multiple stakeholders, particularly those who may not be computer literate.

5.4.6. Flood simulation exercises

The purpose of simulation exercises is primarily to increase preparedness. They achieve this in a multi-faceted way by normalizing response actions; engendering awareness; testing emergency plans; training personnel; and monitoring preparedness, among other benefits. Simulation exercises can range from strategic desktop paper based exercises to full-scale mobilization of at risk populations.

It is important to carry out simulations of relatively likely scenarios, as well as those for the prospective catastrophic failure of structural measures. Desk simulations can identify the potential cases of secondary impacts such as occurred in the 2011 Japanese Tsunami. They can also highlight possible flaws in emergency plans such as where planned evacuation centers may also be inundated in major events or might suffer a loss of power. Real evacuation exercises, in particular, can raise awareness in the wider population.

Many aid agencies cite Mozambique as a role model for other developing countries for its disaster preparedness strategy. Jorge Uamusse, the Head of the Mozambique Red Cross Society's disaster management, said: "The government invests a lot in disaster preparedness. It holds at least two flood simulation exercises for vulnerable communities living along the rivers, without fail, every year."

The success of simulations can be enhanced with the use of sophisticated computer visualizations of full-scale emergency service responses. Actual exercises may be seen as expensive and disruptive. While this may be the case, it is also possible to use low technology paper-based exercises and small-scale training exercises to achieve many of the same objectives. It is important to be clear about the objectives of any exercise as the range of stakeholders will vary depending on the level of sophistication of emergency planning and the cost benefit of large versus small-scale operations.

5.4.6.1. Choosing an appropriate exercise

The appropriate type of exercise may be determined partly by the objectives but also by the maturity of emergency planning existing in the system. Emergency planning maturity and possible suitable simulation exercises can be summarized as shown in Table 5.5.

Table 5.5: Possible simulation exercises

Some awareness of flood risk but no clear idea of roles, responsibilities	Workshop with a wide range of stakeholders to explore and establish roles and responsibilities (for example the UK based dry run exercise which involves communities putting together their own flood plans).
Good understanding of flood risk within government and agencies with clear roles and responsibilities but gaps in emergency plans	Desk-based virtual simulation exercise to formalize operational plans, identify synergies and improve practice.
Detailed and well-formulated emergency strategy but low awareness and preparedness among population and business	Small scale but well-publicized real life emergency scenario. Tajikistan, for example, is prone to flooding. Oxfam held simulations to gather communities together in safe havens, registering and caring for inhabitants before removing them to safer locations elsewhere. The simulations were recorded and web broadcasts are available. Workshops with key stakeholders.
Well-formulated emergency plans with reasonable level of awareness and preparedness among population	Large scale emergency testing. In the Czech Republic a three-day scenario, Vltava Labe 2007, tested the responses of the capital, Prague, and 135 towns and villages. Over the three days different aspects of the response, strategic, political and evacuation was brought under the spotlight. Training exercises In Chibuto in Mozambique, a mobile emergency operations center, government departments, humanitarian agencies, shelter and evacuation planning were tested. The exercise was based on the Government Contingency plan for 2010-11 and for the first time, international partners, including UNDP and some other UN agencies, were involved as participants, and not just observers, as has been the case in previous years. As is usual with this type of exercise, areas for improvement were identified, which will help to strengthen response mechanisms.

5.4.6.2. Evacuation timings

The time taken to evacuate populations can be inferred from known transport parameters and analysis of past emergencies. However, real time large scale flood simulation exercises can reinforce and inform the planning of evacuations: an example of this occurred in the Belize flood simulation, coordinated by the National Emergency Management Organization and the Belize Electric Company Ltd. Potentially catastrophic dam breaks in San Ignacio and St Elena will require early warning and evacuation procedures to save lives.

The flood simulation had as its objectives to test and inform the public about the existing warning system; establish if the initial warning time estimated by the model will give people sufficient time to reach designated safe areas; test the evacuation routes and safe area system; analyze how people, local economies and government would be affected by the flooding; and to record the information to update all plans required to save lives, making this publicly available following the exercise.

5.4.6.3. International cooperation

International cooperation in managing disasters is often necessary as many events cross boundaries; others, although contained within national borders, require the assistance of emergency responders internationally. An example of a regional simulation exercise is the ASEAN Regional Disaster Emergency Response Simulation Exercise ARDEX06 which has the objective of testing and enhancing the capacities and capabilities of member countries.

5.4.6.4. Community awareness

Raising awareness and training of communities can be the aims of simulation exercises. In Vietnam, for example, preparation for the monsoon season, funded by external donors, involves simulation and training rolled into one. Communities learn how to reinforce their homes to better withstand strong winds, to draw up emergency evacuation plans and to practice responding to early warning signs designed to alert fishing boats at sea. First aid training was also offered to communities. The simulation was supervised by the commune's army steering committee and the steering committee for flood and storm control.

"This simulation is a good chance to raise local awareness of flood prevention and to manage storm damage in our areas. It is especially important for us right now with the incoming storm season," said Chairman of the commune's People's Committee, Nguyen Huu Quoc.

Lasting from 1 March 2007 until 30 April 2008, the Community-Based Disaster Risk Management (CBDRM) project aimed to improve disaster preparedness and management by communities and authorities in Vietnam. Some 21,000 impoverished people in central Vietnam have been engaged in various forms of disaster preparedness activities.

5.4.6.5. Communication and learning

Simulations allow for streamlining and optimization of processes. Individuals and organizations may learn how to better manage their own actions and operations. Similarly, the communication between organizations and individuals may be improved. Face to face encounters of responders and officials from adjacent organizations leads to knowledge sharing and increased confidence in emergency plans. The Safer Cities case study of Dagupan City in the Philippines illustrates the significance of setting up an operational early warning system and evacuation plan, as a mechanism to draw people together in pursuit of collective action towards building safe and resilient communities (Iglesias 2007). The approach called for identifying viable preparedness and mitigation measures, CBDRM and good governance. Lessons learned included:

- Early warning systems are more effective if individuals and groups understand the benefits of such systems
- Community involvement in EWS development leads to systems that respond more quickly
- Drills can test plans and show strengths and weaknesses
- The simulation exercise helped each sector involved to share their knowledge and skills in preparedness and response, through allowing others to witness, impart comments, and eventually replicate this kind of endeavor.

5.4.7. Decision Support Systems

Though the above tools can be used independently to inform specific decisions, they can also be combined into a structured Decision Support System (DSS). The aim of a DSS is to provide a comprehensive system to aid communication with other stakeholders and to assist with individual or group decision-making. Typically components of a DSS are:

- A Database Management System (DBMS), which is used to collect and organize data.
- Knowledge or knowledge-base management systems (KBMS). This is the filtered or interpreted result of information from the data and relevant context as opposed to the raw data itself.
- Models of factors such as flooding, urban growth, socio-economic, and climate change form the model base management system (MBMS).
- A Graphical User Interface (GUI), which is typically GIS-based or browser-based.

A DSS can be designed to incorporate a series of scenarios and variables such as growth or climate change, and be used to quickly rule out or prioritize solutions. It is important in identifying solutions that the variables incorporated are clearly expressed in the results, to enable decision makers to make informed choices. As the FLOODsite project argues, “Decision uncertainty can be expressed as the rational doubt as to what choice to make and it is important that all DSSs provide the decision maker with information on uncertainty, allowing the user the choice of either accepting the uncertainty (as the decision they are making is robust to that uncertainty) or exploring ways of reducing doubt.”

Case Study 5.4 examines the application of this principle in Ho Chi Minh City, Vietnam, with the aim of identifying the most appropriate flood management strategy under large hydrological, land subsidence and urbanization uncertainties.

Previous figures have illustrated some of the modeling and visualization components that might be included in a DSS. One such application is the European River Flood Occurrence & Total Risk Assessment System (EUROTAS), which uses ArcView GIS software. This system allows queries to be constructed, based on specific goals and conditions for a given scenario, to identify which simulation satisfies the goals (after FLOODsite 2007).

The specific aim of a DSS, as with any tool, needs to be considered from the outset and is often best designed in collaboration with the intended users to ensure that it is appropriate to the defined objectives.

Case Study 5.4: Integrated Flood Management Strategy for Ho Chi Minh City (HCMC), Vietnam

Some 60 percent of Ho Chi Minh City (HCMC) is comprised of lowland areas subject to tidal effects. Examining flooding in HCMC is complicated as it is affected by upstream, downstream and local impacts.

Despite an increase in heavy rainfall events, an upgrade to the drainage system in the central districts of Ho Chi Minh City has reduced flood risk. Nevertheless, urban growth in the periphery of the city had as a result newly- urbanized districts arising in sites at flood risk.

To protect the city from sea level rise, a dike and tide gate system is planned. The total cost for the construction of 12 large gates and 170 kilometers of dike could reach US$ 2 billion. The Tide Control Project uses large polders but, although approved, it remains controversial as saline intrusion has been more serious than was initially expected. The construction of a sea dike is also being considered.

Hard engineering or structural measures to minimize flood risk might be unsustainable under large hydrological, land subsidence and urbanization uncertainties. The Steering Center for Urban Flood Control in HCMC points out that an integrated flood management strategy (IFMS) is most likely to be successful in reducing flood risk. Components of an IFMS include:

– Protection to an appropriate return frequency, determined by predictions using historical data and non-stationary analysis

– Adaptation to cope with extreme events that surpasses design criteria

– Retreat, which means restoring space for water to adapt to long-term climate changes.

The dynamic balance among the three components may vary, depending on location and timing. As the Steering Center for Urban Flood Control suggests, it should be decided via a robust Decision Support System (DSS). This case demonstrates that urban flood risk management cannot be associated solely with hard-engineered measures, but rather with an integrated and flexible approach in order to respond to future climate and socio-economic uncertainties.

Source: Phi 2011.

5.5. References

ABI (Association of British Insurers). 2002. "ABI Revised statement of principles on the provision of flooding insurance." http://www.abi.org.uk/Publications/ABI_Publications_Revised_Statement_of_Principles_on_the_Provision_of_Flood_Insurance_72b.aspx.

Defra. 2009. *Accounting for the Effects of Climate Change*. London: Defra.

Deltares. No date. "Flood Risk Management" Brochure.

DFID (Department For International Development). 2005. "Natural Disaster and Disaster Risk Reduction Measures: A Desk Review of Costs and Benefits." London, DFID.

Discovery Software Ltd. n.d. "FloodRanger." http://www.discoverysoftware.co.uk/FloodRanger.htm.

ENCORA Coastal Portal. n.d. "Development of Decision Support Tools for Long-term Planning, Review Of Existing Tools." http://www.coastalwiki.org/coastalwiki/Decision_support_tools.

Environment Agency. 2008. *Flood and Coastal Erosion Risk Management appraisal guidance. FCERM - AG.* Bristol: Environment Agency. http://www.environment-agency.gov.uk/research/planning/116705.aspx.

—— 2009. *The Thames Estuary 2100 Environmental Report Summary*. London: Environment Agency.

Evans, E., Ashley, R., Hall, J., Penning-Rowsell, E., Saul, A., Sayers, P., Thorne, C. and Watkinson, A. 2004. *Foresight, Future Flooding*. London: Office of Science and Technology.

FLOODsite. n.d. (a) "Modelling the evacuation process in case of flooding." FLOODsite, HR Wallingford. http://www.floodsite.net/html/cd_task17-19/docs/reports/T17/T17_08_01_Modelling_the_evacuation_process_in_case_of_flood.pdf.

—— n.d. (b) "Evacuation and Traffic Management." FLOODsite, HR Wallingford. http://www.floodsite.net/html/cd_task17-19/docs/reports/T17/T17_07_02_Evacuation_and_traffic_management_D17_1_V4_4_P01.pdf.

—— n.d. (c) "Language of Risk." FLOODsite, HR Wallingford. http://www.floodsite.net/html/partner_area/project_docs/

T32_04_01_FLOODsite_Language_of_Risk_D32_2_v5_2_P1.pdf.

n.d. (d) “INDY.” http://www.floodsite.net/html/cd_task17-19/indy.html.

—– 2007. “Development of DSS for Long-term Planning Review Of Existing Tools - T18-06-01.” FLOODsite, HR Wallingford.

Halcrow. 2009. “Assessing the Benefits of Flood Warning: Phase 3,” Halcrow Group Ltd. for SEPA (Scottish Environmental Protection Agency), SNIFFER, Edinburgh.

HR Wallingford. n.d. “Life Safety Model.” HR Wallingford. http://www.lifesafetymodel.net/about_lsm.html.

Lamond, J. E., and I. J. Bateman. 2012 (forthcoming). Methods for Valuing Preferences for Environmental and Natural Resources: An overview. In Climate change challenges for the built environment, edited by C. A. Booth, F. N. Hammond, J. E. Lamond and D. G. Proverbs. London: Blackwell.

Manous, J. 2011. “Flood Risk Reduction: Projects or Systems” IWR-USACE. http://siteresources.worldbank.org/INTEAPREGTOPHAZRISKMGMT/Resources/4077899-1228926673636/3-Joe_Manous.pdf.

Phi, H. L. 2011. “The Challenges of Urban Flood Management in Ho Chi Minh City (HCMC) and Requirements of an Integrated Strategy.“ Presentation in the consultation workshop “Preparation of a Global Handbook for Urban Flood Risk Management,” Jakarta, May 25-6.

Jha, A. K. and Brecht, H. 2011. “Building Urban Resilience in East Asia.” An Eye on East Asia and Pacific. East Asia and Pacific. Economic Management and Poverty Reduction. Washington, DC: World Bank.

Mechler, R. 2005. *Cost-benefit analysis of natural disaster risk management in developing countries*. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn.

Planning for Real. n.d. http://www.planningforreal.org.uk/planningforreal/default.html.

Reeder, T. and Ranger, N. 2011. “How do you adapt in an uncertain world? Lessons from the Thames Estuary 2100 project.” World Resources Report, Uncertainty Series, World Resources Report, Washington DC. http://www.worldresourcesreport.org/files/wrr/papers/wrr_reeder_and_ranger_uncertainty.pdf.

Ranger N., Millner A., Dietz S., Fankhauser S., Lopez A. and Ruta G. 2010. “Adaptation in the UK: a decision-making process.” Policy Brief, September 2010, Centre for Climate Change Economics and Policy and the Grantham Research Institute on Climate Change, London.

Triadic Game Design n.d. ”Levee Patroller.” http://triadicgamedesign.com/leveepatroller.html.

UNISDR (International Strategy for Disaster Reduction). 2009. “Thematic overview of Urban Risk Reduction in Asia. Global Assessment Report on Disaster Risk Reduction.” Geneva: United Nations.

—— n.d. “Stop Disasters.” http://www.game.org/en/home.html.

Wang, H. and He, J. 2010. “The Value of Statistical Life A Contingent Investigation in China.” Policy Research Working Paper 5421, World Bank, Washington, DC.

White, B. and Rorick M. 2010. *Cost-Benefit Analysis for Community-Based: Disaster Risk Reduction in Kailali, Nepal*. Lalitpur: Mercy Corps Nepal.

World Bank. 2001. “Project Appraisal Document on a proposed credit to the republic of Yemen for a Taiz municipal development and flood protection project.” Report number 22075-RY, World Bank, Washington, DC.

World Bank and United Nations. 2010. *Natural hazards, unnatural disasters*. Washington, DC: World Bank.

Food vendors continue to ply their trade in the middle of rising water on the flooded Meenburi Road in the east of Bangkok, Thailand (2011). Source: Gideon Mendel

Chapter 6

Implementing Integrated Flood Risk Management

Chapter 6. Implementing Integrated Flood Risk Management

6.1. Introduction

Chapter Summary

This chapter discusses the process of implementing integrated urban flood risk management strategies which combine structural and non-structural measures. In implementing an integrated approach, the role of well-functioning institutions, the participation of stakeholders, and the engagement of affected communities are vital. Implementation also requires sustainable arrangements for financing. Maintenance of the implemented measures, preventing their failure, and evaluating their utility are also keys to ongoing successful implementation.

The chapter is aimed at answering questions such as:

What is the role of formal and informal institutions in integrated flood risk management? What are the challenges that policy makers and flood experts may need to overcome? Why are stakeholder involvement and community engagement important in integrated flood risk management? Where can cities find the financial resources necessary for implementing flood risk management measures? What issues need to be considered for maintaining flood risk management measures? Why is evaluation necessary, and what process should be followed?

The key messages from this chapter are:

- Integrated urban flood risk management is set within and can fall between the dynamics of decision making at national, regional, municipal and community levels.
- Integrated flood risk management requires coordination between national governments, city governments, public sector companies, including utilities, along with civil society, non-government organizations (NGOs), educational institutions and the private sector.
- Engagement of the community at all stages of risk assessment through implementation to evaluation will contribute to the success of measures and may generate extra knowledge and resources, as will the utilization of measures that are community-designed and implemented.
- The sources of finance for integrated flood risk management are broad and can benefit from a partnership approach which includes contributions from multiple stakeholders as well as international donors.

– Implementing processes for adequate long-term Operations & Maintenance (O & M) is a critical aspect of implementation.
– A program of monitoring ensures that measures have the ability to perform to the required standards and prevents failure, as well as provides learning for the future.

Action to tackle flood risk is clearly warranted but is often delayed or completely neglected. This is despite the fact that there exist known solutions that can effectively reduce risk. When measures are taken it is also sometimes seen that their implementation falls far short of the original strategy, or into disuse.

Promoting an integrated flood risk management approach for rapidly developing urban settlements is a huge challenge. It involves many changes which may run counter to traditional thinking and to the natural desire of inhabitants to build a structural flood defense – and forget about flood risk. Such traditional methods have served reasonably well in the past, saving millions of lives, protecting assets and giving peace of mind. But they will not be comprehensive or flexible enough to adapt to a future of climate change, urbanization, urban development and expansion, all of which, especially in developing nations, puts millions more at risk.

Modern thinking about flood risk involves dynamic decision making which includes relevant institutions, involves stakeholders, and engages affected communities – which are all the more important attributes as emphasis is placed on non-structural measures to manage risk that require wider participation and often require a change in traditional management methods. It will also remain critical to be able to implement appropriate structural measures, and to maintain and adapt those measures already in place. Implementation, moreover, can be difficult to achieve where municipal management suffers from a lack of technical capacity, funding or resources.

The chapter is divided into seven sections. Section 6.2 covers the role of formal and informal institutions and argues for the creation of strong and effective institutions. Section 6.3 discusses the important role of community engagement in flood preparedness and mitigation and Section 6.4 deals with the specific application of community-based measures to enhance resilience. Section 6.5 describes the financing and resourcing measures required to effect change, while Section 6.6 covers the issues to be taken into account when operating and maintaining both structural and non-structural flood risk management measures once they are implemented. Section 6.7 details the monitoring of projects and processes within integrated flood risk management in order to prevent their failure. Finally, Section 6.8 discusses the range of approaches and methods for evaluation of disaster relief, including urban flood risk management measures.

6.2. Effective institutions and stakeholders

Flood risk management is seldom, if ever, the sole responsibility of individuals. Flood risk is best managed through collective efforts and with the understanding that actions in one location could have a counter-effect on that of a neighbor, as Figure 6.1 below illustrates.

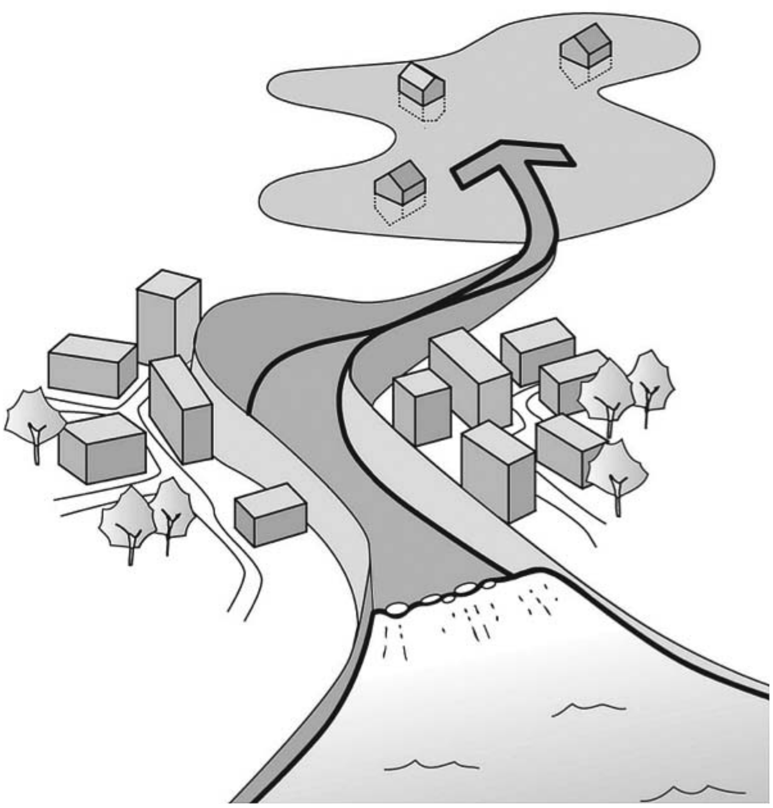

Figure 6.1: Flood defenses in one location could increase risk elsewhere. Source: Baca Architects

Institutions are the set of informal and formal rules that facilitate and constrain human behavior, or define `the rules of the game' (Bromley 1989; Ciriacy-Wantrup 1971; Kiser and Ostrom 1982; North 1990). By its very nature, flood risk management is multi-institutional. A range of institutions have important roles to play, including local, regional and national governments, community groups, utilities, and private businesses – and not forgetting banks and the insurance sector. Developing effective institutions is vital to overcoming the real challenges of managing flood risk, which are illustrated in Box 6.1.

Box 6.1

Challenges for urban flood risk management

Information

- Lack of risk awareness or perception
- Difficulties in responding to the uncertainties of climate risk predictions
- Difficulties in responding to the uncertainties of urban growth and planning and managing informal development.
- Lack of understanding of integrated flood risk management responses

Ownership

- Understanding where responsibility lies
- Taking responsibility and overcoming the "not in my term of office" syndrome, in which difficult decisions and initiatives are deferred to a later political office holder
- Weak municipal capacity and performance
- Lack of engagement of the private sector
- Lack of public engagement and consultation

Resources

- Underfunding or under-resourcing
- Lack of oversight and enforcement of land use regulations
- Lack of supporting infrastructure
- Shortage of skilled personnel
- Inappropriate infrastructure maintenance systems

- Actual cost and perceived cost

Belief

- Fear of lack of effectiveness of measures
- Perceived cost of measures
- Negative perception of the consequences of risk and the benefits of measures
- Lack of faith in government to effect change.

6.2.1. The role of institutions

There are generally considered to be two types of institution, informal and formal.

Formal institutions are those that incorporate written rules or laws, such as governments, religious or faith group organizations, NGOs or other large organizations, such as private corporations; or are those that operate under specific laws, such as banking organizations, and energy and water companies. In flood risk management, formal institutions typically take responsibility for information gathering, communication, policy setting, decision making, defining and enforcing property rights, establishing building codes and planning regulations, financing and implementation.

Informal institutions are those that have been established on the basis of agreed and perhaps unwritten or codified principles, such as community groups. In developing nations, these informal institutions are an integral part of daily life and are relied upon, particularly where formal institutions are highly bureaucratic. Informal institutions are often involved in information gathering, communication, decision making and implementation.

Flood risk management is typically dependent on these two types of institution working together in an ordered fashion over long-term. Establishing which specific institutions are responsible for various elements of flood risk management is critical to implementation, operations and maintenance and ongoing assessment of the measures taken.

Integrated flood risk management often requires greater coordination than is usual between national governments and ministries, city governments, public sector companies, including utilities, meteorological and planning institutions, NGOs, educational institutions and research centers, and the private sector. It is essential to understand the capacities and incentives of these institutional actors, including how they choose or are able to use their own limited resources under high levels of uncertainty. Government decisions about the management of risk are typically balanced against competing, often more pressing, claims on scarce resources as well as other priorities in terms of land use utilization and economic development.

The most appropriate institutional arrangements for managing integrated flood risk management systems need to be identified in any given situation, as well as those for monitoring and regulating the institutions that are responsible for the implementation of the measures undertaken. In Box 6.2 below are a number of factors that need to be considered in order to implement integrated flood risk management across institutions.

Box 6.2: Institutional considerations

- How does the highest political authority show its commitment to flood risk management?
- How adequate are the mechanisms for demonstrating this commitment?
- To what extent are the civil society and the private sector committed to flood risk management?
- Is there a policy that specifies flood risk management and reduction as a priority?
- Is there a process for developing, coordinating and continuously improving policies and strategies for flood risk management?
- Is there separate legislation for flood risk management?
- What participatory approaches do government and NGOs adopt in their risk reduction programs and activities?
- Are there incentive systems that encourage investment in flood risk management?
- Does flood risk management promote individual and community responsibility for protection from flooding and compliance with early warnings?
- What mechanisms exist to coordinate flood risk management and stakeholders at the city level?

Source: Adapted from AfDB et al. 2004

As pointed out by the World Bank, countries with well-performing institutions are better able to prevent disasters (World Bank 2010). Nevertheless, in many countries, there is a lack of both suitable institutional arrangements and suitable policy frameworks to encourage integrated flood risk management. This mismatch between governance of official disaster management mechanisms and what is actually needed for implementing integrated flood risk management is a major barrier to its implementation.

Without technical assistance and other capacity building measures, there is a danger that institutional and policy fragmentation may lead to a failure to address wide-ranging problems in an effective manner. For instance, if a local government's strategy relies on purely structural flood risk mitigation measures, this may create 'false security', which subsequently, may undermine the implementation of an integrated flood risk management approach (Wamsler 2006).

For implementing integrated flood risk management the following success factors therefore need to be considered (AfDB et al. 2004):

– Political commitment to flood risk reduction depends on the ability of decision makers to provide the requisite vision, direction, policy efficiency, material and non-material support.
– Effective implementation of integrated flood risk management depends on the effective utilization of national, regional and local institutional resources, including policy, legislation, structures, financial resources and competencies.
– Rights-based, active and value-enhancing involvement of all stakeholders is a necessary factor for good governance.
– Emphasis on local action while linking the local with the regional, and national is required.
– Consistency by all stakeholders is essential for enhancing the governance of flood risk reduction.

Well-organized institutions are also required to direct flood risk infrastructure operations and maintenance, and to accrue the resources required to fund these. Additionally, it is the role of institutions to ensure that they respond to the whole range of flood sources, from the more frequent to the much rarer extreme events, which are typically, more devastating and more costly to deal with.

Where the roles of different institutions is not well established in flood risk management, they should ideally be developed both to complement each other and existing systems, to create efficiency in the delivery of measures and their faster uptake. Identifying which institutions are most effective in the delivery of these requirements is fundamental to success.

The responsibilities for flood risk management must be clearly allocated. These would normally be held in the first instance by national and regional governments, and implemented through municipal authorities. As such, national and regional politicians must allocate the responsibility to specific organizations; clearly identify and demarcate their responsibilities; provide sufficient funding requisite to flood risk; enforce the 'ring fencing' of those funds; and ensure that required works are carried out. In many cases, as discussed above, informal institutions such as community groups may have a particularly important role (for example, where property rights and ownership are not well-documented in formal institutions or where community groups are more effective or trusted in communication).

In order to initiate this process, advantage can be taken of flood events, as these can make politicians aware of the impacts of floods and how these need to be reckoned with – which can emphasize the necessity for a flood risk management strategy.

6.2.2. How to perform institutional mapping

Flood risk management depends on different institutions as well as individuals working together. Identifying which institutions are most effective in the delivery of these measures is fundamental to success. Institutional mapping is a tool that can be used to identify the awareness and perception of these key institutions, both formal and informal, as well as that of key individuals, inside and outside of a community, a city, a province or a country. It will also help to identify the relationships and importance of these different actors to one another or to individuals.

Method

A facilitator and an observer, or note-taker, will be responsible for the activity. It is important to bear in mind that good facilitation skills are crucial. Complementary tools that can also be used during the institutional mapping may include social mapping and Venn diagramming. A step by step process for institutional mapping is outlined below. This incorporates the factors to be considered at each stage. The procedure should be adapted to local contexts and needs. Required materials are markers and flipchart paper.

1. Select local participants

2. Provide introductions and present the purpose of the activity

3. Produce (draw) an institutional map

4. Analyze the institutional map

5. Wrap-up

1. Select local participants

The first step will be the identification of the groups of people to talk to about their perceptions and experiences with regards to flood risk management. The number of participants may vary, but most often consists of five to twelve people. It will not be enough to focus on formal institutions only. Informal institutions should also be included. Different sessions (with different actors, as necessary) can take place if this will lead to a better outcome.

Appropriate selection of participants means that policy makers and flood experts will have the chance to get valuable feedback from the flood-affected population or other relevant formal or informal institutions. Moreover, flood affected communities will have the chance to have a say about flood risk management.

2. Provide introductions and present the purpose of the activity

The facilitator and observer (or note-taker) should begin by introducing themselves as well as all participants, and clearly explain the purpose of the activity. It is important that participants understand and feel comfortable with what will follow.

3. Produce (or draw) an institutional map

The participants should be asked to identify actors with whom they interact or would interact in the process of flood risk management or a flood emergency. Focus however should not be limited to flood emergency as this will limit the identification of the full range of stakeholders that are, in one way or another, responsible for urban flood risk management. These actors could be physically present in the area or could be associated directly or indirectly and could be individuals, groups, or organizations. Informal relationships should be also considered.

Questions to help inform the mapping may include but not be limited to:

- Which institutions are relevant to flood risk management?
- What are their interests, roles, relative power and capacities?
- What are the mandates of those institutions?

- How do they interact one another or with the local population? Are there any conflicts?
- Where are the overlaps with other organizations?
- What are their plans for responding to an emergency?
- What are the strengths and weaknesses of these institutions?

The visual outcome at this stage (i.e., map) will be used as a source of information for the discussion or the analysis that will take place in the next step. More specifically the map will help to better understand the relationships of different formal and informal institutions or individuals and to identify the key factors affecting their relationships with the others, and the implications of these relationships in managing flood risk or a flood emergency.

4. Analyze the institutional map

At this step the relationships shown on the map can be explored. Discussion may be focused on a number of factors such as but not limited to:

- Influence
- Source of funding
- Availability of information
- Social or cultural issues
- Challenges and opportunities
- Threats and weaknesses
- Legal or institutional aspects
- Collaborations and partnerships
- Good practice (sharing of knowledge)

Participants can be asked to explore and explain the ways in which each of these relationships can be changed or improved. Potential changes with regards to flood risk management (e.g., new measures, policy change) in their area should be discussed on the basis that they might impact these relationships in a positive or a negative way.

This stage will identify potential ways for strengthening or improving relationships between key actors and explore possible opportunities and challenges for flood risk management. This will form the basis with which current measures can be improved or new measures can be adopted.

5. Wrap-up

It should be made clear to the participants how the information will be used. Participants can also reflect on the advantages and disadvantages of the process.

Further reading

World Bank. n.d. "Institutional Perception Mapping." Available at:

http://siteresources.worldbank.org/EXTTOPPSISOU/Resources/1424002-1185304794278/4026035-1185375653056/4028835-1185375938992/2_Insti_perception_mapping.pdf

Mukerhjee, N. and van Wijk, C., ed. 2003. Sustainability Planning and Monitoring in community water supply and sanitation – a guide on the Methodology for Participatory Assessment (MPA) for community-driven development programs. Washington, DC: World Bank.

6.2.3. Linking flood risk management with urban governance and management

According to the United Nations Development Program, "Governance is the umbrella under which disaster risk reduction takes place" (UNDP 2010: 1). In well-planned and well-managed cities the impacts of flooding can be mitigated because of the measures that have been implemented to reduce flood risk and flood impacts. Such measures may include provision for drainage systems, flood zoning restrictions and land use management to increase surface water management capacity.

However, typically this is not the case in cities and towns that are not adequately planned and managed. Often areas, particular informal settlements, lack adequate drainage systems and rely on natural drainage channels. It is also common for buildings or infrastructure to be constructed either in locations that actually further increase their exposure to flood risk, or in a way that increases their vulnerability to flooding.

Even when policy makers accept the necessity for implementing an integrated flood risk management approach, a lack of capacity to plan, design, implement, operate and maintain flood risk management systems is likely to be a severe constraint on efforts to ensure its adoption. Box 6.3 outlines the way in which constraints on city governments can be further linked to legal, vertical as well as horizontal government relationships, and organizational aspects.

In order to link flood risk management to local realities, the decentralization of local governance functions must also be taken into account (Christoplos 2008). Decentralization can make city governments more efficient, responsible and responsive. Due to spatial proximity, local authorities are able to make well-informed decisions. Nevertheless, decentralization may not bring the anticipated results if local governments lack the technical capacity and resources to implement measures. Wider supportive political and organizational underpinning is vital to ensure the success of integrated flood risk management as local authorities may suffer from constraints similar to those described belowin the box.

Box 6.3: Constraints on local governments

Legal exclusions

- City boundaries often do not include areas where the urban poor live, thus placing them outside of municipal jurisdiction
- Municipal divisions may geographically and functionally separate responsibilities
- Legal restrictions on working in informal areas, for example, not being able to supply those populations which do not pay property taxes with services
- Vertical relationships
- Lack of supportive financial and planning frameworks
- Unclear and overlapping responsibilities
- Political competition with higher levels of governments

Horizontal relations

- When cities or provinces share the same water resource that is the source of flooding, but do not perceive this issue as a common problem
- Lack of understanding, information sharing and cooperation between relevant departments or institutions at the local, regional and central level of governance

Limits of organization

- Lack of financial resources in order to increase service provision and build infrastructure
- Weak managerial and technical capacities
- Leadership without institutionalized accountability
- Unwillingness to address urgent local problems
- Local governments are often not responsible for many public services including land allocation, housing, water and other public services
- Lack of adequate information on poverty, environmental conditions, service and infrastructure deficiencies

Sources: Devas and Batley 2004; Satterthwaite 2001; Tanner et al. 2009; Corfee-Morlot et al. 2009

6.2.4. Allocation of stakeholder responsibilities for urban flood risk management

The above discussion about the limitations of local government to fully implement flood risk solutions reinforces the conclusion that there will need to be collaboration from many stakeholders.

For flood risk management to be implementable, its operational requirements must be compatible with the knowledge and technical capacity that are available. In practice, even the simplest technologies can fail due to a lack of attention to operational and maintenance requirements. As seen above, flood risk management, as a multi-disciplinary and multi-sectoral effort, falls under the responsibility of diverse institutions. Therefore, flood risk reduction measures need to be comprehensive, locally specific, integrated, and balanced across all involved sectors.

AfDB et al. (2004) suggests that this can be achieved through:

- Institutional collaboration between stakeholders
- Clear assignment of roles, assumption of responsibilities and coordination of activities
- A common vision by all stakeholders
- An adequate institutional framework.

The case study of Cambodia below illustrates how a program of enhancing flood preparedness can incorporate changes to governance structures and building of capacities at appropriate governmental levels.

Case Study 6.1 Flood preparedness and emergency management programs in Cambodia

Prey Veng which is located on the east bank of the Mekong River, and Kandal which borders Prey Veng in the mid-south of the country, both rank among the most flood-prone provinces in Cambodia. For the communities living along the floodplains of the Mekong River, flooding is a common situation. In 2004, to enhance the capacity of the local governments in flood preparedness and mitigation, the Mekong River Commission (MRC) initiated a three-year comprehensive program aimed to formulate and develop provincial and district flood preparedness programs (Figure 6.2).

Despite the fact that Cambodia had a disaster risk management system in place, consisting of the National Committee for Disaster Management (NCDM), the Provincial Committee for Disaster Management (PCDM) and the District Committees for Disaster Management (DCDM), there was no clear allocation of roles and responsibilities. Through institutional analysis, the Flood Preparedness Programs (FPPs) identify the issues that need to be addressed and prioritize flood risk management measures that need to be implemented.

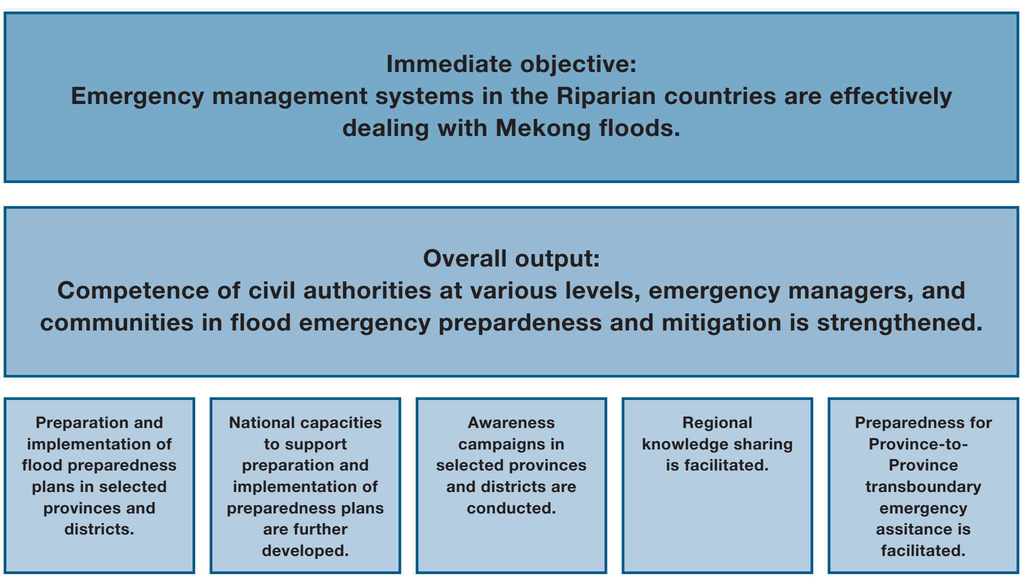

Figure 6.2: Flood preparedness and emergency management program, Source: adapted from MRC and ADPC 2008.

Although integration of flood risk into local development planning processes is not yet completed, significant lessons can be drawn from this initiative:

- Political will at the highest level of government officials and departments is a prerequisite to successfully mainstream flood risk concerns within their sectors and spheres of influence;
- Acknowledgement of the problems, participation and ownership of the local government officials and departments is also necessary to sustain the undertaken activities;
- Identification of local advocates or 'program champions' can increase local stakeholder ownership and facilitate the integration process;
- Decentralization provides an enabling environment for integrating DRR into official development plans;
- Significant efforts should also be given in awareness raising, advocacy and capacity building;
- For effective DRR integration it is vital that institutional capacity for disaster risk reduction is equally provided to all other government departments, such as those dealing with health or gender issues;
- Integration should take place using horizontal and vertical approaches. This means that integration should take place at the level of overall local government development planning processes, and involve departmental or sectoral plans of the various departments;
- Given limited financial resources, integrating DRR into local development plans can be a viable long-term resource allocation option for flood risk reduction.

Source: MRC and ADPC 2008.

Clarity in establishing responsibility for aspects of flood mitigation is crucial. Flood management institutions, which can be the local government or separate administrative bodies, have to face the challenge of managing the whole system properly on behalf of the citizens. When ongoing operation and maintenance tasks are transferred to others, such as private companies, households or communities, it is essential that responsibilities are clearly negotiated, enumerated – and if necessary legislated for. When large river basins are under consideration, the responsibility can cross provincial or even national boundaries and, therefore, greater coordination amongst all relevant stakeholders will be necessary.

Figure 6.3 below shows some of the agencies and legislative acts involved in flood risk management in the UK. These include government departments, 'quangos' (quasi-autonomous, non-governmental organizations), private companies and individual private landowners. The Pitt Review (2008) into the large-scale flooding in 2007 in England, concluded that more clarity was needed regarding the roles and responsibilities of the different organisations responsible for managing flooding from all sources. The subsequent Flood and Water Management Act of 2010 assigned the strategic overview for all sources of flooding and coastal erosion to the Environment Agency (in England) and the responsibility for local flood risk was assigned to Lead Local Flood Authorities. In Wales, the Environment Agency was assigned a Strategic Oversight role for all sources of flooding and coastal erosion and the responsibility for local flood risk was assigned to Lead Local Flood Authorities.

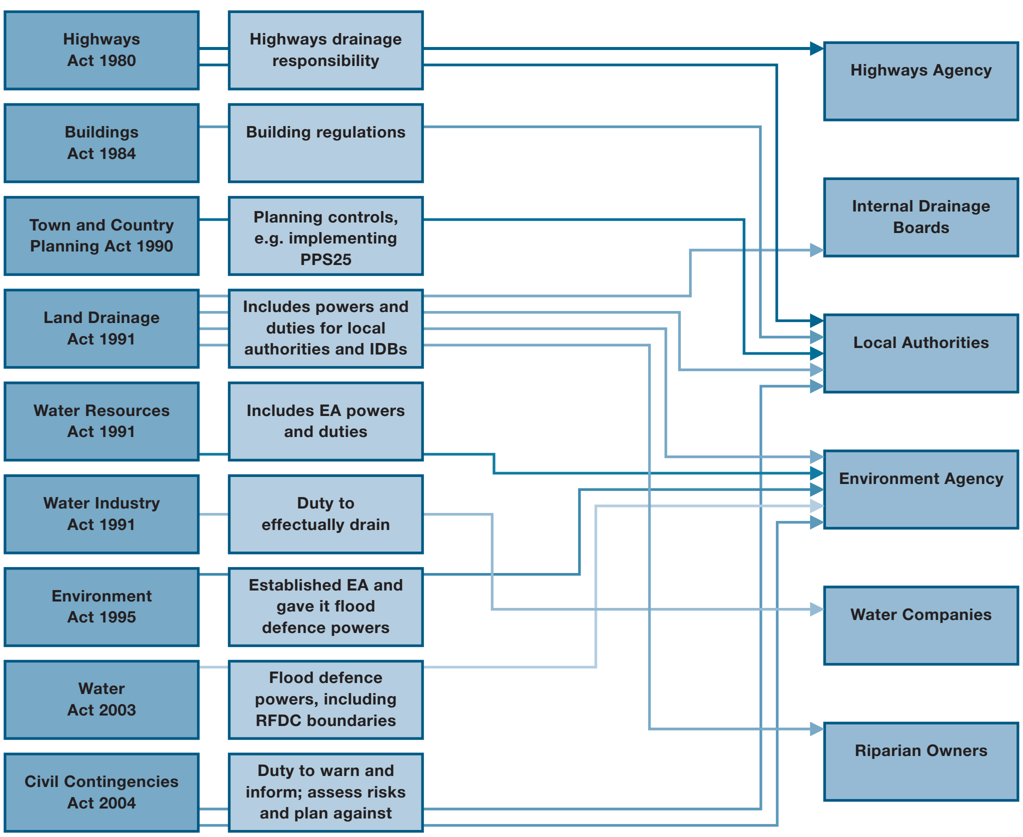

Figure 6.3: Summary of legislation in UK FRM, Source: Adapted from Pitt 2008

Case Study 6.2 below uses the example of the Murray-Darling Basin in Australia to indicate the interplay of institutions and interests in the management of a large-scale catchment area.

Case Study 6.2: Murray-Darling Basin

The Murray-Darling Basin is named for the Murray and the Darling Rivers. It is located in south-eastern Australia, and contains an area of approximately one million square kilometres. The basin area encompasses parts of the states of New South Wales, South Australia, Victoria and Queensland and the whole of the Australian Capital Territory. Major urban and township settlements within the basin include Australia's capital Canberra, Tamworth, Wagga Wagga, Albury, Bendigo, Renmark and Mildura. It supports a population of over two million people and grows more than one third of Australia's food. The basin has a diverse landscape and includes over 77,000 kilometres of rivers, more than 25,000 wetlands, floodplain forests and the Coorong and Lower Lakes that support a wide range of complex and dynamic ecosystems. The basin also contains Ramsar wetlands.

Climate patterns in Australia are characterised by periods of drought and heavy rains. Over time, landscapes, species and ecosystems shift from being flood dependent to flood tolerant. Flooding events in the Murray-Darling Basin enable exchanges and linkages between rivers and flood plain areas to take place, allowing the ecosystem to remain healthy. Flood risk management within the basin is therefore addressed at the broader catchment level and within a water resource and environmental management framework.

Management of the Murray-Daring Basin has occurred over the last 90 years and has always been characterised by inter- and intra-government coordination between the national and state governments and their various department and institutional bodies all of which represent different political, environmental, industry and community interests. Management of the basin has evolved over time and through legislative change. Recent and proposed changes to the management of the basin have caused controversy within various sectors in Australia as institutions compete to ensure their interests are protected.

The Murray-Darling Commission established in 1988 under the Murray-Darling Basin Agreement marked the beginning of a more targeted and integrated approach. The role of the Commission was firstly to manage and equitably distribute water resources; secondly, to protect and improve the environment; and finally to advise the Murray-Darling Ministerial Council. This framework remained largely unchanged until the enactment of the 2007 Water Act. The introduction of the Act can be seen as a direct response to the prolonged drought that Australia was experiencing at the time. Through its enactment the Australian Government recognised the need for legislative and policy instruments to respond to challenges due to climate change, climate variability and reduced water availability. In 2008 this act was amended to transfer power from the Murray-Darling Basin Commission to a newly-established Murray-Darling Basin Authority (MDBA).

The MDBA is an independent, expert-based authority whose principal aim is to manage the Basin's water resources in the national interest. The establishment of the MDBA is the first time a single agency is responsible for the planning and management of the Murray-Darling Basin water resources. Participation from the State Governments in this structure is via the Ministerial Council and the Basin Officials Committee. Representation on the Council is by one Minister from each state government and chaired by the Commonwealth minister. Representation on the committee is by senior government/departmental officials of each state. Both bodies have advisory roles with the Committee also being responsible for implementing policy and decisions of the Council. Local government and community representation occurs at the operational and implementation level through advisory groups that report back via the Committee.

Management of the basin and water allocation has long been a contentious issue within Australia. There was a widely held view that changes to the way the basin is managed were required. Competition between sectors, urbanisation pressures and changes to the economic bases of urban centres continue to provide the political backdrop to management of the basin. These circumstances coupled with prolonged drought followed by severe flooding in parts of Australia, including within the basin, have extended and sharpened the debate around what is the best long-term management solution. The 2010 floods in the state of Victoria caused significant economic damage but were a welcome event for communities further down the system in South Australia as the flood waters enabled the natural flushing process of the Murray River mouth, something which had not occurred naturally for over 10 years. However, in contrast, the 2010/2011 flood events in the state of Queensland, affecting over 200,000 people and providing substantial flows of water into the system, have caused some people to challenge the need for the reform measures proposed (detailed below) within the basin.

Through the 2007 Water Act and subsequent amendments, a legally enforceable national basin management plan has been drafted. The Draft Basin Plan prepared and currently being consulted on seeks to establish a long-term management framework for the Basin. The draft plan seeks to redress the imbalance in water flows throughout the whole system and improve the environmental condition of the Basin area. A central tenet of the plan is a reduction in consumptive water use and reinstatement of environmental flows within the system. The MDBA's fact sheet 'flooding and the Basin Plan' outlines four key messages:

– Periodic flooding is a natural process of critical importance to the environmental health of the Murray-Darling Basin
– The Basin Plan will restore more natural flows to the river.
– State environmental watering and management plans associated with the Basin Plan will be required to detail plans, policies and operating procedures to manage and mitigate unacceptable flood risk
– MDBA is undertaking technical assessments to identify physical or policy barriers that limit effective delivery of environmental water.

The MDBA acknowledges that the Basin Plan will have no effect in circumstance where periods of very high and prolonged rainfall (relatively infrequent) produce large flows that cannot be contained by the regulatory structures (such as dams) on some rivers. Rather, through the reinstatement of environmental flows (Environmental Watering Plan (EWP) linked to the Basin Plan) it is planned to undertake a catchment level water resource and environmental management approach. As part of this integrated and holistic approach, the MDBA requires state water resource plans developed under EWP to be accredited by MDBA and detail the environmental delivery mechanisms and flood-control mitigation measures. The proposed environmental watering as part of the Basin Plan anticipates that through 'piggy-backing' on existing, naturally-occurring small flood events within the Basin that implementation of environmental watering can occur, albeit differently across the Basin. This integrated approach consistent with the catchment level, water resource and environmental management philosophy that underpins the MDBA and the proposed Basin Plan.

The proposed management plan is not without its significant challenges. In attempting to redress the water flow imbalance and implement environmental watering, a buy-back scheme of water allocation rights by the Commonwealth Government is proposed. The allocation of water within the Basin has been a long standing issue of contention with large political implications. Competition between those in the upper catchment area of the basin and those in the lower more arid areas (all in different states and local authorities) is a cause of much debate. Historic agreements to guarantee fixed annual volumes for the most downstream state by the upper states is at the trade-off that the upper states can share equally what remains from the Murray itself, plus can use all the water they wish from their own tributaries of the Murray River, with the exception of declared drought years. These negotiations and agreements sit within a wider political context of differences between primary producing or largely agricultural areas and those of townships or cities. The township and cities debate is divided further politically between those areas that support and/or are supported by agriculture and those which have a more diversified economy.

The proposed reforms attempt to entrench a 'national' approach to managing the basin. However, the proposed reforms continue to fuel intense political debate as the government institutions responsible for implementation and the numerous industry and community groups it affects, continue to have differing and competing interests.

Sources: Murray-Darling Basin Authority website; World Bank, 2006, Integrated River Basin Management: From Concepts to Good Practice

6.2.5. Public-private cooperation

Inclusion of the private sector in flood risk management may involve the utilization of the financial and human resources of business enterprises, or to working with the insurance sector to mitigate the effects of flood disasters. For the private sector to get involved, governments must first put in place the appropriate policy, institutional and infrastructural frameworks. Often the outcomes of mitigation or prevention measures undertaken by private interests depend on what government does (or fails to do) to incentivize them to participate. Resources from both government and the private sector can be combined to form an effective management system.

The role of the private sector in the implementation and delivery of urban infrastructure has been increasingly recognized. Public-private cooperation is often a fundamental component of the strategies adopted by international development organizations and governments, particularly when it comes to infrastructural investments (Tanner et al. 2009).

In flood risk reduction, public-private partnerships can provide to the private sector a better understanding of their interdependence with locally critical infrastructure, and improve coordination with the local stakeholders before, during, and after a disaster (NRC 2011). This was put into practice in Metro Manila as Case Study 6.3 below illustrates.

Case Study 6.3: Multi-stakeholder collaboration for better Flood Risk Management in Metro Manila, the Philippines

Metro Manila consists of 17 cities and municipalities, including the City of Manila, and has a population of over 14 million people. It is a low-lying area intersected by the Pasig River and its tributaries. Severe flooding caused by Typhoons "Ondoy" and "Pepeng" in 2009 has raised public awareness of the underlying causes of flooding. In September 2010, the Mayors of all Metropolitan Manila cities signed a covenant known as the "Estero Declaration", affirming their commitment to protect Metro Manila's waterways, control environmental pollution and prevent the recurrence of flooding.

The Metro Manila Mayors pledged to implement their own anti-littering ordinances as well as clean and dredge the esteros, creeks and other waterways located within their jurisdiction. They also expressed their support to the campaign to dismantle and remove all structures, constructions, and other encroachments along waterways and help relocate informal settlements in coordination with the national government agencies.

On a similar note, the Cities of Pasig, Marikina, Antipolo and the Municipalities of Cainta, San Mateo and Rodriguez signed a Memorandum of Understanding in 2010 on the "Formation of the Marikina Watershed Environs Integrated Resource Development Alliance" also known as the Alliance of Six. The Alliance aims to restore, protect and preserve the Marikina watershed and its environs. The Metropolitan Manila Development Authority (MMDA) supported this initiative by mobilizing various stakeholders such as civic and business organizations, faith-based organizations, non-government and community organizations, within the Marikina watershed to take action on issues such as disaster preparedness and disaster risk reduction.

As part of the Alliance's efforts to involve the private sector in its various activities, a Memorandum of Agreement was put in place with a private firm, which pledged financial support in the cleaning of the local drainage systems. Moreover, two construction companies made available heavy equipment for dredging waterways, esteros and canals – either free of charge, or under a “Borrow Now, Pay Later Scheme”.

The case demonstrates that implementing integrated flood risk management requires the involvement of the full range of stakeholders, including regional and local government officials, and the private sector. It is important that these actors show they are committed to address existing and future problems.

Source: Personal communication with MMDA

6.3. Community engagement

Engaging the community in flood preparedness and mitigation is crucial to the success of many measures such as warning and evacuation, and can reduce the cost of other measures such as constructing local defenses or contributing to maintenance of drainage systems. Therefore, community engagement is important for both structural and non-structural measures. Engaging the community throughout the project cycle of flood risk management (assessment, design, implementation, monitoring and evaluation) is also a prerequisite to ensure that the undertaken measures are equitable and effective, and meet the needs and priorities of the entire affected population (Sphere Project 2004; WMO 2008).

Engaging the community in flood risk management is about involving them in measures that may be carried out by such institutions as government, non-government actors, or the private sector. Flood mitigation solutions, both structural and non-structural, thus seek to benefit from community views or participation. Community-based measures, which are covered in the next section, are related but distinct, as they are driven by the community itself: the community designs and implements the measures. Such community-based measures, take their impetus and direction from the experience, capacity and capabilities of the community.

An example of community engagement is seen in Jakarta in Case Study 6.4 below, where the engagement of the community strengthened flood risk management activities and led to the development of greater local capacity to cope with flooding.

Case Study 6.4: Communities engaged in flood risk management in Jakarta

Jakarta is a megacity with complex urban development challenges. After the 2002 flood disaster affected 24 percent of its total land area, UNESCO,, together with local government institutions, non-government organizations (NGOs) and the Indonesian Red Cross, implemented activities to strengthen the flood resilience of communities living in the city sub-district of Bidara Cina.

Bidara Cina has a population of approximately 43,000 and is located in the eastern part of Jakarta along the Ciliwung River, which is one of the major drainage systems in Jakarta. Waste disposal, water supply, health and public hygiene are amongst the main problems that Bidara Cina faces, all of which exacerbate the impacts of floods. During flooding, which usually occurs once or twice a year, many residents have to evacuate to safe places.

Non-structural flood mitigation and preparedness measures were implemented to raise the community's understanding and awareness on the physical and social implications of floods, and to strengthen people's capacity to cope with floods. To ensure the success of the initiative, and maintain the continuity of the project, local organizations were actively involved in all processes, and carried out the various project activities, which included:

- Water quality, supply and user assessment study in collaboration of the Laboratory for Industrial Hygiene and Toxicology – Institute of Technology in Bandung, Jakarta;
- Vulnerability and capacity assessment using Participatory Rural Appraisal (PRA) methods, focus group discussions and questionnaires;
- Public education and training;
- Capacity building for community organizations;
- Publication of a practical handbook for community participation in flood management informed by the outcomes gained from the community.

The establishment of a local community organization for flood preparedness and mitigation provided training and capacity building for existing local organizations. These local organizations then contributed to the dissemination of flood-related information to other communities, and have been actively involved in disaster preparedness activities undertaken by other community organizations in these communities and the government.

This case demonstrates that local community organizations can and should be actively participate in flood preparedness and mitigation, as the success of flood risk management measures considerably depends on the involvement of the full range of stakeholders.

Sources: UNESCO 2007; UNESCO 2004

Each community is unique. Community engagement thus has to take into consideration such issues as their size, income, homogeneity, history of cooperation, and political participation. It is vital that community based organizations (CBOs), community leaders and NGOs that work at the community level are actively involved (Moga 2002). The Sphere Project (2004) recommends that community engagement should, as a minimum, ensure that:

- Women and men of all ages, including the most vulnerable and marginalized groups that live in areas exposed to floods, receive information about the measures undertaken, and at the same time, are given the opportunity to comment and provide their inputs throughout the project cycle.
- The objectives of the measures reflect the real needs, priorities, concerns and values of at risk communities, and particularly those belonging to vulnerable groups, and contribute to their protection.
- Measures are designed in a way that maximizes the use of local skills and capacities.

6.3.1. Why is community involvement important?

The success of flood preparedness and mitigation measures depends considerably on the involvement of local communities. Engaging the communities can further increase the effectiveness of the undertaken measures, and can also add an element of sustainability on their outcomes.

Flood risk management measures have typically been driven by top-down decision making, without the active involvement and participation of the affected communities (WMO 2008). Often, top-down approaches have not only resulted in unsustainable measures, which failed to meet the real needs of flood-affected communities, but in more severe cases led to serious disagreements, or even conflicts. It is increasingly recognized that top-down DRR measures often fail to address specific local needs and priorities of the most vulnerable communities, ignore the potential of local resources and capacities, and may in some cases even increase people's vulnerability (Abarquez and Murshed 2004). Local communities understand local problems and priorities better. By engaging with them, it is likely that the underlying causes of vulnerability to flood risk can be more effectively addressed.

International agencies, government and NGOs may initiate and implement flood risk management measures before and after a disaster. However, once the external support comes to an end, such initiatives may be neglected. To a certain extent this lack of continuity may be linked to the lack of participation, empowerment, and ownership by the local communities (Kafle and Murshed 2006). For example, small-scale flood mitigation measures and basic service provision improvements, such as for water and sanitation infrastructures, are often found to be unsustainable and are not scaled up. Agencies that implement flood mitigation projects often fear the cost of participation in terms of both time and money. However, community involvement in the planning and implementation of flood preparedness and mitigation can save wasted investment in inappropriate interventions in the long run. This was demonstrated in Malawi in Case Study 6.5 where the involvement of communities in risk assessment and planning provided extra resources to the project and led to better understanding of and commitment to the implemented measures.

By enabling communities to organize themselves and linking them with local decision-making mechanisms, the continuity of flood risk management initiatives can be maintained. It is recommended that decision making should be seen as a "combination of top-down and bottom-up approaches which enables the involvement of all stakeholders on the basis of equity" (WMO 2008: 34).

Case Study 6.5: Multi-stakeholder flood management in Malawi

Heavy rains in Malawi very often give rise to flooding. It is expected that changes in the seasonality and volume of precipitation due to climate change and variability may result in more flood events in the future.

In a project implemented by the NGO Tearfund in 2003, local communities in the area of Mthumba, Chikwawa District, in the southern part of Malawi, were engaged throughout the process of design and construction of small- to medium-scale flood prevention activities. This provided the communities with a better understanding of the rationale of flood prevention measures, which included the construction of structural measures, such as building storm drains and planting trees along the river to slow down water runoff, and involved a range of different actors, including the government and private companies.

Methods that were used included participatory assessment for disaster risk to identify the main type of hazards, their sources and their potential impacts, while communities were trained on environmental resource management, such us the use of vegetation to prevent river bank erosion. Moreover, historical data about the previous course of the river were gathered by the community elders, to better inform the choice of mitigation measures needed to re-establish the previous route of the river away from current community structures, like residences and shops.

This initiative shows that when communities are involved they can better understand flood hazard and flood risk. Moreover, ownership from the communities is necessary to guarantee long term sustainability of any initiative. Local governments need to engage with communities and also mobilize the necessary resources.

Source: Tearfund (n.d.).

6.3.2. Stakeholders involved in community engagement

It is crucial that the flood-affected communities and all other relevant stakeholders are carefully identified, as illustrated in Figure 6.4. Identification of stakeholders needs to consider potential differences or conflicts. It is important, therefore, that this is done in an inclusive manner.

Consulting and working with local governments is not only essential but also a democratic necessity. Often, international agencies that implement urban flood mitigation projects work with national or federal government bodies (for example Ministries, or Water Development Boards); they may ignore (or almost ignore) the municipalities or local authorities, mayors, ward councilors and commissioners. However, these stakeholders are particularly important to urban flood risk mitigation.

Box 6.4: Relevant stakeholders in urban flood risk management

- Communities which are affected by the implementation (or non-implementation) of measures
- Community based organizations (CBOs)
- Non-governmental organizations (NGOs)
- The responsible municipal authorities
- River basin organizations or authorities
- Regional development authorities
- Scientific institutions, including universities
- The private sector

Source: adapted from WMO 2008

Involvement of all relevant stakeholders is important because (WMO 2008):

- It brings knowledge and experiences from different perspectives together, and thus enabling a more insightful understanding of flood risks.
- Members of flood-affected communities have the chance to express their real needs and priorities, and promote the consideration of their demands in the decision-making.
- Stakeholder involvement ensures that a wide range of actors support the undertaken flood risk management measures, thus ensuring that they are sustainable.

Time constraints is an issue that needs to be considered by decision makers in relation to the involvement of communities and other stakeholders in flood risk management. The time that people, especially poorer people, have to participate in flood risk management measures, in public consultations and other activities, is often limited. Moreover, mobilization of the community to engage in voluntary service is also a challenge. For this reason, it is important to identify special means to facilitate people's participation. This is further discussed on Section 6.3.4.

Figure 6.4: Stakeholders and actors involved in flood risk management
Source: Adapted from Abarquez and Murshed 2004: 19

6.3.3. Understanding local knowledge and capacities

Communities often have first-hand experience of flood disasters. It is quite common for them to have developed coping mechanisms, such as local institutions and CBOs, to deal with adverse effects of flooding. However, the understanding and capacities of the local communities are often overlooked (Moga 2002).

Pioneering examples in community disaster mitigation include PREDES, the network for social studies on disaster prevention in Latin America, and Duryog

Nivaran, a network of organizations and individuals in South Asia which has been promoting community management and mitigation activities since 1994. Similarly, in South Africa, Periperi (Partners Enhancing Resilience to People Exposed to Risk) emphasizes disaster risk reduction by bringing in resilience to the community as a whole. The Asian Urban Disaster Mitigation program under ADPC, in collaboration with USAID, has also started the program of enhancing the resilience of selected cities in South Asia by encouraging community participation in resilience building to reduce vulnerability.

It is vital that flood risk management solutions acknowledge communities' existing ways of dealing with floods. Solutions should complement existing coping mechanisms, resources and social capital, and not compete with them (Alam 2008). Communities that live in locations where floods occur regularly will probably be more prepared than people living in areas where floods are rare. Often communities establish their own local and traditional institutions to deal with disasters, including flooding. These are discussed further in the section which follows on community-based measures. If external flood risk management support complements these existing mechanisms and local institutions, it is likely to be more sustainable after the external assistance stops (Sphere Project 2004).

In areas which have not or have rarely experienced floods, community participation and motivation in preparedness and mitigation activities is also important, as discussed above. However, experience shows that participation is difficult in an emergency (ActionAid 2002). Community engagement in flood risk management should strengthen people's sense of dignity, and also give hope in times of crisis (Sphere Project 2004). It can also contribute to equitable and sustainable community development in the long term (Abarquez and Murshed 2004).

6.3.4. Sharing of information and knowledge

Communities need to be well-informed about flood risks to actively participate in flood preparedness and mitigation. Information should be complete, unbiased, and minimize controversies (Creighton 2005). The sharing of information and knowledge among all the stakeholders involved is vital to better understand the problems and to provide coordinated assistance (Sphere Project 2004). In particular, communities and all other relevant stakeholders need information about the ways in which the undertaken measures could affect their livelihoods (Creighton 2005).

The process of engaging local communities in flood preparedness and mitigation requires information on flood risk and the recommended management measures to be generated in a manner and language that is understood by the local communities (Kafle and Zubair 2006). Moreover, mechanisms should be established to allow communities and other relevant stakeholders to comment on the undertaken measures, for example in public meetings or through CBOs. Specific provision should be taken into consideration for individuals who are confined to their shelters (disabled people, for example).

6.3.5. How to engage local communities in flood risk management

Engaging the concerned community in flood risk management will ensure that the public's real needs, priorities, resources and capacities are taken into consideration. Experience shows that that flood risk is more likely to be successfully reduced when the communities are fully engaged. The general problems observed in communities are a lack of appreciation of risk and a lack of motivation to participate in flood mitigation activities. At the same time, official agencies often do not appreciate the potential benefits of community participation and do not have the skills or experience in participatory activities.

Method

A step by step process for achieving effective engagement of communities in flood protection is outlined below. Communities should be involved in all processes of flood risk management, including assessment, planning, implementation, monitoring and evaluation. Community participation means that the management of flood risk is more effective and proactive.

The situation differs from one area to another as defined by social, economic, political and cultural context. It is important to ensure that these factors are taken into account when working with communities.

1. Raising awareness of flood risk and motivating community action

2. Strengthen relevant community institutions

3. Ensure inclusion

4. Planning for real

5. Actively encourage participation for sustainability

6. Monitoring and evaluation

1. Raising awareness of flood risk and motivating community action

Although the situation varies from one area to another, it is commonly observed that communities often lack an appreciation of the flood risk and hence have little motivation to participate in flood protection activities. Generating public awareness of flood risk is therefore core to successfully engaging communities in flood risk management.

Appropriate communication techniques should be selected dependent on the social, economic, and cultural context. Formal communications through pamphlet or leaflet drops will deliver information to people's doorstops. Motivation through radio and TV infomercials may work in some communities. However, in many communities more innovative participatory communications will raise awareness most effectively. Participatory techniques include group discussions, participatory mapping, Venn diagrams, timelines, transect walks and ranking exercises. It may be particularly effective to identify organizations which have ongoing engagement with the communities and work with and through them to introduce flood awareness and risk mitigation.

Public awareness of flood risk directly feeds into motivating them for flood risk management. Again different techniques will be appropriate for motivation in different communities. The facilitation of these participatory sessions will not be easy where there is little public confidence in the authorities' ability or interest in working with communities. For effective public participation it is essential to build trust and understanding between the community and the concerned professionals. This may take time and will require facilitation by experienced participatory communications expertise.

As awareness rises and motivation grows, weekly workshops perhaps using models and photo-montages to communicate and develop ideas, or group planning and design sessions which combine experts' and public's ideas will collectively develop technically effective risk mitigation solutions that meet local needs. Walkabout mapping exercises can be used by residents to highlight the perceived problems and possible benefits of risk management interventions. It is important to have representation from all sections of the community to ensure that all risks are identified and mitigated. Events (e.g., simulation exercises, big tent events, fete style events, town hall meetings, etc.) can be used to encourage local people to consider flood risk and make suggestions for possible changes or interventions.

Communities who face regular flood events will have their own indigenous methods of flood risk mitigation. It will be important for practitioners to understand, reflect and learn from these as building on existing mitigation mechanisms will often be the best starting point for encouraging active community participation. Exploiting existing expertise and building additional capacity within the local community will make the flood risk management work of professional bodies much easier. Effective community engagement will also enhance sustainability.

2. Strengthen relevant community organizations

For sustainability of any community engagement it is vital that there are appropriate active institutions of the community. There is usually a clear choice either

a) To identify an appropriate existing organization and bring flood prevention into their mandate, or

b) To establish a new flood-specific community organization.

Motivating existing active community organizations to focus on flood issues and providing them with training and any necessary technical skills will enable them to integrate flood risk planning and mitigation into their existing activities (e.g., health, education etc.). Starting a new community organization to work specifically on flood issues, in parallel with those that already effectively working on other community services, is likely to require significantly more input both at the start-up and to ensure sustainability.

Either way, capacity building input will be required to strengthen the concerned institution’s knowledge base – specifically their understanding and appreciation of flood prevention activities to be undertaken by the community – and their management capacity. Training courses, exposure visits, transect walks, roundtable workshops – there are a range of possible interventions which will be appropriate to meet the institutional strengthening needs of any specific community organization.

One vital aspect is to ensure that the community organizations have open two-way communication with the concerned authorities. This will enable decision making to benefit by input from the community, and also for communities to activate the authorities should they require any official support.

3. Ensure inclusion

Whatever institutional arrangement is developed at the community level, the flood mitigation practitioners must ensure that all segments of the community are included.

As discussed elsewhere, floods have a differential impact within communities, often impacting the poorest and most marginal most (e.g., slum and squatter communities, settlements on flood plains or riversides etc.). Similarly, within any community, the aged, disabled, young mothers and children will have specific vulnerabilities which will need to be recognized and addressed. It is essential to ensure the involvement of the most marginal in any community engagement process. This may require detailed mapping to guarantee geographical coverage, and social mapping to ensure that any plan includes the most vulnerable. If representatives of these groups cannot be included at the institutional level, then these marginal groups should be specifically consulted on their flood experience and any anticipated difficulties which would arise for them. Any specific needs should be incorporated into planning.

4. Planning for real

This is an exercise which integrates in the planning process the local community knowledge with external expertise and any appropriate options presented by new technology. There are many ways to do this but central to the approach is that the professionals must be open to the input of local communities and communities should be confident that their voice will be heard.

Planning using normal paper-based plans and diagrams should be avoided as this does not facilitate understanding by non-technical participants. Models and pilot demonstrations are much more useful to elicit informed reaction from the community. Joint visits to other sites where any proposed flood measures have already been successfully carried out is an important motivational and planning tool. The experts can hear directly the local opinions on where and how such interventions might work in their community.

Where appropriate, the consultation and information sharing process can take advantage of web-based tools alongside any standard planning procedures and also invite the submission of written comments. Utilizing higher technology can make work easier and faster, however, if used inappropriately they can exclude people, especially the more remote and more vulnerable in the communities.

After detailed planning consultations, a participatory design review should be carried out to ensure local understanding and buy-in. This will be in addition to the standard good practice of having an expert review of the proposals.

5. Actively encourage participation and sustainability

It is vital that professionals recognize that community engagement is not a one-off activity but a process that requires sustenance and support. It should also appreciate that capacity building of the local community for flood risk mitigation will make the work of professional bodies much easier. Planning should include on-going mechanisms that support community self-help initiatives and motivate communities to sustain agreed activities or maintain operational readiness. This might or might not include funding. Provision of continuous education and training can be a good incentive. Regular dialogue and participatory status reviews are essential.

6. Monitoring and evaluation

A well-designed flood risk mitigation strategy will clearly define anticipated outcomes. These will be established as part of the planning process. The strategy should also incorporate a monitoring system to ensure effective implementation, and an evaluation process to assess impact and guide subsequent improvements. This monitoring and evaluation should also include participatory activities as communities are usually in the best position to know what worked and what did not. Professionals, especially technical professionals, often find it difficult to submit their interventions to evaluation by the public. However this is a vital dimension of community engagement in flood protection.

The concerned community will be able to record and report the impact of flood risk mitigation interventions, and most importantly is likely to understand the reasons for any failures, thereby provide feedback that will help avoid repeats. A well-designed monitoring and evaluation process will also be able to disaggregate the impact on different segments of the community. Again the techniques for recording community responses to a flood event will depend on the social, economic and cultural background of the local communities. In many places, participative consultation and evaluation techniques may well be the most appropriate.

There needs to be a feedback mechanism which ensures the monitoring and evaluation findings feed directly back into improved flood protection. If this is publicly acknowledged and community organizations are fully involved in the process, then it will further enhance public trust and community engagement.

6.3.6. Further reading

Abbot, Jo, 1999, ‘Beyond Tools and Methods: Reviewing Developments in Participatory Learning and Action’, Environment and Urbanization, Vol. 11, No. 1, pp. 231-235. http://www.ucl.ac.uk/dpu-projects/drivers_urb_change/urb_governance/pdf_partic_proc/IIED_Abbot_participatory_learning.pdf.

CARE. 1999. “Embracing Participation in Development: Wisdom from the field. Worldwide experience from CARE’s Reproductive Health Programs with a step-by-step field guide to participatory tools and techniques.” Edited by Meera Kaul Shah, Sarah Degnan Kambou and Barbara Monahan. http://www.care.org/careswork/whatwedo/health/downloads/embracing_participitation/embracing_participitation_en.pdf.

Chambers, R. 2007. “From PRA to PLA and Pluralism: Practice and Theory” IDS Working Paper 286. http://www.forum-urban-futures.net/files/Preparational%20Text%20PUA%20Chambers%202007.pdf.

DFID. 2003. “Tools for Development. A handbook for those engaged in development activity”, Performance and Effectiveness Department, Department for International Development, Version 15.1. http://onlinewomeninpolitics.org/sourcebook_files/Resources/Tools%20for%20Development-%20Handbook%20for%20those%20engaged%20in%20development%20activity%20(DFID).pdf.

Müller, D. and Wode, B. 2003. “Manual on Participatory Village Mapping Using Photomaps.” Social Forestry Development Project (SFDP) Song DA. http://www.iapad.org/publications/ppgis/participatory_mapping_using_photomaps_ver2.pdf.

World Bank. 1998. “Participation and Social Assessment: Tools and Techniques”, Compiled by Rietbergen-McCracken, J. and Narayan, D. http://info.worldbank.org/etools/docs/library/238582/toolkit.pdf.

6.4. Community-based measures to increase resilience

Community engagement, as seen above, is vital for effective flood risk management. In many instances, this should be complemented by community-based flood risk management measures, which can result in progressive improvements in public safety and community disaster resilience. The measures are specific to a community, in that they are identified, designed, implemented, monitored and evaluated by the community themselves, although very often with external technical and financial assistance.

The whole approach is based on the belief that local people can and will help themselves to prevent or reduce disaster risks.

The purpose is for a community to be prepared to face floods in the short term and for its members to be more resilient to floods in the longer term. This issue most frequently arises in communities which have a history of repeated flood events or have previously been flooded. Community-based flood risk management measures are based on using community resources to reduce the risk and impact of flood events.

6.4.1. Key components

The community is likely to be defined either by the geography of the flooding (for example, particularly low-lying or river-side settlements) or by administrative boundaries and the socio-economy of the urban area (comprising an electoral ward, neighborhood or housing colony). Either way, the spatial dimension is an essential element in defining the community that is at risk.

Communities are also complex and dynamic. People may join together for common goals and separate once they have been achieved (Twigg 2007). There will be differences in wealth, social status and employment of people living in the same area as well as, potentially, other more serious divisions within the community. Communities are likely to have worked together previously to manage other community activities, either informally (such as for festivals, sports clubs, clean up campaigns) or more formally for initiatives such as ‘neighborhood watch’ (a local security and safety program), garbage collection, crèches or health camps. It is vital that, if the initiative for undertaking flood mitigation measures comes from outside the community, the external agency researches the community activities which already exist within the area, as well the ways in which participants define the membership and boundaries of their community.

Good, strong, committed management is essential for effective community-based flood risk mitigation. Either an existing community organization will need to be trained and strengthened to take on this management role, or else a new organization will need to be built up during the process of risk assessment and mitigation planning. There is mixed evidence of the value of new community disaster management organizations, when formal or informal community organizations that might undertake the task already exist (Delica-Willison n.d). In either case it is clear that for management to be the most effective, both the management role and the tasks need to be clearly specified.

The community-based organization will need to ensure that the needs and priorities of the various stakeholders and different interest groups within a community are heard and balanced. Most particularly, to be effective, it must make sure that the more vulnerable segments – the women, children, elderly and disabled people, as well as any ethnic or otherwise marginalized minority groups – are given space to voice their opinions and are properly heard. Incorporating indigenous knowledge is also very important. The flood early warning system set up in eight villages in Dagupan City, Philippines, for example, has revived the use of the 'kanungkong' along with staff gauges as flood markers in strategic locations in the villages of the city.

The kanungkong is a bamboo instrument, which was traditionally used to call community members to assemble at the village hall for meetings, alert people or call children home. The indigenous knowledge is combined with modern scientific knowledge and equipment for use in disaster risk reduction (ISDR 2008).

The use of indigenous practice is also illustrated in the following Case Study 6.7 from Bangladesh.

Case Study 6.7: Learning from grassroots coping strategies for climate variability in Dhaka, Bangladesh[1]

Valuable lessons can be drawn from grassroots experiences of dealing with environmental hazards to reduce vulnerability. Understanding such local responses can contribute to the strengthening of planning strategies for adaptation to climate change and variability in cities.

Primary research carried out in Karail, the largest informal settlement in Dhaka, by the Development Planning Unit at University College London (UCL) in co-operation with BRAC University in Bangladesh, examined household and collective adaptation strategies to cope with existing environmental hazards such as flooding.

1 http://www.bartlett.ucl.ac.uk/dpu/adaptation_to_climate_change_in_cities

Photo 6.1: Informal settlements in Karail, Dhaka, Source: Huraera Jabeen

In 1988, 1998 and 2004, Dhaka experienced major floods that were caused by overflowing of the surrounding rivers. People living in Karail, however, experience environmental hazards nearly every year due to increased rainfall and flooding. The research found that local coping strategies that have been adopted either at the household or community level to reduce vulnerability include:

- Physical modifications (higher storage, increasing the height of furniture, installing rain gutters, making barriers at the door front, changing building and plinth materials after the disaster)
- Savings and access to credits (half of the households save regularly with a savings group or an NGO)
- Diversified income sources (households with diversified income sources are less vulnerable to floods)
- Strong social networks (37 percent of the households are part of some form of social network and can seek assistance in case of emergency)
- Accumulations of assets (saleable household assets, building materials, investing in children's health and education).

To mainstream local coping strategies into flood risk management and urban planning there are several aspects that decision and policy makers can take into consideration. First, it is important to integrate local knowledge to define patterns of vulnerability. Second, adaptation plans can be embedded into wider development goals. Third, risk transfer mechanisms for low income groups, such as collective savings schemes and insurance should be supported. Last but not least, a combination of "structural" and "non-structural" approaches developed by partnerships of government, utilities and civil society should be instigated.

Source: Jabeen et al. 2010.

Led by the CBO, the community will carry out a disaster risk assessment and prepare a disaster management plan. There are several useful and very detailed guidelines for these two key activities referenced at the end of this Section. Based on their disaster management plan, the CBO will ensure that a number of preparedness, emergency and recovery activities are carried out. Examples are listed in Box 4.8.

Box 4.8: Possible community-based flood risk management activities

- Flood preparedness
- Conduct disaster preparedness training with community members
- Raise community awareness on what to do before, during, and after a disaster
- Monitor disaster threats, conduct drills, and draw lessons to improve the plan
- Network and coordinate with local government authorities, government disaster management agencies, NGOs, other communities
- Engage in advocacy and lobbying work regarding disaster management to support community preparedness and resilience
- Expand community involvement in disaster risk management and activities.
- Flood emergency
- Issue warnings and manage any necessary evacuation
- Organize search and rescue with community participation and external assistance, as required
- Provide first aid and arrange subsequent medical assistance
- Conduct damage needs capacity assessment and report both damage and needs to government and disaster management agencies for assistance

- Coordinate, plan and implement relief delivery operations with aid agencies
- Recovery
- Facilitate social, economic and physical rehabilitation of the community; e.g. livelihoods, trauma counseling, reconstruction of houses and infrastructure
- Coordinate with government and aid agencies to receive assistance in rehabilitation
- Ensure that risk reduction measures are integrated during the reconstruction and rehabilitation phase
- Evaluate the performance and identify strategies for future improvement.

Source: adapted from Abarquez and Murshed 2004.

6.4.1.1. External Support

The initiative to mobilize community-based flood risk management may originate from the community or from an external agency. Either way, it is quite likely that external agencies will be involved in the process. If, however, the interests of professionals rather than those of the community dominate the stakeholder groups or the discussions, and the agenda revolves around of a set of pre-defined professional objectives, then the process will be flawed (Fetzner–Wilson 2009).

To support or promote community-based measures, it is vital that any external agency works in ways which ensure the interventions address specific local needs of the vulnerable community and recognizes and builds on the potential of local resources and capacities. The external agencies must be sensitive to maintain community leadership in the process and not come with pre-prepared interventions, for which they are simply seeking local support. As recently argued, "programs that directly support communities and their local organizations have proved to work best for immediate reinforcement of coping and resilience capacities" (Bhatt and Aysan 2008).

6.4.1.2. Institutional Responsibility

However effective or efficient the community-based measures become, it should be noted that this does not reduce the overarching institutional responsibility of government for flood risk management. To acknowledge and support this, it is therefore incumbent on community organizations to keep government authorities fully aware of their priorities and activities.

Similarly, the government should acknowledge that they cannot have effective risk mitigation without mobilizing the cooperation of residents and their community organizations. In all flood management measures, the objective must be for different stakeholders to work in productive partnership and all partners should take responsibility for promoting this.

6.4.1.3. Evaluation, Lesson Learning and Federating between Community Organizations

Effective and sustainable actions include transparent monitoring and evaluation procedures. Particularly after any significant flood event, an independent but participative evaluation of the effectiveness, efficiency and impact of the various flood mitigation measures undertaken by the community is very instructive. Full disclosure to the community is essential, as any positive lessons will directly strengthen support for the approach and enhance sustainability of the measures, while any negative lessons must be seen to inform improvements to the system.

Dissemination of evaluation findings is fundamental to improving practice through lesson learning and sharing. This can be formalized by creating links between CBOs, perhaps through a federating or coordinating body, so that lessons from one area immediately and effectively inform the activities undertaken in another. There is no more helpful way of learning than doing so from a peer group.

6.4.1.4. Grievance Redressal

Well-managed community-based flood risk mitigation is likely to be the most appropriate and effective within the resources available. However, some people's interests might not be protected to the expected extent. In anticipation of this, the CBO should establish a grievance redressal mechanism. It will most probably require a committee, formed in association with representatives of local government and locally respected persons, ensuring an appropriate gender and social balance (Prasad 2005). The existence of the mechanism must be well-publicized in the community; when any lapses are reported, the CBO should facilitate the redress of the grievances to the satisfaction of the concerned parties, through the established mechanism. This will help maintain harmony and mutual trust between residents, and will be an important factor in the long term effectiveness of community-based measures.

6.4.1.5. Legislative and policy changes

If the community-based approach to flood management becomes widespread and popular, it may be valuable for the relevant government to consider legislation to formalize the CBOs' role and status in this regard, and establish policies to ensure their proper consultation and participation in larger scale structural and non-structural flood management activities.

6.4.1.6. Sustainability

Several commentators note that, due to funding constraints, disaster risk management work by agencies and smaller NGOs is often unsustainable and not scaled up. As a route to longer-term success 'strong engagement with the community' has often been proposed (as discussed by Alam 2008 and Moga 2002 amongst others). This rather begs the question of how the sustainability of community-based actions can be ensured.

Communities are certainly capable of initiating and sustaining their own development. Flood risk management does not need to be any different, but the following are important to increase the likelihood of both success and sustainability:

- The short and long term benefits should be clear to all concerned.
- Strong involvement of all stakeholders is needed in determining risk reduction priorities and mitigation options (Abarquez and Murshed 2004).
- Good participatory processes within the community and between any external agency and the community are required (as discussed in detail by Abarquez and Murshed 2004; Prasad 2005; IFRC 2007 and Creighton 2004) .
- Include specific indicators of sustainability when establishing the monitoring and evaluation processes.

6.4.2. When and where to use Community-Based Measures

On the positive side, most urban environments have considerable strengths in terms of economic production and distribution, human resources, social capital and civil society. Cities in fact are by definition 'resource-rich' – the wealth of human and social capital in cities is part of what draws people to them and should be used to support humanitarian response, recovery and development throughout disaster-response efforts (O'Donnell and Smart 2009). Community-based measures are appropriate wherever urban communities face flood risk and are interested in working together to lessen the impact of those risks. There are examples in many countries, both developed and less developed, and in richer and poorer communities within those countries.

The approach is probably most valuable in low-income informal settlements for three reasons:

- Assets function as a buffer to help people cope with disasters; however poorer people have fewer assets, so they rapidly become more vulnerable to the next flood (Alam 2008).
- Ongoing development initiatives in these communities (for example, basic service provision, health awareness, and financial services) will benefit from incorporating disaster risk management into their development strategies.
- It is often more problematic for formal government-led interventions to reach into these poor communities.

For the latter reason, any such measures should include, as an important component, building and strengthening the flood risk management partnership between the community organization and local government authorities.

6.4.3. Benefits

Community-based measures can be of many different types and at different scales of operation, leading to different contributory benefits. However, the overall benefit will be the sustainable reduction in the impact of flood events.

Successful community organization for flood management may lead to other parallel, related interventions, such as improved environmental management or ongoing support for the community's most vulnerable members. Success in disaster risk management can only strengthen the community, which then has the potential to lead to further activities for the community's wellbeing and development.

6.4.4. Drawbacks

A number of limitations can affect measures:

Scale: community-based measures by definition work at the community level so, although the approach can be carried out in a number of communities, and communities may be networked into a larger federation, it is not by its nature a large scale or citywide intervention.

Coordination and Communication: coordination is a major challenge in any disaster event. The involvement of numerous community-based organizations could further exacerbate this challenge unless effective systems for communication and coordination are agreed upon and put in place as part of the preparedness planning. Working to build good relations between CBOs and official agencies and among CBOs (see discussion of networking above) while carrying out flood preparedness activities will be fundamental to effective coordination and communication during a subsequent disaster event.

Sustainability: this is a key challenge. Many disaster risk management approaches are built on the assumption that informing the individual or community about a hazard will lead to awareness, and awareness to action, and that will result in sustained behavioral change. In practice it is not always so simple. Stakeholders perceive risk differently, and people do not believe that all risks are of the same type, size or importance (Abarquez and Murshed 2004). Sustainability is discussed above as one of the key components requiring special attention in any community-based measure.

Accountability: there is a risk, especially if significant resources become involved, that the CBO may be hijacked by certain more powerful interests. Maintaining both the community-wide quality of the measures, and also the full transparency in all dealings, are essential for the credibility and sustainability of community-based measures.

Coverage: including the most vulnerable is a challenge. For example, orphans and street children in urban areas may be invisible to external agencies working either for flood preparedness or emergency relief. Community-based measures may recognize them as a particularly vulnerable group and, in coordination with local organizations already working with orphaned and street children, may be able to ensure that these children are included in formal programs (O'Donnell and Smart 2009 and WFP 2002).

6.4.5. Essential considerations

Community-based measures must build productive partnerships with local government and be aligned with the official flood risk measures which are often being implemented in parallel. The initiative for this partnership can come from either side, but both partners must recognize this as essential for coherent flood risk management: the community cannot manage in isolation from the local authorities, and the authorities' own measures can only benefit from close cooperation with local communities.

Without external technical and financial support community-based measures will remain small. This support may come from government, local government, NGOs or international donor agencies. This is discussed below and it is only repeated here to stress the need for any external support to be balanced against the inherent community-driven nature of the approach. Whatever support is provided should, with appropriate oversight, leave the community to guide and manage the process.

6.4.5.1. Guidelines for Community Disaster Management Activities

Abarquez, I. and Murshed, Z. 2004. "Community-based disaster risk management: Field Practitioners' Handbook." ADPC.

Creighton, J. 2004. "The public participation handbook: making better decisions through citizen involvement." Wiley, San Francisco.

ISDR. 2008. "Indigenous knowledge for disaster risk reduction: good practices and lessons learned from experiences in the Asia-Pacific region." UNISDR, Bangkok.

Prasad, K. 2005., "Manual on community approach to flood management in India, Associated Program on Flood Management." WMO/GWP.

Twigg, J. 2007. "Characteristics of a disaster-resilient community, a guidance note, DFID Disaster Risk Reduction Interagency Coordination Group." DFID, London. http://www.benfieldhrc.org/ disaster_studies/projects/communitydrrindicators/ community_drr_indicators_index.htm.

Shaw, R. and Okazaki, K. ed. 2003. Sustainability in grass roots initiatives: Focus on community based disaster management. Hyogo, UNCRD. http://www.hyogo.uncrd.or.jp/publication/pdf/GrassRoots.pdf.

6.5. Financing flood risk management measures

6.5.1. Financing integrated flood risk management

The choice of flood risk management and mitigation measures will also be critically constrained by the available resources to implement the chosen scheme. As an illustration, in England and Wales, the Environment Agency has powers for both the provision and maintenance of flood defences and detailed risk reduction project evaluation guidance. The number of eligible projects, however, far exceeds the funds available to the Agency to carry out those projects. National government, which has responsibility for allocating funds across competing priorities, of which flood defense is a very small part, is currently limiting the resources available. Wamsler (2006) notes that funding for integrated risk reduction and urban planning measures may be constrained by non-existent or insufficient financial support, or because funding is allocated towards non-integrated risk reduction or planning measures. In low- and middle-income countries, the constraint on funding is even greater.

Governments, which may be highly reliant on development assistance, may find that the best opportunity for fund raising is generally after the disaster. Data shows that between 2000 and 2008, about a fifth of total humanitarian aid was spent on disaster relief and response; in 2008, only 0.7 percent was put towards disaster prevention (World Bank 2010). However, flood and other disaster risk reduction activities are long-term processes that increase the sustainability of development interventions, and donors therefore need to incorporate this perspective into their plans and programs.

In most developing countries, city government authorities lack the resources to invest in new infrastructure; they tend to rely on funding from higher levels of government to finance improvements in service provision, including flood risk reduction (Parkinson et al. 2003). The urban poor also lack the financial resources to invest in improved housing, which would increase their resilience to flooding. Lack of access to the credit or the insurance market is another factor that reduces their capacity to cope with flood events. Moreover, those with a lack of secure tenancy may lack the incentive to invest in better housing in order increase their resilience to flooding.

One key constraint is that sometimes there is no real demand for implementing effective systems for flood risk management; as a result there is generally little willingness to invest. This may relate to a lack of awareness of flood risk and of the implications relating to flood disasters. However, it is a commonly held myth that awareness of flooding will engender a desire to respond to, or a willingness to comply with, flood management measures. Populations and institutions can be focused on short-term certainties rather than long-term possibilities and therefore mandatory compliance or strong incentives may be needed.

The fact that flood risk management measures may not offer quick returns to donors and governments can further limit available funding opportunities. It can, therefore, be helpful to link flood risk management with poverty reduction and climate change adaptation, or with more specific issues of urban planning and management such as housing, land tenure, and basic service provision and infrastructure. Robust solutions can contribute to flood risk reduction, while at the same time addressing wider development objectives. Nevertheless, to integrate flood risk reduction objectives within urban planning in general will first need flood experts and development practitioners to find a way to fit with the "current language of policymakers" (Wamsler 2006).

The large amount of financial investment required to implement flood risk management schemes is often regarded as a major constraint. Adaptation to flooding is one of a number of competing priorities for overstretched national, local and individual purses. Moreover it is one which does not usually provide immediate visible benefits to populations. The notion of "Not in my Term of Office" may lead to politicians and government officials placing flood risk management lower on the agenda than other, more tangible or immediate programs, and deferring or delaying action. Often it is observed that funding for flood risk management is most available after a flood event when public pressure demands action. Therefore, in many instances, financing of measures to reduce flood risk is closely related to the previously discussed topic of insurance and recovery, as measures are implemented in the aftermath of disasters and use disaster recovery or insurance payouts.

However, this can be seen as an inefficient approach and 'ex ante' flood prevention must also be considered within the holistic context of the costs and benefits of pursuing alternative strategies to managing risk. When the full range of available measures detailed in Chapters 3 and 4 are considered, it becomes clear that flood risk management spending does not always have to be explicit: it can be form part of broader development spending, climate change adaptation spending, integrated water projects, slum upgrading, or education. Disaster risk spending is also to some extent already mainstreamed into the work of multiple departments and agencies (Jackson 2011). Capital investment in large sale engineering projects specifically to address the risk of flooding may be in the minority but these also require funding mechanisms.

Decisions about the source of financial support for flood risk management need to be based on the distribution of costs and benefits arising from such investment – and also upon the capacity of individuals, governments and other stakeholders to make a contribution. Thus, in the developing world, it may be assumed that the largest financial impacts from flooding are currently borne by government in the form of infrastructure damage; likewise, the major burden of flood mitigation spending will also be placed on governments, who must find the money from a wide variety of sources. A first source of funds for national programs is naturally the tax base, but in developing nations this may be a severely limited natural revenue stream.

It has been estimated that the capacity of developing countries to invest in their own adaptation strategies will not meet their needs. External sources of funding in the forms of debt, equity, grants, lease financing, loans, overseas development assistance, payment for ecosystems services, risk management, structural finance and technical assistance, are also necessary. The international community is therefore a key partner in flood risk reduction. This section considers the various established international funding options, but also looks at other sources of financial support.

6.5.2. Grants and Loans from international development funds

The provision of development funding grants from international donor organizations towards flood management programs has been significant over decades. Many large-scale programs have been developed, for example, the Global Fund for Disaster Reduction and Reconstruction (GFDRR) has recently funded NADI, a program towards integrated flood management in the Pacific.

Table 6.1 below lists some of the donor agencies and their focus areas. In the past there has been an emphasis on large-scale structural measures in the form of engineering works, but agencies are moving towards a more integrated approach. The focus on funds for provision of warning systems, for example, is a recent welcome development. The list below is indicative as new and emerging focus areas may evolve in the future.

Table 6.1: Donor agencies and focus areas

Canadian International Development Agency http://www.acdi-cida.gc.ca/home	Mandated to support sustainable development in developing countries to reduce poverty and contribute to a more secure, equitable, and prosperous world.
Deutsche Gesellschaft fur Technische Zusammenarbeit (GIZ) http://www.giz.de/en	An international cooperation enterprise for sustainable development with worldwide operations. Its corporate objective is to improve people's living conditions on a sustainable basis.
The World Bank/International Development Association (IDA) http://www.worldbank.org/	IDA aims to reduce poverty by providing interest-free credits and grants for programs that boost economic growth, reduce inequalities and improve people's living conditions
OPEC Fund for International Development (OFID) http://www.ofid.org/	Supports finance for development in Sub-Saharan Africa
Islamic Development Bank (IDB) http://www.isdb.org/	Fosters the economic development and social progress of member countries and Muslim communities individually, as well as jointly, in accordance with the principles of Sharia (Islamic) Law.
USAID http://www.usaid.gov/	Supports long-term and equitable economic growth and advances US foreign policy objectives by supporting: Economic growth, agriculture and trade; Global health; Democracy, conflict prevention and humanitarian assistance.
Development Bank of South Africa http://www.dbsa.org	Its purpose is to accelerate sustainable socio-economic development by funding physical, social and economic infrastructure. DBSA's goal is to improve the quality of life of the people of the region.
European Bank for Reconstruction and Development (EBRD) http://www.ebrd.com/pages	Supports projects from Central Europe to Central Asia, investing primarily in private sector clients whose needs cannot be fully met by the market, the Bank fosters transition towards open and democratic market economies.

Japanese Bank for International Cooperation http://www.jbic.go.jp/en/	Sustainable and sound development of the international as well as the Japanese economy.
US Trade and Development Agency (USTDA) http://www.ustda.gov/	An independent US Government foreign assistance agency that is funded by the US Congress. Helps companies create US jobs through the export of US goods and services for priority development projects in emerging economies.
Asian Development Bank (ADB) http://www.adb.org/default.asp	An international development finance institution whose mission is to help its developing member countries reduce poverty and improve the quality of life of their people.
AusAID http://www.ausaid.gov.au	The Australian aid program aims to assist developing countries reduce poverty and achieve sustainable development, in line with Australia's national interests.
DFID http://www.dfid.gov.uk/	The agency that manages Britain's aid to poor countries and works to get rid of extreme poverty. Working to reach the Millennium Development Goals (MDGs), the international targets agreed by the United Nations (UN) to halve world poverty by 2015.
EuropeAid http://ec.europa.eu/europeaid	EuropeAid Development and Cooperation is responsible for designing EU development policies and delivering aid through programs and projects across the world.
UNDP http://www.undp.org/	Integrating environment and sustainable development, including climate change, in national development planning and implementation is central to UNDP's poverty reduction and MDG mission

6.5.3. Climate change adaptation schemes

Another source of flood adaptation funding is from specific commitments to climate mitigation and adaptation funds. Although inadequate to meet the total needs of developing nations, the international community has committed significant funds to this purpose. New funding pathways are currently being developed, some of which fall under traditional overseas development assistance, whilst others are coordinated under the United Nations Framework Convention on

Climate Change (UNFCCC) (IFRC 2010). Spending on flood adaptation can be justified under these schemes, although there may be difficulty in apportioning the element of costs directly related to climate change (Pielke 2006). There may also be a lack of clear mechanisms through which international climate change adaptation funds can be transferred to local governments.

Funds are available both for mitigation and adaptation. Both sources may be appropriate for flood risk management schemes. For example, it may be possible to access the funds for ecosystem services, in order to implement natural flood protection buffers such as forests (which also contribute to mitigating reforestation targets). Defense barriers are more appropriately managed under adaptation funds. Examples of potential climate funding sources are shown in Table 6.2.

Table 6.2: Climate funding sources

Name of the fund	Accessibility for humanitarian actors	Relevance and potential for humanitarians	Current size of the fund
UNFCCC Adaptation Fund	Direct and Indirect	High	Net funding US$ 23.53 million with significant extra envisaged
Japan Cool Earth Partnership	Direct	High	Up to US$ 2 billion pledged for adaptation
Global Facility for Disaster Reduction and Recovery	Direct	HIgh	US$ 135 million contributed
German International Climate Initiative	Direct	Medium	US$ 162 million/ year earmarked for developing and transition countries
UNFCCC Least Developed Countries Fund	Indirect	High	US$ 180.8 million pledged
European Commission Global Climate Change Alliance	Indirect	High	US$ 187 million deposited. In addition US$ 240 million will be used for DRR to serve the objective o the alliance

World Bank Pilot Program for Climate Resilience	Indirect	Medium-low	US$ 614 million pledged
UNDP-Spain Millennium Development Goals	Indirect	Low	US$ 90 million deposited. Further funding may be forthcoming from the US$540 million pledged

Information on climate funding sources is also available from the following website: http://www.climatefinanceoptions.org/cfo/Funding%20Sources.

6.5.4. Insurance measures including government, private and micro-insurance schemes

Insurance schemes have been previously discussed in Chapter 4. The role of such schemes in providing funding for flood management measures is covered here. Flood insurance can be a mechanism for providing cash in the aftermath of a disaster. This cash can be used to finance reconstruction in a flood resilient manner, particularly if this can be achieved in a cost-neutral way. Where flood protection will increase the cost of reconstruction, then many insurance schemes will fail to contribute. For example, in the UK the privately provided insurance cover for households has been seen to restrict the investment in resilient reinstatement (Lamond et al. 2009). To some extent regulation could address this problem. However, it could also be possible to use the power of insurance to bring in private funds for flood reduction measures by providing an incentive via restriction of cover, excess payments and premium incentives.

6.5.5. Foreign direct investment

The amount of inward direct investment is greater than the funds available through Overseas Development Assistance (ODA) by a factor of four (Bouwer and Aerts 2006). If such investment can be used for flood risk management, either via incentives or regulation, this could make a significant contribution to national resilience. For example, the bank HSBC has recently worked with city partners to deliver climate mitigation programs such as renewable energy in schools.

6.5.6. Public-Private-Partnerships

This aspect of funding, using the 'win-win' impacts of some flood prevention activities which may benefit private businesses, may be of more relevance in developed countries. However, many examples of Public-Private-Partnerships (PPP) also exist in the developing world. Examples of such multi-purpose flood prevention activities include dams which generate electricity and control flooding; and warning systems which may allow electricity companies to make better predictions. Tourism providers may also benefit greatly from the security of coastal warning systems.

Two cases of PPPs are illustrated below in Case Studies 6.8 and 6.9 below.

Case Study 6.8: Flood control in the city of Córdoba, Argentina

The drainage system of the city of Córdoba currently has 28 ha of retardation basins to attenuate surface flows. This area rises to 102 ha if the retardation structures associated with new urban developments currently at the design stage are included.

On-site observation during rainfall events and an analysis of reports indicate that so far there have been no problems with the hydraulic operation of these structures. The basins constructed in the 1990s are linked to existing storm drains, which act as a collector system. A small number of the planned structures discharge by overflowing into ditches.

Most basins have so far been built by private enterprise, and are generally linked to large industrial plants and supermarkets. These are usually small structures, each with its own maintenance requirements. In some cases, as a result of a good maintenance plan, there is very good integration with the surrounding urban environment which serves to minimize potential environmental problems.

The larger basins have so far been built and maintained by the municipality. They typically present a worrying environmental problem: contamination by liquid and solid residues (grey water, accumulation of refuse and the like.) that cause odors and may carry disease deterioration of the infrastructure (erosion of banks, sedimentation and so forth) and the presence of weeds and mosquitoes. In short, they are poorly integrated into the urban and suburban environment.

The Córdoba case demonstrates the way in which the private sector can be involved in the implementation of flood risk management measures, such as small retardation structures.

Source: Tucci 2007.

Case Study 6.9: Alandur Sewerage Project, India

The Alandur Sewerage Project (ASP), initiated in 1996 by the Alandur municipality, is a PPP directed at providing sanitation services to the city of Alandur in India. Alandur is a suburb of the Chennai Metropolitan Area (CMDA), which has a population of more than 125,000 with approximately one quarter of those living in slums.

Because the municipality needed resources, both in financial terms and technical expertise to undertake such infrastructural projects, the construction of the sewerage system was done under Bill of Quantities (BOQ) basis, and the sewerage treatment plant under Build, Operate and Transfer (BOT) basis, which is a type of arrangement in which a contractor builds the project, operates it and eventually transfers ownership of the project to the government.

In addition to the construction, the contractor also had to undertake operation and maintenance (O&M) of the sewerage system for a period of five years from the date of completion of the construction, on a fixed fee basis. The collection of tariff and provision of new connections during the O&M phase would be undertaken by the municipality.

A ‘Willingness to Pay’ survey, which covered more than 10 percent of the city’s population, was conducted by the consultants in order to assess the scheme’s acceptability by the residents. It was found that about 97 percent of the people wished to have the sewer connection and would be willing to pay a reasonable amount for the service. According to the survey, people would be willing to pay up to Rs 2,000 (US$ 44) for connection and Rs 21-50 (US$ 0.5-1.1) per month for maintenance, as in the case of water supply.

The municipality revised the initial tariff structure, and reduced the ceiling limits on the basis of the ‘Willingness to Pay’ survey and discussions with residents and municipal officials. In addition, the municipality issued a public notice in the local newspapers and the television in order to raise the awareness among the public about the project. As per the available information, all the civil works related to these service lines are completed.

For the success of such projects, a real ongoing commitment towards the project prior to implementation, political will and strong decision making are all preconditions. In addition, procedures in the bidding and contracting should be transparent and accountable, while stakeholder involvement and interdepartmental (horizontal) coordination further contribute to the successful implementation of the project. Finally, awareness campaigns were key components of the project, as communities supported the initiative, including the fact that about 29 percent of the project cost was covered from public contributions.

Sources: Mathur 2002; IWA Water Wiki (no date);
Government of India (no date); NIUA 2001.

6.5.7. Incentives for individual private investment

The insurance mechanism has already been mentioned as one method of encouraging private investment in flood resilience. Other potential schemes in place or suggested include tax incentives such as the abolition of sales tax on flood mitigation products such as flood doors, flood gates, flood boards. flood vents and pumps.

6.5.8. Integration of polices and activities

The selection of robust solutions which can be incorporated within existing programs, departments and agencies can result in an increase of funds into flood risk management. Solid waste management is a possible example of this practice: not only can waste management provide many health and environmental benefits but can also, potentially, generate some revenue and reduce the impacts from flooding. Arguably, this will be most effective at a local level where the need for such management is most apparent (Jackson 2011).

6.5.9. Charitable funding

Charitable NGOs channel donations from private and institutional donors to 'ex post' disaster relief to a significant extent, but also invest in 'ex ante' prevention. Often such agencies can be key players in engaging the community in flood risk management as part of wider outreach activities. A recent example of charity donations funding flood risk mitigation was the retention of some disaster relief donations from Hong Kong towards the construction of flood resilient housing in China (Lamond and Proverbs 2009).

6.5.10. Market-based loans

International loans for specific infrastructure projects are common. The structure of such loans is complex and they are typically of long duration. As such the banks usually require credit guarantee which is provided by organizations such as the World Bank and Export Credit Agencies.

Individuals or communities may also acquire funds for property level adaptation or local community schemes. This may be based on mortgage finance or security-backed loans. However, many individuals and communities in the developing world have difficulty in accessing finance via traditional market-based routes, and may rely on microfinance.

6.5.11. Microfinance

Microfinance arrangements have the potential to empower individuals and communities to implement flood risk management solutions for themselves. They can form a vital part of development strategy (ADB 2000) as they provide a broad range of financial products to poor individuals and micro enterprises. Microfinance can be supplied by market based financial institutions (MFIs), and also by NGOs for the poorest sectors of the population. Sri Lanka has a long tradition of microfinance (with more than 15 million deposit accounts and 2 million loans in 2005 from a population of 20 million); providers include the national government, commercial banks and finance companies, cooperatives, NGOs, and informal providers such as money lenders and shopkeepers.

A community-owned disaster fund can be set up which can accept funds from multiple sources including micro investments from the community. Allocation of grants and micro credits towards flood or other disaster mitigation can be determined by the community organization controlling the fund.

The Indian SEWA housing program supports individual loans for pre-disaster monsoon-proofing of homes, as well as loans to repair roofs, walls or doors damaged by floods. Through the Mahila Housing SEWA Trust, SEWA also supports community financing in urban slums to protect against future flooding by improving drainage and sewerage systems (O'Donnell 2009). Other schemes exist in Bangladesh, (as shown in Photo 6.2) El Salvador and Nicaragua in which MFIs have extended their portfolios to include loans for housing repair or reconstruction.

Photo 6.2: Microfinance via women's group in Bangladesh, Source: Shehzad Noorani

6.6. Sustainable maintenance systems

The section discusses the role of sustainable operation and maintenance systems once structural works have been completed. The cost of operation and maintenance is a critical aspect in the long term, so there will be a preference for designs that minimize maintenance. Realistic ways of revenue generation for sustainability and general awareness from the public and local authorities will be key issues.

Flood mitigation infrastructure requires regular repair and maintenance on a risk-assessed basis, so that the most critical elements are inspected and maintained and repaired at the most frequent intervals.

6.6.1. Operation and maintenance considerations for structural works

Unfortunately, despite appropriate design, high maintenance requirements are often introduced at the procurement and construction stages through the constraints of the bidding process, poor contractual enforcement, and the desire for low-cost solutions with little regard to subsequent upkeep. The maintenance requirement may not become obvious for some years after construction when project funds have been finalized and the maintenance responsibilities passed to the municipal authorities.

All structural measures should therefore be:

- Designed to minimize maintenance requirements.
- Use local materials and processes where these do not jeopardize construction quality.
- Be procured from reliable suppliers and contractors and not necessarily at the lowest price.
- Constructed under a precise contract adapted to the specific works with enforceable penalty clause(s) for non-compliance.
- Framed to include an extended maintenance element so that the contactor has a responsibility for rectifying any failures resulting from the use of poor materials and construction practices.
- Supervised by independent organizations capable of enforcing the contract without prejudice.

It is recognized that these are ambitious objectives but their implementation can improve sustainability by reducing maintenance requirements.

6.6.2. Maintenance of flood prevention infrastructure

Structural solutions including flood protection infrastructure needs to be maintained by:

- The de-silting and dredging of drains and watercourses to reinstate their natural or design capacity.
- The regular inspection of flood protection walls and levees for signs of structural failure and repairing these.
- The maintenance of pumps and ensuring sufficient fuel available for their operation during a flood event through regular inspection and test operation.

The Jakarta Globe (14 July 2009) reported that, if Jakarta's rivers and canals had been dredged regularly, the number of people directly affected by the 2007 floods would have dropped from 2.6 million to one million.

Maintenance should be undertaken at regular intervals and at low flows, before any significant seasonal rainfall.

6.6.3. Waste management and drain cleaning

The need for continued effective waste management to prevent the restriction and blockage of drains was discussed in some depth in Chapter 4. Briefly, this requires the following approach:

- Educating the community on the adverse effect of poor waste disposal
- Training of municipal workers and commercial concerns not to deposit waste in the drains
- The relocation of informal settlements and encroachments which may hinder the cleaning of the drains
- Effective enforcement of relevant land use regulations preventing the above from developing
- The provision of effective waste management services in informal settlements
- Monitoring of drainage effectiveness.

In Faisalabad, Pakistan drain volumes are drastically reduced as a result of the washings from small foundry workshops: these deposit significant volumes of foundry sand in the drains. The narrowness of the lanes prevents access by mechanical equipment, so that the drains have to be excavated manually. No enforcement mechanism has yet been found to stop this recurring after the drains have been cleared.

Maintenance requirements should be a key element of the design of the structural works. The main drainage channels should be:

- Designed to allow self-cleaning by maintaining low velocities even during the dry season by "benching" so that low flows are contained within a narrow channel in the center of the drain and larger flows are accommodated by the entire width of the drain.
- Lined channels to maintain flow velocities and prevent erosion, and to deter encroachment and restrict vegetation which would slow flows.

– Designed with access for maintenance by providing a track alongside at least one side of the drain.

– Designed with local materials so that repairs can be made quickly and cost-effectively. For example, the lining of a drain in Lahore (Photo 6.3) represents good practice by using bricks which are abundant locally; they are cheap and their use is familiar to every laborer.

Photo 6.3: The retrofitting of a lining of local bricks along a drainage ditch in Lahore Pakistan. Accumulated debris, sediment and vegetation has been removed from the ditch, the bank re-profiled. Source: Peter Lingwood.

6.6.4. Planning regulation, enforcement and integration of policies and activities

The importance of planning regulations as a tool in spatial planning and reducing vulnerability has been described above. However, one of the most prevalent and insidious forms of unplanned development is though progressive encroachment which may:

– Prevent effective drain cleaning.

- Reduce drain capacity through covering or even infilling of drains.
- Impair the effective operation of flood protection measures.
- Specifically affect low-lying areas which are at greater risk of flooding.

6.6.4.1. Integration of policies and activities

Political commitment is a precondition in order to facilitate the allocation of resources for integrated flood risk management, and to strengthen the capacity of the most vulnerable communities to cope with flood risk. This commitment should be implemented through policies and institutional frameworks that explicitly incorporate flood risk concerns (AfDB et al. 2004).

The integration of flood risk management into wider development plans is vital because city governments cannot afford to ignore risk considerations, particularly those related to climate change, unplanned urbanization and environmental degradation. Dagupan City in the Philippines demonstrates a successful example of community resilience to flood and tropical cyclone disasters (ADPC 2010). It is one of the few cities that mainstreamed DRR into local governance during the implementation of the Program for Hydro-Meteorological Disaster Mitigation in Secondary Cities in Asia (PROMISE). Absence of integrated DRR in many low- and middle-income countries may be linked to the failure to main¬stream risk reduction in development plans (Wamsler 2006). Hazard-related vulnerability should be addressed as an integral part of poverty reduction initiatives, given that the linkages between poverty, vulnerability and natural hazards are increasingly recognized (ODI 2005; UNISDR 2008). Practical ways to ensure that flood risk management is effectively incorporated into development plans are needed. Flood risk mitigation goals that should be considered in relation to mainstreaming are outlined below (adapted from ADPC 2010):

- Reduction of flood risk accumulated from previous urban development
- Avoid creating new urban flood risks in the future
- Build the capacity of all stakeholders – city governments, private sector, civil society and communities – to effectively respond to any type of emergencies.

Incentives for the integration of flood risk management include (ADPC 2010):

- Legislation for integrated flood risk management, including the integration of flood risk management into development plans, to provide an enabling environment in which integrated flood risk management strategies can be encouraged.

- Appropriate institutional arrangements for integrating flood risk management. The institutional structure should strengthen the horizontal and vertical integration of DRR between different levels of government and public administration, between other stakeholders, including the civil society, private sector, and universities, and between neighboring localities.
- Allocation of funds to city governments to support flood risk management institutions and their activities.
- Skills, capacities and tools need to be developed by government agencies for incorporating flood risk considerations in their day-today activities.
- Awareness-raising among government officials and the public to better understand the linkages between flood risk management, sustainable development and poverty reduction.
- Engaging with other stakeholders, including the local communities, in integrating flood risk management.

6.6.4.2. Oversight and enforcement of land use planning regulations

Much of the physical expansion and economic growth in the developing world takes place without following official plans, and outside official guidelines and regulations, in unplanned central city and peri-urban areas. To some extent, this is because large sections of the population cannot afford housing that meets official standards.

In addition, there is a mismatch between urbanization processes, urban governance, and decision making. The competence, capacity and accountability of local government structures often fall short of what is needed to adequately address urban growth and expansion (Satterthwaite et al. 2007). Enforcement of standards and regulations is often incomplete or even absent. Regulatory frameworks often demand unrealistic minimum standards while at the same time there is lack of adequate mechanisms for the enforcement of regulations.

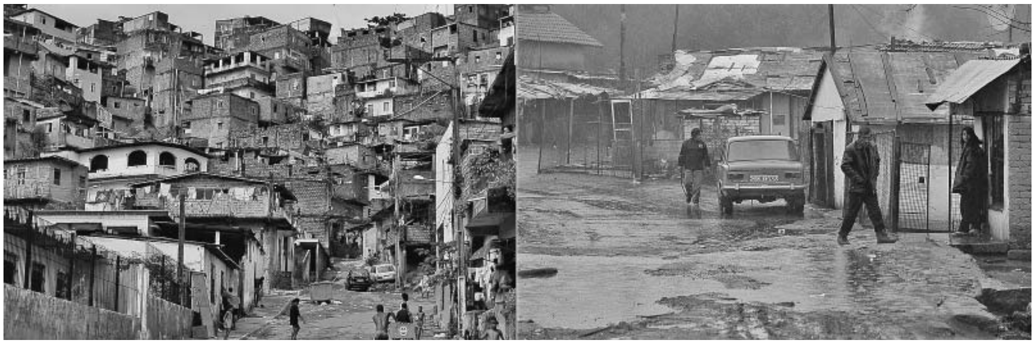

Photo 6.4: Slum conditions in Brazil and Bulgaria, Source: Scott Wallace

Even when land use planning takes flood risk into consideration, the implementation and enforcement of guidelines and regulations often remains problematic. Potential constraining factors are outlined below (ADPC 2010):

- Lack of political will
- Lack of a legal frameworks with responsibilities clearly established
- Political influence of landowners and developers
- Public disregard for government policies and regulations
- Governmental disregard for policies and regulations established by other governmental levels or agencies
- Corruption
- Economic factors
- A perceived (or real) lack of viable alternatives

To overcome these constraints and facilitate the implementation of land use management, possible incentives and disincentives may include (ADPC 2010: 17):

- Offering land development subsidies in some areas and levy development overhead charges in others.
- Encouraging the location of industries and housing in safe areas by prioritizing in those areas the installation of utilities and urban services.
- Encouraging the use of certain areas through differential land pricing (in the case of undeveloped or underdeveloped land) or by subsidizing transportation from those areas to areas of employment, shops and businesses.

6.6.5. Financing operations and maintenance

Many municipal authorities do not have sufficient funds to meet their existing commitments, still less to meet additional responsibilities. Indeed, there is little incentive to do so, because there may be an expectation that flooding events will be funded by national government or external agencies.

Possible sources of financing for flood risk management measures were discussed in the previous section. The operation and maintenance of relevant infrastructures may however require additional finance from a local taxation base.

The raising of additional revenue, in many cases, may be problematic, and the retention of those funds for flood alleviation even more so. The charging of fees on insurance companies, which would benefit from lower claims, is likely to be inappropriate in developing countries because of the generally low level of cover and the requirement for national legislation. Additional local property fees could be levied, but these are likely to be ineffective in raising funds for the following reasons:

- Unrealistic level of rates
- Low yield
- Corruption
- Incapacity of the municipality to administer the system.

Case Study 6.10 which follows provides interesting insights into the incorporation of Disaster Risk Reduction (DRR) concerns into municipal budgeting.

Case Study 6.10: Integrating Disaster Risk Reduction in planning and budgeting in Palo in the Philippines

Some 12 of the 33 barangays (wards) in the city of Palo in the province of Leyte are flooded twice a year, experiencing from 0.3 to over 3 meters of floodwater. Floods adversely affect the living conditions and livelihoods of local communities as a result of deaths by drowning, and by exposure to water-borne diseases and drinking water problems. To reduce the impacts of flooding, the municipality initiated a review of their local planning and development tools to incorporate DRR.

Undertaken activities included participatory hazard, vulnerability and capacity assessments, in order to support the identification of appropriate flood risk management measures and the integration of these into the development planning and budgeting of the barangays, while aligning this with the systems of the overall municipal government. The assessment process identified the following challenges:

- Weak Barangay Disaster Coordinating Councils (BCCCs)
- Many houses were constructed using inadequate and flimsy materials and in hazard-prone locations
- Inadequate source of drinking water
- Absence of water-sealed latrines
- Eroded or unstable riverbanks
- Clogged waterways and drainage systems.

After the assessment process, the most appropriate measures and potential sources of funding were identified and responsibilities were allocated amongst the relevant administrative bodies. As an example of good practice, this case demonstrates the way in which DRR can be successfully incorporated into a municipality's Annual Investment Program (AIP). This included the provision of safe and potable water to households and the construction of school buildings that can be also used as evacuation centers.

Sources: DILG, GTZ. & DIPECHO 2008.

6.7. Preventing failure: effective monitoring systems and protocols

Monitoring of flood risk management programs needs to be twofold: firstly, the implementation of measures must be monitored and evaluated; secondly, and perhaps more importantly the fitness of purpose of the implemented system (i.e., its ability to reduce risk) must be monitored in the long term, as systems may not be regularly tested by actual flood events. The responsibility for carrying out a monitoring program is, ideally, delegated to the agency which is responsible for maintaining and operating the risk reduction solution. However, it may be appropriate for the requirements and design of the monitoring protocol to be enshrined in regulation or legislation. Either way, the system should be transparent and accountable if public funds are used in the development or maintenance of the measure.

Monitoring procedures and systems are needed to ensure that measures have the ability to perform to the required standards. Just as deterioration of levees can lead to early breaches (as they did in New Orleans in 2005), and drainage systems can become blocked (as they did in Mozambique in 2010), other measures and systems can also become prone to failure. This may be due to inattention to maintenance, to obsolescence, or to the departure of experienced individuals.

Different protocols and systems will be needed for each specific set of flood risk management methods but there are common threads which can be identified for categories of measures. As a first step it is necessary to analyze why a measure may fail and whether a monitoring procedure can be put in place to prevent this failure route.

Monitoring may also encompass the impact of flood defense on other systems such as ecosystems, or the livelihoods of local people, to determine whether remediation is necessary. This section focuses on the regular monitoring of implemented flood risk reduction measures.

6.7.1. Failure routes

It is instructive to examine why flood risk management solutions fail in the event of a flood. Evaluation of flood disasters in the past can help with this process, if this is carried out in a scientific and structured manner. Often, in the aftermath of a disaster, blame is attributed to a number of different sources: inevitably the authorities are blamed by the public, and frequently by the media, without the full picture being examined objectively. It is important to determine the underlying causes if useful lessons are to be learned, rather than to implement popular solutions in a 'knee jerk reaction' to media and public pressure.

6.7.1.1. Flooding which is outside the design standards

This is not really a failure of implemented measures, but may be perceived to be so by the public and the media. For example, the Japanese Tsunami disaster of 2011 saw overtopping of sea walls which was viewed as a failure. But, in reality, the structures had not 'failed' because they simply were not designed to withstand tsunamis of the scale of that event.

6.7.1.2. Failure due to unexpected consequences

Usually flood risk management solutions are unique in that, although the solutions are tried and tested elsewhere, the particular flooding scenario, topology and political and cultural environment are unique. There is also a need to design novel approaches for specific sets of circumstances; furthermore, new approaches may be developed which are seen to be more effective or efficient. This can result in unexpected consequences arising from a solution: an example would be the devastating environmental consequences of major flood control dam projects, which were not predicted in advance.

The US National Flood Insurance Program (NFIP) was set up in 1968 with the dual aim of protecting individuals from the financial consequences of flooding and directing development away from the floodplain. A recent evaluation concluded that while the scheme is partially successful in protecting against financial loss, it is far less successful in the second objective. The cause of this failure can be attributed to lack of awareness but also to 'moral hazard': the provision of insurance allows development in the floodplain to continue, and supports the reconstruction of previously flooded property, rather than encouraging resettlement. As a result, more homes are at risk of flooding than would be the case had the program succeeded in both of its aims. This failure can be seen to be behavioral with affected populations reacting to policy in an unanticipated fashion.

6.7.1.3. Failure due to structural deterioration

If structures are not monitored regularly they can deteriorate, and therefore fail in the event of a flood. Failure of levees in New Orleans was blamed on structural deterioration. Similarly, in Bangladesh the levees also sometimes fail for the same reason.

6.7.1.4. Failure due to lack of maintenance

This can range from failure to dredge channels to failure to check operation of floodgate mechanisms. For example, in Mozambique newly installed drainage channels failed to protect urban areas, due to the fact that they were blocked with debris: the emergency services were therefore forced to clear the drains through deep flood water.

6.7.1.5. Failure due to non-compliance

Floodplain regulations and building codes, evacuation and emergency plans can only succeed in their aims if people cooperate in complying with their stipulations. Often, due to complacency or self-interest people and organizations fail to comply and the solution fails in its protective aim. For example, in Venezuela the 1999 flood and debris flow killed an estimated 30,000 people, many of whom were living in slum developments in highly unsafe areas. Groundwater management programs have also failed to achieve their ends due to non-compliance.

6.7.2. Hard engineered defenses

The potential causes of failure of defense structure can be identified using a fault tree as illustrated in Figure 6.5 below in an example from the German Bight coastal area. Failure types and their probably of occurrence are evaluated. In this way the most likely failure route and underlying cause can be identified. Types of failure mechanism are also discussed in FLOODsite reports (2007; 2008).

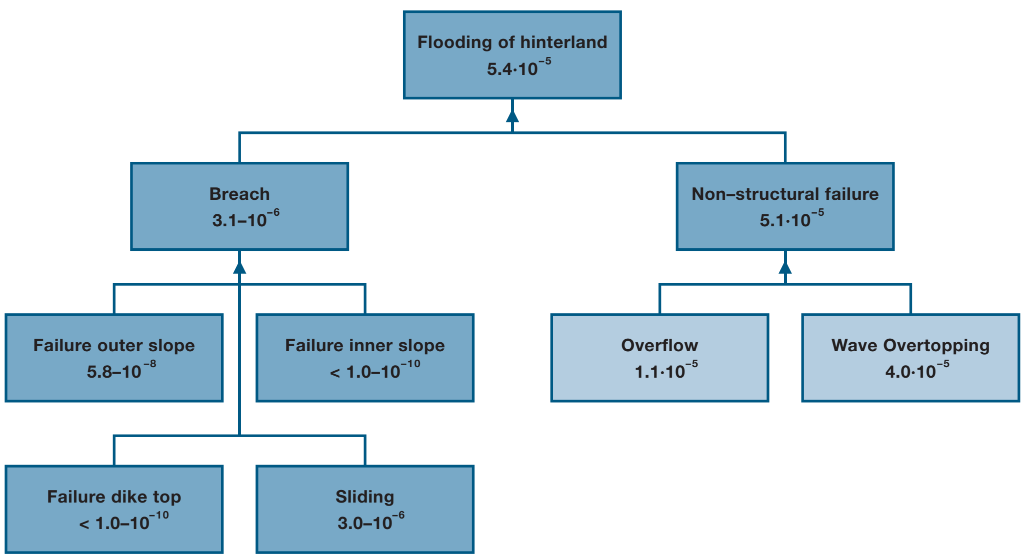

Figure 6.5: Failure tree for a dyke. Source: Adapted from Floodsite 2008

In this example failure caused by overflow and overtopping may be due to flows or levels exceeding the design standard. Regular updating of flood hazard maps should be used to establish whether the design standard is still appropriate.

Breaching (i.e. water passing through rather than over the defense) may also be caused by events exceeding the design capabilities of the system. However, the deterioration of the structure is another likely cause of breaches. Structural integrity can be periodically checked by visual inspection either on site or remotely, by the inclusion of sensor and structural tests, such as displacement sensors, water pressure sensors or periodical checks with an electromagnetic measurement system. Structural integrity testing is also required after any event has occurred. An appropriate monitoring schedule can extend the life of a hard defense by prompting remedial action.

The timetable of site inspections can be tailored to the flood type and frequency. Where there is a specific flood season, inspection can be carried out just prior to its commencement. If enough lead time is available then inspection can be carried out in anticipation of flooding, and any necessary emergency remedial work undertaken. However a program of regular inspections will allow for a smooth maintenance schedule and minimize the risk of failure.

Failure of operation is another potential route for failure of some types of defenses. Drills and tests of the mechanism should be carried out regularly. The use of a fault tree allows all failure routes to be considered and identifies which structures and elements of structures need checking.

Half of the Netherlands lies below sea level and is protected by over 15,000 levees, which are known as dikes or dykes. Failure of the levees could be catastrophic so the Dutch Water Boards employ levee patrollers in addition to laser and satellite scanning to monitor the stability of the levees and check for failures. The Dutch have also developed ways of reinforcing their dykes in difficult circumstances.

In the Netherlands during the heat wave of 2003 a dyke near Wilnis was breached due to the drying out of the peat, which is normally kept quite wet. During subsequent heat waves, such as that which occurred in July 2010, the monitoring program on the 3,500 kilometers of peat dykes is stepped up (RNW, 2010). Most levee patrollers have never seen a real levee failure as there is a relatively high turnover of staff (on average five years) and breakdown is rare. There is, therefore, a need for drills to educate the patrollers about the signs indicating imminent failure and the means of communicating that failure properly. The previously discussed game ‘Levee Patroller’ was designed to help with this training need, as discussed in Section 5.4.4.

6.7.3. Drainage systems

Some major causes of failure of drainage systems include deterioration of the structure leading to leaks; blocking of structures by waste, silt and debris; and demand exceeding the designed flow.

Deterioration of the structure can be monitored by regular inspections; this may need to be done remotely, via cameras, as many drainage systems are not readily inspected at surface level. Sensors and monitoring devices can also prove useful.

Blockage by waste, silt and debris can destroy the effectiveness of drainage infrastructure and can cause flooding in unexpected areas, often with contaminated floodwater. Regular clearance is necessary. Enlisting the help of the local population to alert the authorities to blocked systems can be invaluable. Local wardens or 'mile men' can be appointed to oversee a particular section of drainage.

Excess demand on drainage should be avoided via the use of planning systems which make new drainage a necessary part of construction. However, as this is not always possible, the demands on drainage due to urban expansion should be tracked to identify when remedial action is needed.

6.7.4. Forecasting and early warning systems

Forecasting and early warning can lead to flood emergency action and loss prevention, but relies on all elements to work together, as any weak link will result in partial or total failure. Therefore monitoring protocols are necessary for all elements. Failure of physical tracking system involving remote sensors, gauges or satellites can be made less likely by regular physical inspection. The data from these tracking systems is usually accessed regularly and so failure is likely to be picked up quickly. However, preventative inspection measures are also warranted, as even short term down time of the tracking system could cost lives in the event of a flood.

Software or model failure can be monitored regularly by checking the accuracy of forecasts against reality; continuous adjustment of models and model parameters to address any shortcomings in forecasts is required. Regular forecasts should be made in order to keep the system active.

Communication via hardware such as loudhailers, sirens and flags can be facilitated by regular physical testing of the equipment. Communications protocols can be tested via regular drills or desktop exercises. Failure to react due to desensitization of the population can become an issue, particularly if the incidence of false alarms is high. Attitude surveys can be used to assess the state of preparedness or apathy amongst populations at risk.

6.7.5. Emergency procedures

Emergency plans may fail because of problems with communications (as above), lack of clarity of roles and responsibilities, lack of trained personnel, outdated information or unforeseen difficulties with the planned actions. Simulations as described in Chapter 2 are a useful way to check the completeness and effectiveness of emergency plans. The lack of trained staff and high staff turnover issues both need to be addressed, via structured training for new employees, for example. Many emergency plans involve networks of individuals and organizations: a mechanism for notifying any changes of personnel, contact details and other important details should, therefore, be instituted.

6.7.6. Land use planning regulations

Land use planning and control regulations can fail for a number of reasons: illegal settlement; unauthorized building; building codes not adhered to; post-construction alteration of structures; and unauthorized changes of use. Tracking of settlement patterns and vulnerable assets (such as hospitals, schools, power infrastructure, and government control centers) should be an integral part of any flood risk management strategy. This information can also be used to assess the effectiveness of land use control programs. For example, in England and Wales, the Environment Agency reports regularly on any developments undertaken contrary to its planning advice, thereby providing a check on the effectiveness of the advice it gives (Environment Agency no date).

Similarly, a national indicator has been set up to monitor progress in delivering agreed actions towards flood and coastal risk management plans. Local authorities are scored based on percentage of these achieved.

6.7.7. Environmental monitoring

Flood defense systems may perform as expected in preventing flood risk but can have an impact on the environment over the long term, either positive or negative. Where such concerns exist, it is good practice to set in place a monitoring protocol which will track the environmental impacts and allow for remedial actions to be taken to prevent long-term damage.

6.8. Evaluation

6.8.1. Design of evaluations

The range of approaches and methods for evaluation of disaster relief or development interventions has grown considerably since the early 1990s. However, techniques specifically to evaluate disaster risk management programs, including flood risk, are somewhat less developed, and certainly less ‘tried and tested’.

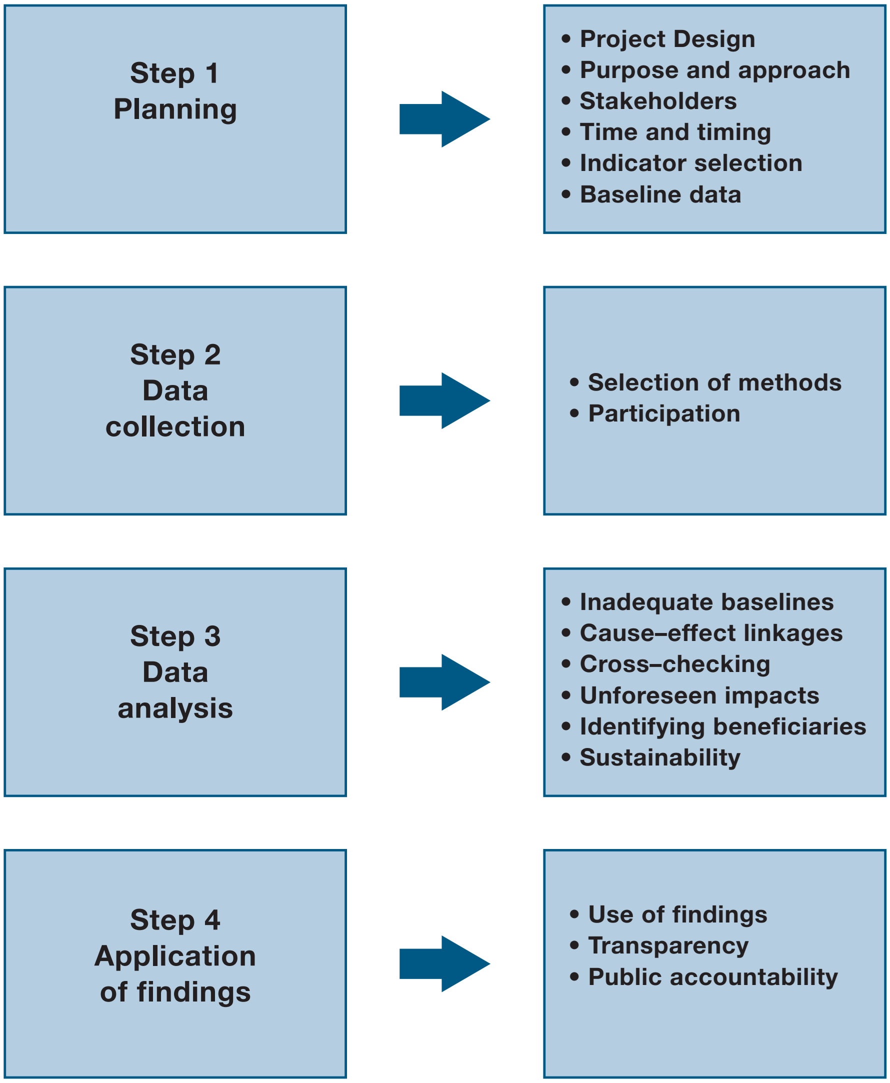

Figure 6.6: Steps in evaluating disaster risk management, Source: Adapted from Twigg 2007

There is a great diversity in possible purpose, approach and scope of evaluation. It is, therefore, necessary to make strategic (and often difficult) choices early in the process. It is important to determine why, and for whom, the evaluation is being carried out. This is schematically presented alongside/below (Figure 6.7) showing the range of stakeholders involved in even the simplest flood management intervention. Different stakeholder groups also need different types of information for different purposes. The evaluation aims and methods need to be specified for the particular disaster risk management project or program, including those directed at flood risk.

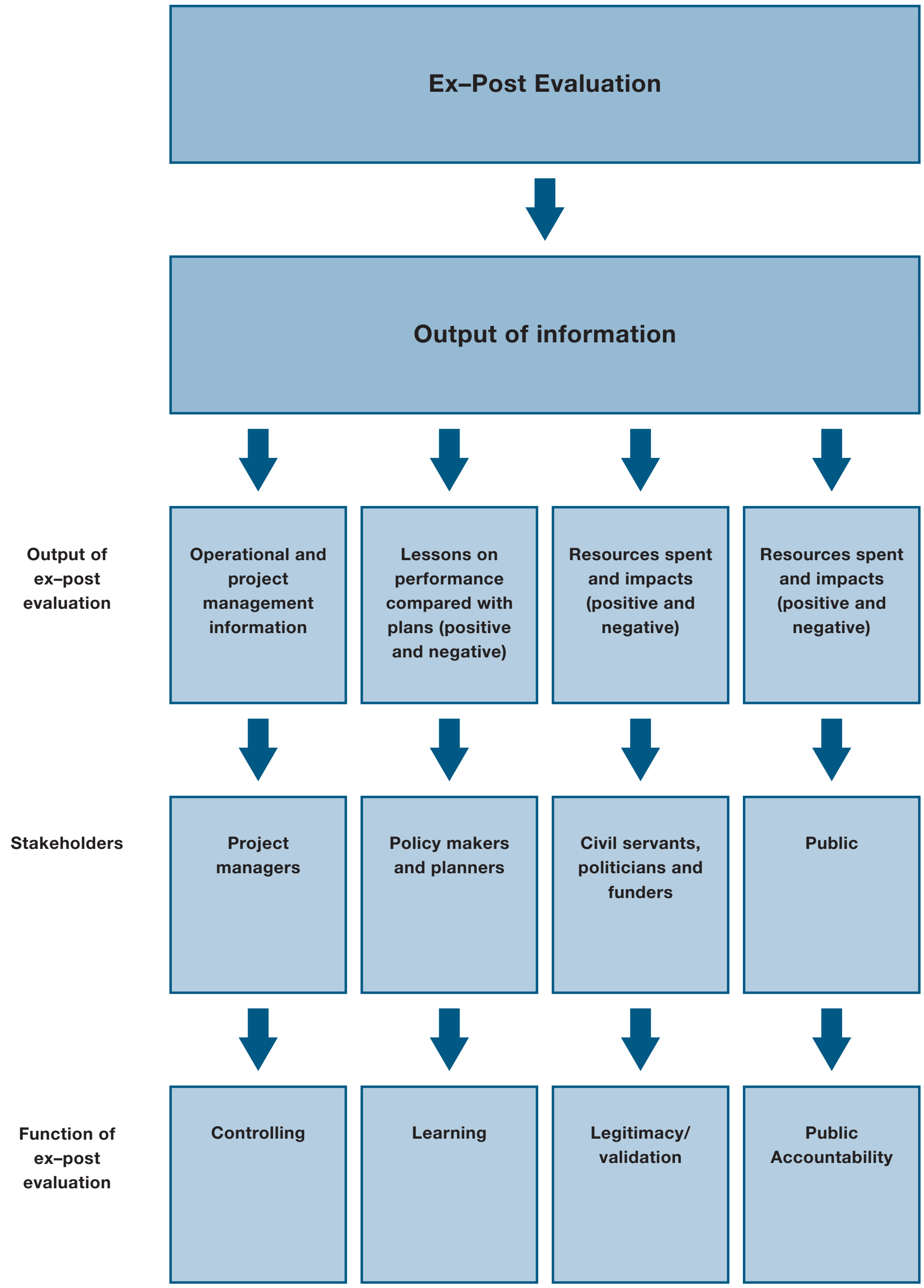

Figure 6.7: Ex post evaluation process. Source: Adapted from Olfert 2008

6.8.1.1. Clarifying the relevant dimensions of the evaluation

There are a number of dimensions to overall performance. It is important to determine which of these dimensions need to be evaluated, so as to ensure the output provides a comprehensive understanding of the overall performance of a solution, measure or instrument. The dimensions (sometimes termed criteria) can form the structure for reporting the evaluation findings. Examples are:

- Effectiveness - extent to which objectives are achieved
- Efficiency - in relation to costs
- Robustness or Sustainability - performance over time and under scope, scale and approach of the evaluation

The first step in planning an evaluation is to determine whether the object of the evaluation is a single ‘stand-alone’ intervention, or a wider portfolio of measures and instruments.

Usually, an evaluation covers all aspects of a project or program in order to capture the interactions and inter-relationships of different aspects of the intervention. However, evaluations can usefully be carried out for specific segments of a risk reduction intervention (an example is provided in Box 6.5).

Box 6.5 Evaluating Flood Forecasts

... access to information, reliability of forecasts and public trust are critical issues to be addressed when developing an advanced flood forecasting system.

Good transparent evidence of the forecasting effectiveness will greatly enhance public’s willingness to respond. To maintain public confidence it is vital to evaluate the effectiveness of forecasts and warnings. This is very often missing, thereby undermining this important aspect of flood risk management.

Source: WMO/GWP (2005)

Some evaluations may assess a number of projects, perhaps each comprising several instruments. In these cases, clarifying the different conditions under which each project operates will be very important if findings are to be properly interpreted.

At a wider scale, an evaluation may assess disaster risk management structures, systems or organizations, as discussed in Benson and Twigg (2001). Alternatively, a risk management policy, or country strategy may be addressed, as described in (UNDP and UNISDR 2006).

6.8.1.2. Approach

Evaluations do not have to be formal, externally-led actions, such as those often required by donors after completion of a project. They can take many other forms, including real-time evaluations, after-action reviews with communities, strategic reviews and internal or self-evaluations by project staff and partners.

Where the evaluation process is led by the project in partnership with other stakeholders, there is stronger and more widespread ownership of the results; lessons can feed directly into the ongoing implementation or, where necessary, redesign of the project. The team chosen to carry out the evaluation should be selected on a range of factors: these include the balance between internal and external evaluators; the need for both technical and local knowledge; evaluation experience; relevant flood risk mitigation experience; and the gender balance within the team. Involvement of community representatives may be highly desirable; participatory processes, or beneficiary assessments, can complement or help validate information gathered through more formal or quantitative methods. Each approach should be selected according to its value in helping to understand the project's impact.

Good monitoring is an integral component of the evaluation system. It facilitates ongoing lesson learning by project managers, as well as provides data for subsequent evaluation. Traditionally, monitoring has been seen as relatively distinct from evaluation, but they are increasingly being treated as part of a single process directed towards lesson-learning and accountability (Wilkinson and Twigg 2009).

6.8.1.3. Time and timing

It is important that sufficient time is allocated to each stage of an evaluation – planning, design, mobilization and implementation; quality will almost certainly suffer if insufficient time is allowed.

Evaluations can take place at any point in the project cycle (for example, mid-term, end of project or post-project); however, the project should be sufficiently advanced to be able to assess effectiveness, at least at the level of outcomes. Retrospective, post-project evaluations provide a more comprehensive picture of impacts. Ideally, there should be a series of evaluation exercises during and after the project, to permit longitudinal analysis, but this rarely happens.

6.8.2. Measuring and analyzing impact

There are broadly three main approaches to impact assessment:

- Scientific approach, which generates quantitative measures of impact;
- Deductive or inductive approach, which makes use of anthropological and socio-economic methods;
- Participatory approach, which gathers the views of program stakeholders.

Participatory approaches are widely recognised as a key component in understanding impact, but have not been much used in the risk management sector to date. Depending on the approach, or combination of approaches being used, data may be collected through a number of methods as described by Wilkinson and Twigg (2009):

- Documentary evidence (for example, data records)
- Statistically valid formal surveys (for example, those affected by floods)
- Structured and semi-structured interviews
- Group discussions
- Rapid assessments (participative or otherwise)
- Direct observation
- Case studies
- Simulations.

Information and data is collected on the following:

Baseline state - the state before intervention

Target state - the state as was intended by the intervention

Observed state - the actually observed state

Indicators fall into two main types (although the terminology sometimes varies):

a. Those that relate to the implementation of programs (input, process and output indicators); and

b. Those which are concerned with the effects of programs (outcome and impact indicators).

Impact is often the most difficult to measure and attribute, this being further exacerbated by the dynamic and complex context of urban floods. The difficulty in specifying and measuring impact does not mean, however, that it is impossible; careful specification of impact indicators is an area where application and effort is required.

Process or output indicators, although usually easier to specify and measure, do not in themselves provide evidence that the intervention has had any impact. For example, the number of staff trained, or the regularity of water level measurements, would not necessarily result in flood risk mitigation. Output indicators may, in some circumstances, be used as proxies for impact but there needs to be strong evidence of causality between the action being measured and the related impact.

The selection of indicators is the most sensitive step in the evaluation process. Often they are established during design (in the project log frame, for example) to ensure that the expected outcomes or impacts are clearly specified. There is a web-based tool available to assist in this process (FLOODsite n.d.); the selection of appropriate indicators does, however, rely on clarity on the evaluation's purpose, the designer or evaluator's experience, and an in-depth knowledge of the intervention, project, program or portfolio in question.

6.8.3. Benefit-Cost Ratio

Benefit-cost ratio (BCR) is a commonly used economic efficiency indicator that captures the overall 'value for money' of a project or proposal. It is the ratio of the monetized benefits relative to costs, both usually expressed in current values or prices. It is also used as part of the cost-benefit analysis in the project planning process (as discussed in Chapter 5). The indicator measures how economically an outcome or impact has been generated.

A significant shortcoming of BCRs is that, although attempts may be made to monetize non-monetary impacts, often they are not accounted.

6.8.4. Gender and cultural aspects: the distribution of benefits

Benefits are unlikely to be evenly spread across a city, town or community. It is important to identify exactly who benefits from flood risk management initiatives, by assessing the socio-economic characteristics of beneficiary communities (disaggregated by gender and particular vulnerabilities, such as ethnicity, age and disability). There is plenty of guidance on incorporating gender and vulnerability into risk mitigation planning and design, and although less prolific, there is some specifically for evaluation for example, Benson and Twigg (2001); other gender-related references are listed at the end of this section.

Analysis of context is of particular importance for assessing the relevance and appropriateness of interventions. Evaluators should examine the extent to which the planning, design and implementation of interventions takes into account the local cultural milieu. A design which has clearly identified, in a participatory fashion, the differentiated risks and needs of citizens (women, men, girls and boys, or different social groups), is likely to result in appropriate outcomes and impacts for the various beneficiaries. Cultural appropriateness should also be considered: for example, an evaluation after the 1998 floods in Bangladesh found that shelters would have been more appropriate if they had been constructed with private space, including latrines, for women and girls, given the cultural seclusion norms (ALNAP 2006).

6.8.5. Providing evaluation feedback

An important outcome of any evaluation in this field must be to learn lessons and improve future project design and implementation. As a result, decisions on how the evaluation findings will be presented and disseminated are particularly important. This will depend upon the stakeholders for whom the evaluation was conducted: the output may take the form of a formal report and presentation to relevant officials, but if any aspect of public accountability is anticipated, then options such as public presentations, websites and public documents should also be considered.

6.8.6. Experience of evaluating flood risk measures

It is important that well-designed evaluations are carried out and the findings shared, so the sector can benefit. However, closer investigation shows that there have been relatively few coherent and comprehensive evaluations of disaster risk management concerning flood risk measures or projects, compared, say, to evaluations of disaster relief operations or development programs.

A study of 44 US state and territory post-disaster mitigation plans found that only 23 percent provided for evaluating success or failure (Godschalk et al. 1999). Similarly, a research project studied 22 international relief and development NGOs based in the UK, analyzing 75 mitigation and preparedness projects of different kinds. The researchers found that assessment or evaluation of impact had taken place in only 12 of the 75 projects (Twigg 2004). There is a general consensus amongst flood risk practitioners that real improvements in evaluation are required, in order that the utility and impact of flood risk management investment and initiatives is far better understood, and modifications are then made as necessary.

6.8.7. Further readings

6.8.7.1. Gender Aspects of Evaluations

Gander, C. et al. 2003. "Gender equality results and indicators for disaster-related programmes -,Evaluation of PAHO's Disaster Preparedness Programme in Latin America and the Caribbean." DFID, unpublished evaluation report, reproduced in Benson and Twigg (2001), Annex 8.2.

Levy, C. 1996. "The Process of Institutionalising Gender in Policy and Planning: The 'Web' of Institutionalisation." Working Paper No. 74, Development Planning Unit, UCL, London. http://www.ucl.ac.uk/DPU/publications/working papers pdf/wp74.pdf.

ILO (International Labor Organisation). 2004. "The Manual of Implementation of Guidelines on Gender Mainstreaming in National Development Planning." Annex of Circular of Minister of Women Empowerment, no. B-89/Men.PP/Dep. II/IX/2002, International Labor Organization, Geneva. http://www.ilo.org/public/english/employment/gems/eeo/download/manual.pdf.

6.8.7.2. Guidelines for Evaluation of Relief Programs

ALNAP (Active Learning Network for Accountability and Performance in

Humanitarian Action). n.d. Homepage. http://www.alnap.org.Beck, T. 2006. “Evaluating Humanitarian Action using the OECD-DAC Criteria.” ALNAP. http://www.alnap.org/publications/eha_dac/index.htm.

ODI Humanitarian Policy Group. n.d. “Approaches to Measuring the Impact of Humanitarian Assistance. Research Framework.” http://www.odi.org.uk/hpg/papers/Impact - research framework.pdf.

OECD-DAC (Organisation for Economic Co-operation and Development, Development Assistance Committee). 1991. Principles for Evaluation of Development Assistance. Paris: Organisation for Economic Co-operation and Development, Development Assistance Committee. http://www.oecd.org/dataoecd/secure/9/11/31779367.pdf.

Proudlock, K., Ramalingam, B., and Sandison, P. 2009. “Improving humanitarian impact assessment: Bridging theory and practice.” In 8th Review of Humanitarian Action: Performance, Impact and Innovation, ALNAP/ODI, London.

6.8.7.3. Other Sources of Information

Feinstein International Center. 2008. “Participatory Impact Assessment: a Guide for Practitioners.” https://wikis.uit.tufts.edu/confluence/download/attachments/10979253 /Part_Impact_10_21_08.pdf?version=1.

Godschalk, D.R., Beatley, T., Berke P., Brower, D.J. and Kaiser, E.J. 1999. Natural Hazard Mitigation: Recasting disaster policy and planning. Washington, DC: Island Press.

Freeman, P.K., Martin, L.A., Linnerooth-Bayer, J., Mechler, R., Pflug, G. and Warner, K. 2003. Disaster Risk Management: National Systems for the Comprehensive Management of Disaster Risk and Financial Strategies for Natural Disaster Reconstruction. Washington: Inter-American Development Bank (IADB). http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=560964.

ISDR/ World Bank (2006) Global Facility for Disaster Reduction and Recovery: A Partnership for Mainstreaming Disaster Mitigation in Poverty Reduction Strategies. Geneva: ISDR and New York: World Bank. http:// www.unisdr.org/eng/partner-netw/wb-isdr/wb-isdr-GFDRR.pdf.

La Trobe, S. and Davis, I. 2005. Mainstreaming Disaster Risk Reduction: A Tool for Development Organisations. Teddington: Tearfund. http://www.tearfund.org/webdocs/Website/Campaigning/ Policy and research/Mainstreaming disaster risk reduction.pdf.

Venton, P. and. La Trobe, S. 2007. Institutional donor progress with mainstreaming disaster risk reduction, UK: Tearfund. http://www.tearfund.org/webdocs/website/Campaigning/Policy and research/DRR donor progress 2007.pdf.

Wamsler, C. 2006. “Mainstreaming risk reduction in urban planning and housing: a challenge for international aid organisations.” Disasters 13(2): 151-77.

WFP (World Food Programme). n.d. “Monitoring and Evaluation Guidelines.”http://www.wfp.org/operations/evaluation/guidelines.asp?section=5 &sub_section=8.

IEG (Independent Evaluation Group). 2006. Hazards of Nature Risks to Development, An IEG Evaluation of World Bank Assistance for Natural Disasters. Washington, DC: World Bank.

6.9. References

Abarquez, I. and Murshed, Z. 2004. *Community-Based Disaster Risk Management: field practitioners’ handbook*. Bangkok: ADPC.

ActionAid. 2002. *Emergencies impact review*. London: ActionAid International.

ADPC (Asian Disaster Preparedness Center). 2010. *Mainstreaming Disaster Risk Reduction. Urban Governance and Community Resilience Guides*. Bangkok: ADPC.

AfDB (African Development Bank); African Union (AU); New Partnership for Africa’s Development Planning and Coordinating Agency (NEPAD); United Nations International Strategy for Disaster Reduction Secretariat - Africa (UNISDR - AF). 2004. *Guidelines for mainstreaming disaster risk assessment in development*. Geneva: United Nations.

Alam, Khurshid. 2008. “Flood disasters: Learning from previous relief and recovery operations.” ALNAP Lessons Paper. ALNAP and Provention Consortium. http://www.alnap.org/pool/files/ALNAP-ProVention_flood_lessons.pdf.

ADB (Asian Development Bank). 2000. *Finance for the Poor: Microfinance Development Strategy*. ADB.

Bouwer, L. M. and Aerts, J. C. J. H. 2006. “Financing climate change adaptation.” Disasters, 30: 49-63.

Christoplos, I. 2008. “Incentives and Constraints to Climate Change Adaption and Disaster Risk Reduction – a Local Perspective." Commission on Climate Change and Development. http://www.ccdcommission.org.

Corfee-Morlot, Jan, Lamia Kamal-Chaoui, Michael G. Donovan, Ian Cochran, Alexis Robert and Pierre-Jonathan Teasdale (2009), "Cities, Climate Change and Multilevel Governance." OECD Environmental Working Papers N° 14. OECD.

Creighton, J. L. 2005. The Public Participation Handbook: Making Better Decisions Through Citizen Involvement. San Francisco, CA: Jossey-Bass (a Wiley Imprint).

Dale N., Nyirongo J., Anderson C., Baker L., Dilloway S., Faleiro F., van den Ende P., Bercilla J., and Beesley J. 2009. *Local voices, Global choices: For successful disaster risk reduction*. Christian Aid, Oxfam, Practical Action, Save the Children and Tearfund.

Devas, N., and Batley, R. 2004. "Urban governance and poverty: lessons from a study of ten cities." Paper presented at ADB Regional Seminar and Learning Event, "Local Governance and Pro-Poor Service Delivery," Manila, February 10-12.

DILG., GTZ. & DIPECHO (Disaster Preparedness European Commission Humanitarian Aid Department). 2008. "Mainstreaming Disaster risk reduction in local governance." Proceedings of the National Conference on Mainstreaming Disaster Risk Reduction In Local Governance, March 4-6, Makati City, Philippines.

Emergency Management Australia. 2000. *The Good Practice Guide*. Canberra: EMA.

Environment Agency. n.d. http://www.environmentagency.net/cy/ymchwil/cynllunio/33704.aspx.

Flood & Water Management Act 2010 (c29). London: HMSO.

Flood Plan UK "Dry Run: A Community Flood Planning Guide." Flood Plan UK.

FLOODsite. 2007. "Failure Mechanisms for Flood Defence Structures – report no T04-06-01." Floodsite. http://hikm.ihe.nl/floodsite/data/Task4/pdf/failmechs.pdf.

FLOODsite. 2008. "Reliability Analysis of Flood Defence Systems –factsheet no T07-08-03." Floodsite. http://www.floodsite.net/html/partner_area/project_docs/Fact_Sheet_Task_7_v2_0.pdf.

Government of India. n.d. "Public private partnerships in India (2010-11), Case studies Alandur Sewerage Project (online)." Ministry of Finance, Government of India. http://toolkit.pppinindia.com/highways/module3-rocs-asp8.php?links=asp8.

Hellmuth, M. E., Moorhead, A. and Williams, J. 2007. *Climate risk management in Africa: Learning from practice*. The International Research Institute for Climate and Society (IRI).

Iglesias, G. 2007 *Cooperation between Local Authority and Communities: Reducing Flood Disaster Risk in Dagupan City, Philippines*. Safer Cities, No. 16, Bangkok: ADPC.

IFRC (International Federation of Red Cross and Red Crescent Societies). 2010. *World disasters report: focus on urban risk*. IFRC.

International Water Association (IWA) Water Wiki. n.d. "Alandur Sewerage Project." (created June 01, 2011) http://www.iwawaterwiki.org/xwiki/bin/view/Articles/Alandur+Sewerage+Project+-+India?language=en.

ISDR (International Strategy for Disaster Reduction). 2004. *Living with risk: A global review of disaster reduction initiatives*. Geneva: United Nations Publications.

Jabeen, H, Johnson, C., and Allen, A. 2010. "Built-in resilience: learning from grassroots coping strategies to climate variability." *Environment and Urbanization* 22 (2): 415-432.

Jackson, D. 2011 *Effective Financial Mechanisms at the national and local level for Disaster Risk Reduction*. United Nations Capital Development Fund.

Jha, A., Lamond, J., Bloch, R., Bhattacharya, N., Lopez, A., Papachristodoulou, N., Bird, A., Proverbs, D., Davies, J. and Barker R. 2011. "Five Feet High and Rising: Cities and Flooding in the 21st Century." Policy Research Working Paper 5648, World Bank, Washington DC. http://econ.worldbank.org/docsearch.

Kafle, S. Kanta and Murshed, Z. 2006. *Participant's Workbook: Community-based Disaster Risk Management for Local Authorities*. Bangkok: ADPC.

Kiser, L. and Ostrom, E. 1982. "The Three Worlds of Action, a Metatheoretical Synthesis of Institutional Approaches." In *Strategies of Political Inquiry*. ed. Ostrom, E. Elinor. Beverly Hills: Sage.

Lamond, J. and Proverbs, D. 2009. "Resilience to flooding: learning the lessons from an international comparison of the barriers to implementation." *Urban Design and Planning* 162: 63-70.

Lamond, J., Proverbs, D. and Hammond, F. 2009. Accessibility of flood risk insurance in the UK - confusion, competition and complacency. *Journal of Risk Research* 12: 825-840.

Lovelock, D. 1994. "Eight Propositions and a Proposal." Paper presented at ABSEL/SAGSET Conference, Warwick, UK.

Mathur, P. M. 2002. *Alandur Sewerage Project: A success story of Public-private partnership arrangements. Published in the India Infrastructure Report 2002, Governance Issues for Commercialization*. New Delhi: 3iNetwork, Oxford University Press.

MRC and ADPC. 2008. *Sustaining the Flood Preparedness and Emergency Management System in Cambodia: Creating the momentum for mainstreaming. Flood Emergency Management Strengthening - Component 4 Of The MRC - Flood Management And Mitigation Program (FMMP). Safer Communities Case Study 4*. MRC and ADPC.

Mukerhjee, N. and van Wijk, C, ed. 2003. *Sustainability Planning and Monitoring in community water supply and sanitation – a guide on the Methodology for Participatory Assessment (MPA) for community-driven development programs*. Washington, DC: The World Bank.

North, D. 1991. Institutions, Institutional Change and Economic Performance. Cambridge: Cambridge University Press.

NIUA. 2001. *The Alandur Underground Sewerage Project, Experiences with the implementing a private sector participatory project (draft report)*. New Delhi: Alandur Municipality, Tamil Nadu.

NRC (National Research Council). 2011. *Building Community Disaster Resilience through Private-Public Collaboration. Committee on Private-Public Sector Collaboration to Enhance Community Disaster Resilience*. Geographical Science Committee, National Research Council. Available online: http://www.nap.edu/catalog/13028.html.

ODI. 2005. "Aftershocks: Natural Disaster Risk And Economic Development Policy." Overseas Development Institute Briefing Paper, ODI.

O'Donnell, I. 2009. *A Contribution to the 2009 ISDR Global Assessment Report on Disaster Risk Reduction. Practice Review on Innovations in Finance for Disaster Risk Management*. ProVention Consortium.

Olfert A. 2008. "Guideline for Ex-Post Evaluation of Measures and Instruments in Flood Risk Management." Sixth Framework Programme, Wallingford. http://www.floodsite.net/html/publications2.asp+Olfert+A.+2008.+"Guideline+for+Ex-Post+Evaluation&cd=1&hl=en&ct=clnk&gl=uk.

Parkinson, J. and Tayler, K. 2003. "Decentralized wastewater management in peri-urban areas in low-income countries." *Environment and Urbanization* 15 (1): 75-90.

Pielke, R. A. 2006. "White paper prepared for the workshop." Paper presented at "Climate change and disaster losses workshop, understanding and attributing trends and projections." Hohenkammer. 25-26 May.

Pitt, M. 2008. *The Pitt Review: Learning lessons from the 2007 floods*. London: Cabinet Office.

RNW. n.d. http://www.rnw.nl/english/article
dutch-heat-wave-raises-dyke-safety-concerns.

Satterthwaite, D. 2001. "Environmental governance: a comparative analysis of nine city case studies." *Journal of International Development* 13: 1009–1014.

Satterthwaite, D. Huq, S. Pelling, M. Reid, H. and Lankao P. R. 2007. "Adapting to climate change in urban areas: the possibilities and constraints in low and middle income nations." Human Settlements Working Paper Series, Climate Change and Cities No. 1. London: IIED.

Sphere Project. 2004. "Humanitarian charter & minimum standards in disaster response." Geneva: The Sphere Project. http://www.sphereproject.org/content/view/27/84.

Tanner, T. Mitchell, T. Polack, E. and Guenther, B. 2008. "Urban Governance for Adaptation: Assessing Climate Change in Ten Asian Cities". Report to Rockefeller Foundation. Brighton: IDS.

Tearfund. n.d. "Disaster Risk Reduction: Multi-Stakeholder Flood Mitigation in Malawi. A Case Study." http://tilz.tearfund.org/webdocs/Tilz/Topics/DRR/Benefits%20of%20Multi-stakeholder%20Flood%20Mitigation%20in%20Malawi.pdf (accessed September 1, 2011)

Tucci, M. 2007. Urban Flood Management. WMO, Cap-Net, APFM.

Twigg, J. 2007. "Evaluating Disaster Risk Reduction Initiatives." Guidance Note 13, Tools for Mainstreaming Disaster Risk Reduction, ProVention, Geneva.

UNDP. 2010. *Disaster Risk Reduction, Governance & Mainstreaming*. Bureau for Crisis Prevention and Recovery.

UNISDR. 2008. "Linking Disaster Risk Reduction and Poverty Reduction: Good

Practices and Lessons Learned." A Publication of the Global Network of NGOs for Disaster Risk Reduction. Geneva: UNISDR.

UNESCO. 2007. Petunjuk Praktis: Partisipasi Masyarakat dalam Penanggulangan Banjir. Jakarta: UNESCO.

UNESCO. 2004. *Flood Mitigation. A Community-based Project. Maximizing Knowledge to Minimize Impacts*. Jakarta: UNESCO.

UN-HABITAT (United Nations Human Settlements Program). 2003. *The Challenge of Slums: Global Report on Human Settlements 2003*. London: Earthscan.

ALNAP. 2006. Evaluating Humanitarian Action using the OECD-DAC criteria: An ALNAP Guide for Humanitarian Agencies. London: ODI.

Benson, C. and Twigg, J. 2004. Measuring Mitigation. Methodologies for assessing natural hazard risks and the net benefits of mitigation – a scoping study. Geneva: International Federation of Red Cross and Red Crescent Societies/ProVention Consortium.

FLOODsite. n.d. "Selection of Indicators - FLOODsite report T12-07-03." http://www.floodsite.net/html/work_programme_research.asp?taskID=12#6.

Godschalk, D.R. et al. 1999. In Wilkinson, E. and Twigg, J. 2009. "Monitoring and Evaluation Sourcebook." Provention. http://www.proventionconsortium.org/?pageid=61.

Twigg, J. 2004. Disaster Risk Reduction: Mitigation and preparedness in development and emergency programming. London: ODI.

UNDP and UNISDR (United Nations Development Programme and United Nations International Strategy for Disaster Reduction).. 2006. Integrating Disaster Risk Reduction into CCA and UNDAF: Guidelines for Integrating Disaster Risk Reduction into CCA/UNDAF. Geneva: United Nations Development Programme and United Nations International Strategy for Disaster Reduction. http://www.unisdr.org/eng/risk-reduction/sustainable-development/cca undaf/cca-undaf.htm#2-3.

Wilkinson, E. and Twigg, J. 2009. "Monitoring and Evaluation Sourcebook." Provention. http://www.proventionconsortium.org/?pageid=61

WMO/GWP. 2005. "Overview Situation Paper on Flood Management Practices." Associated Programme on Flood Management, Technical Support Unit, WMO/GWP.

Boats travel through an urban landscape of flooding along the Borommaratchonnanee Road in the Taweewattana district in Bangkok, Thailand (2011). Source: Gideon Mendel

Chapter 7

Conclusion: Promoting Integrated Urban Flood Risk Management

Chapter 7. Conclusion: Promoting Integrated Urban Flood Risk Management

7.1. Introduction

Chapter Summary

This chapter summarizes the essential considerations for ensuring that flood protection is provided in an integrated fashion. It addresses the questions of how to initiate integrated flood risk management and how to calculate progress towards an effective integrated flood risk management framework. Evaluation and benchmarking are important steps in improving the design and implementation of flood risk management measures, both structural and non-structural.

The key messages from this chapter are:

- Flooding is having a major impact on millions of people every year and therefore flood risk management measures need to be implemented in the short term
- Impacts from flooding are growing and may become much worse in the future. Schemes must balance the short and long term and integrate structural and non-structural measures
- Successful long term implementation of flood risk management measures requires clear leadership, strong champions and the right institutional and legislative frameworks
- It is critically important to monitor and benchmark flood risk management even when there has not been a flood event for some time.

In the first six chapters of this guide the integrated urban flood risk management process has been described, from understanding the hazard and the risk, through to identifying appropriate measures, selecting these measures and implementing them. It has always been recognized that these measures will reduce but never entirely eliminate risk; similarly, the maximum potential protection may not be provided in the short term due to practical and resource considerations. Urban flood risk management then becomes an iterative process, with a long term target to be approached through a series of steps.

The chapter starts with 12 guiding principles for integrated urban flood risk management. The next Section 7.3 focuses on a five-step process to integrate flood risk management.

In the following Section 7.4, benchmarks are set out for the 12 principles of integrated flood risk management. These are designed to test progress towards the full integration of structural and non-structural measures, involving multiple stakeholders and within wider urban management in the longer term. This is helpful for discussions regarding the setting of future targets for the improvement of flood protection.

In Section 7.5 four detailed case studies of urban flood risk management illustrate how integrated flood risk management operates in a number of different city and town settings. Final remarks follow in Section 7.6.

7.2. Twelve key principles for integrated urban flood risk management

1. Every flood risk scenario is different: there is no flood management blueprint.

Understanding the type, source and probability of flooding, the exposed assets and their vulnerability are all essential if the appropriate urban flood risk management measures are to be identified. The suitability of measures to context and conditions is crucial: a flood barrier in the wrong place can make flooding worse by stopping rainfall from draining into the river or by pushing water to more vulnerable areas downstream, and early warning systems can only have limited impact on reducing the risk from flash flooding.

2. Designs for flood management must be able to cope with a changing and uncertain future.

The impact of urbanization on flood management is currently and will continue to be significant. But it will not be wholly predictable into the future. In addition, in the present day and into the longer term, even the best flood models and climate predictions result in a large measure of uncertainty. This is because the future climate is dependent on the actions of unpredictable humans on the climate – and because the climate is approaching scenarios never before seen. Flood risk managers need therefore to consider measures that are robust to uncertainty and to different flooding scenarios under conditions of climate change.

3. Rapid urbanization requires the integration of flood risk management into regular urban planning and governance.

Urban planning and management which integrates flood risk management is a key requirement, incorporating land use, shelter, infrastructure and services. The rapid expansion of urban built up areas also provides an opportunity to develop new settlements that incorporate integrated flood management from the outset. Adequate operations and maintenance of flood management assets is also an urban management issue.

4. An integrated strategy requires the use of both structural and non-structural measures and good metrics for "getting the balance right".

The two types of measure should not be thought of as distinct from each other. Rather, they are complementary. Each measure makes a contribution to flood risk reduction but the most effective strategies will usually combine several measures – which may be of both types. It is important to identify different ways to reduce risk in order to select those that best meet the desired objectives now – and in the future.

5. Heavily engineered structural measures can transfer risk upstream and downstream.

Well-designed structural measures can be highly effective when used appropriately. However, they characteristically reduce flood risk in one location while increasing it in another. Urban flood managers have to consider whether or not such measures are in the interests of the wider catchment area.

6. It is impossible to entirely eliminate the risk from flooding.

Hard-engineered measures are designed to defend to a pre-determined level. They may fail. Other non-structural measures are usually designed to minimize rather than prevent risk. There will always remain a residual risk which should be planned for. Measures should also be designed to fail gracefully rather than, if they do fail, causing more damage than would have occurred without the measure.

7. Many flood management measures have multiple co-benefits over and above their flood management role.

The linkages between flood management, urban design, planning and management, and climate change initiatives are beneficial. For example, the greening of urban spaces has amenity value, enhances biodiversity, protects against urban heat islands, and can provide fire breaks, urban food production and evacuation space. Improved waste management has health benefits as well as maintaining drainage system capacity and reducing flood risk.

8. It is important to consider the wider social and ecological consequences of flood management spending.

While costs and benefits can be defined in purely economic terms, decisions are rarely based on economic considerations alone. Some social and ecological consequences such as loss of community cohesion and biodiversity are not readily measureable in economic terms. Qualitative judgments on these broader issues must therefore be made by city managers, communities at risk, urban planners and flood risk professionals.

9. Clarity of responsibility for constructing and running flood risk programs is critical.

Integrated urban flood risk management is often set within and can fall between the dynamics and differing incentives of decision-making at national, regional, municipal and community levels. Empowerment and mutual ownership of the flood problem by relevant bodies and individuals will lead to positive actions to reduce risk.

10. Implementing flood risk management measures requires multi-stakeholder cooperation.

Effective engagement with the people at risk at all stages is a key success factor. Engagement increases compliance, generates increased capacity and reduces conflict. This needs to be combined with strong, decisive leadership and commitment from national and local government.

11. Continuous communication to raise awareness and reinforce preparedness is necessary.

Ongoing communication counters the tendency of people to forget about flood risk. Even a major disaster has a half-life of memory of less than two generations; and other more immediate threats often seem more urgent. Less severe events can be forgotten in less than three years.

12. Plan to recover quickly after flooding and use the recovery to build capacity.

As flood events will continue to devastate communities despite the best flood risk management practices, it is important to plan for a speedy recovery. This includes planning for the right human and financial resources to be available. The best recovery plans use the opportunity of reconstruction to build safer and stronger communities which have the capacity to withstand flooding better in the future.

7.3. The integrated urban flood risk management process

The figure 7.1 illustrates the process for integrated urban flood risk management. It overs all steps from understanding flood hazard and identifying the most appropriate measures, to planning, implementing and finally evaluating the strategy and its measures.

In this process three important issues should be highlighted. First, it is important to ensure that consultation is carried out for each stage of the process in a meaningful and effective way. Second, integrated urban flood risk management is a continuous process in which effectiveness will depend on how relevant stakeholders seek to raise awareness about flood risk and improve implementation of urban flood risk management. Third, failure to enforce and implement appropriate measures could increase the impact of flood events and undermine the resilience of a system.

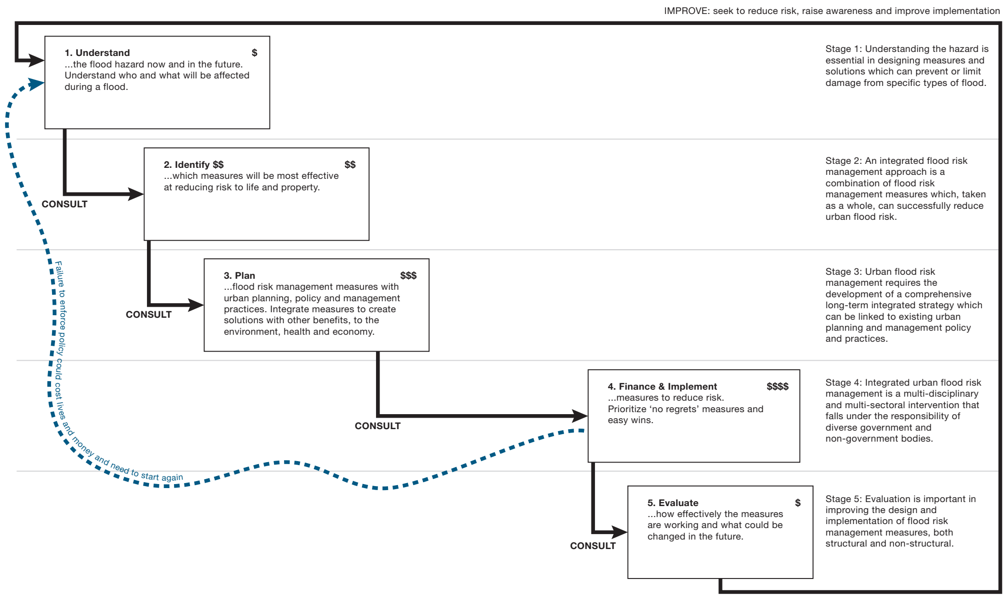

Figure 7.1: The integrated urban flood risk management process

7.4. Benchmarking progress

The concept of benchmarking can be useful to aid decision makers in assessing how well they are progressing with delivering integrated flood risk management. The following table sets out benchmarks in the development of better flood risk management, in alignment with the 12 underlying principles and the five stages of delivery. The user can review the work that has been done in a particular urban area or country, identify from the table, broadly speaking, how far they have met the principles at that stage, and thereby establish what is required to advance towards a more integrated solution. Case studies in the guide which illustrate the principles are listed.

Table 7.1: Benchmarking progress.

Principle	Case studies	Understand	
Every flood risk scenario is different: there is no flood management blueprint.	Spatial analysis of natural hazards and climate variability risks in the peri-urban areas of Dakar A megacity in a changing climate - Kolkata	Understand the multiple sources of hazard and risk	
Designs for flood management must be able to cope with a changing and uncertain future.	Flexible planning: Thames Estuary 2100, UK Integrated Flood Management Strategy for Ho Chi Minh City (HCMC), Vietnam	Consider climate change and urbanization and look for other uncertainties	
Rapid urbanization requires integration of FRM into regular urban planning and governance.	Integrating Disaster Risk Reduction in planning and budgeting in Palo in the Philippines	Understand the diversity of flood management roles and urban conditions	
An integrated strategy requires the use of both structural and non-structural measures and good metrics for "getting the balance right".	Flood management in Jakarta, Indonesia Vaisigano Catchment Cost Benefit Analysis: Samoa	Understand the benefits and limitations of different approaches	
Heavily engineered structural measures can transfer risk upstream and downstream. It is impossible to entirely eliminate the risk from flooding	The Mississippi River Floods of 2011 - Morganza Floodway Modernization of the Wroclaw floodway system Camanava anti-flood project 2003-2011, the Philippines	Consider the wider catchment and whether the measures will make it worse elsewhere Understand that rare extreme events, outside the observed record will occur	
Many flood management measures have multiple co-benefits over and above their flood management role.	Solid waste disposal in Bamako, Mali Kuala Lumpur SMART Tunnel, Malaysia New York City Green Infrastructure Program	Understand how flood risk fits within broader natural hazards and urban development concerns	

	Identify	Plan	Implement	Evaluate
	Consider range of alternatives appropriate for specific risks	Look at existing structures, measures and plans	Tailor implementation to fit in with local customs and preference	Recognise the relative risk reduction rather than absolute risk levels
	Carry out sensitivity testing and choose robust alternatives	Identify under what circumstances plans would need to change	Build in maximum flexibility to built structures, systems and policies	Test robustness to future scenarios and plan regular revisions to coincide with new forecasts
	Look for synergies with existing roles and other development goals	Consult widely and engage in joint planning	Coordinate implementation to maximize efficiency and demonstrate benefits	Agreed targets can be monitored as part of regular monitoring programmes
	Consider both types of measures and mixtures of the two	Ensure that all required elements are planned for and particularly that capital investment is backed up by the right forecasting and warning regime	Implement the most cost effective measures first and often makes sense to put the non-structural elements in place first	Evaluate as a scheme but identify where failures are most likely
	Identify measures which transfer least risk, look for ways to deal with any flows conveyed elsewhere	Consult widely and set up compensation schemes or mitigation actions in areas at increased risk	Communicate changes in risk and implement schemes to offset risk in other areas	Monitor the effectiveness of compensation and awareness of changing risks
	Choose measures which will not cause more harm if they are overtopped or fail	Determine the appropriate level of protection and plan for what will happen when it is exceeded	Set up warning and evacuation systems for the residual risk	Always measure against planned levels of protection rather than zero risk
	Identify measures which have the potential to contribute other goals	Consult widely and engage in joint planning and target setting	Consider co-financing and involve all stakeholders during implementation	Measure against wider goals but specifically identify the impact on flood risk

Table 7.1: Benchmarking progress continued.

Principle	Case studies	Understand	
It is important to consider the wider social and ecological consequences of flood management spending.	The Dilemma of Poverty and Safety: The Case of Urban Flooding in the Aboabo River Basin in Kumasi, Ghana Surat Vulnerability Analysis, India Cost-Benefit Analysis for Community-Based Disaster Risk Reduction in Nepal	Undertake vulnerability analysis in the broadest possible sense	
Clarity of responsibility for constructing and running flood risk programs is critical.	Flood preparedness and emergency management programs in Cambodia	Identify communities at direct risk but also those indirectly affected. Map the organizations agencies and governance structures surrounding these communities.	
Implementing flood risk management measures requires multi-stakeholder cooperation.	Flood and Typhoon Resilient Housing in Vietnam Flood risk management and children's participation in Mozambique Chengdu urban revitalization Multi-stakeholder collaboration for better Flood Risk Management in Metro Manila, the Philippines	Use participatory risk and vulnerability assessment procedures alongside the best available scientific predictions	
Continuous communication to raise awareness and reinforce preparedness is necessary.	Raising awareness of disaster risk through radio drama in Afghanistan Multi-stakeholder flood management in Malawi	Share hazard and risk maps with the public in the most accessible way possible	
Plan to recover quickly after flooding and use the recovery to build capacity.	The case of the tsunami-damaged village of Xaafuun, Somalia	The residual risk should be measured	

	Identify	Plan	Implement	Evaluate
	Consider all impacts of proposed measures e.g. via environmental and social impact assessment	Use MCA to select measures and engage and consult with affected stakeholders throughout the planning process	Continue to engage stakeholders, take mitigating actions and ensure grievance and compensation procedures are in place	Track and monitor potential impacts identified in earlier assessments. Use participatory approaches
	Identify measures that can be either controlled or influenced by the agencies and government bodies involved in the decision	Engage all stakeholders in decision making but clearly define roles and responsibilities	Assign responsibilities for implementation as well as for running and maintaining systems. Enshrine in legislation, redefine departmental roles or set up new structures if necessary	Involve all stakeholders including hard to reach groups and those who were involved in the planning stages
	Consult widely including the use of local networks to reach vulnerable people. Assess capabilities of available experts, peer knowledge networks, local businesses, and NGOs.	Put in place agreements for support and mutual cooperation amongst stakeholders	Engage the maximum number of stakeholders during implementation to cement relationships	Ensure stakeholders' goals are addressed in the evaluation
	Consult on different options setting out clearly the costs, benefits and consequences,and respond to feedback	Detailed plans should also be shared and consulted on.	Many measures require detailed communication of expected behavior or compliance procedures. Communication should be wider including the limitations of measures and the need to maintain vigilance.	Two way communication of the success of measures, particularly damage avoided and the need for more and better FRM is needed in the long term.
	Ways of dealing with residual risk usually include emergency planning warning systems insurance etc	Plan to fail gracefully and put in place emergency procedures. Ensure that disaster management infrastructure is situated in the lowest possible risk area	Prioritise critical infrastructure and vulnerable people. Take the opportunity to build in resilience	Check that the recovery has increased the resilience to future events

7.5. City case studies: integrated urban flood risk management

7.5.1. Argentina: Urban Flood Prevention and Drainage Program

Over 80 percent of Argentina's population and economic activity is located in the alluvial flood plain of the Parana and La Plata Rivers; in areas subject to flash floods, near rivers draining the foothill of the Andes; and in flood-prone urban river basins. As a consequence of such vulnerabilities, the country has suffered widespread floods in 1983, 1985, 1992 and 1998, causing direct damage in excess of US$1 billion each year. Cities are particularly at risk due to the uncontrolled urbanization of flood plains, insufficient drainage infrastructure, decimated storm water storage systems, and weak institutional and policy frameworks.

Since the early 1990s, reducing flood-related risks became a top priority of the National Government which has led and financed strategic programs to reduce vulnerability to flood hazards countrywide. These programs are being implemented in close coordination with provincial governments, the City of Buenos Aires, and local authorities; and with participation of international institutions like the World Bank and the Inter-American Development Bank. The strategic approach started from initial emergency response programs targeting the rehabilitation of damaged infrastructure, disaster response programs and institutional coordination. Flood prevention programs followed; encompassing structural and non-structural measures to protect lives, defend infrastructure and reduce loss of economic output. A third phase includes support to enhance the capacity of drainage infrastructure, further improvements of land use planning and integrated water management, among other policy and institutional interventions, to increase the level of flood protection in urban centers and in selected rural areas.

In the case of the city of Buenos Aires, a basic drainage system was built in the 1930s. However, existing drainage infrastructure is not capable of handling the combination of intense storms with less than 10 years of frequency period, distributed over almost 100% land imperviousness, and deficiencies of the solid waste collection system of a city with average population densities of about 150 inhabitants per hectare—reaching 300 in some part of the city. Weather variability is also a factor because there is evidence of more intense storms originating on the southern Atlantic system, which are frequently combined with higher sea surge events. The combination of these factors—urbanization, imperviousness, high groundwater table, and climate variability—makes drainage a very complex issue for the entire city of Buenos Aires.

To address these issues, the Government of the City of Buenos Aires requested the financial assistance of the National Government to undertake a comprehensive urban drainage master plan. It was finished in 2004 by a consortium of international and local consulting companies, under World Bank financing. The master plan allowed for a better understanding of flood issues in Buenos Aires, and for a sound evaluation of flood management options within an integrated approach encompassing structural and non-structural measures, sound socioeconomic analysis, and environmental impact assessments. In 2007, a flood management and investment project was approved for the Maldonado river basin, which received the highest priority because it is the most affected urban basin of the city. By the end of 2011, large underground tunnels are almost completed, a network of secondary drainage conduits is under construction, and non-structural measures are underway; including installation of rain and gauging stations, operation of sophisticated drainage models, and studies to improve land use management and solid waste collection. A follow up program is envisaged to other urban basins and consolidate ongoing non-structural efforts.

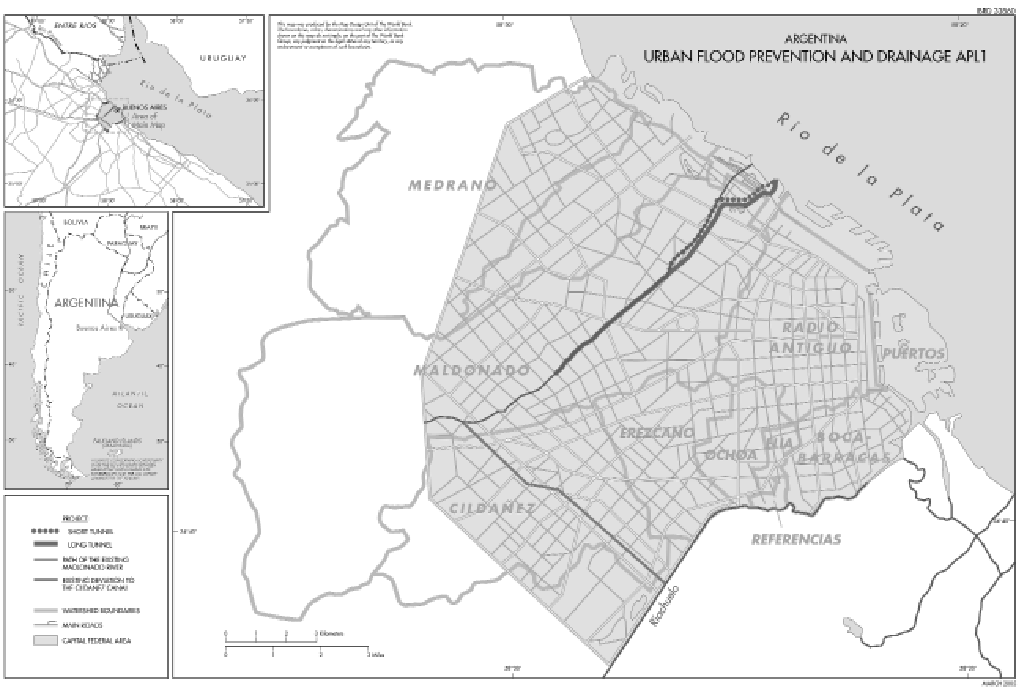

Figure 7.2: Buenos Aires drainage master plan, Source: World Bank (2005)

The next sections describe the two phases of the program currently underway for both Buenos Aires and for selected provinces. These phases aimed at protecting valuable economic assets and persons living in flood-prone areas by constructing physical defenses, by implementing a housing program to increase the resilience of lowest-income population, and by strengthening national and provincial institutions and systems for dealing with flooding.

Phase 1

The proposed measures intended to reduce Buenos Aires's exposure to flooding through the improvement of the level of protection provided by its drainage system and the implementation of a risk management program. The project focused on the issues of risk identification and reduction through prevention, mitigation, and education.

To achieve this, the project aimed at increasing the city's resilience to flooding through: (a) land use planning, building codes, construction practices, urban environment management, increasing information through hazard maps, contingency plans and vulnerability analysis; and (b) the improvement of the city's flood defenses through water drainage. The project has three main components as described below:

Component 1: Risk management scheme

This component has funded actions aimed at providing assistance to the city government to promote a risk management approach in dealing with floods, including prevention, mitigation and response. In addition, the component would strengthen the existing administrative bodies so that the transfer of responsibilities from the implementation unit to the agencies would be planned during project implementation.

Component 2: Development of key defense facilities

The structural measures component funds works for a total of US$ 282 million, including the construction of two collection tunnels of respectively 9.9 km and 4.7 km (US$ 192 million), and 46 km of additional secondary connections (US$ 90 million) to improve the functioning of the existing draining system in the Maldonado Basin. The tunnels were designed to complement existing underground systems to increase peak flow discharge capacity for the entire basin. Main underground tunnels are expected to be finalized by mid-2012. However, a large part of the secondary network should have to be completed in a follow-up phase.

This component also includes:

- Development of detailed project feasibility studies for the other water basins of the city to assist decision making for future drainage infrastructure investments aligned with the Master Plan
- The component included contracting a specialized team to supervise tunnel construction, as well as a Technical Panel of Independent Advisors to review the strategic approach of the project and assist with engineering design

Implementing non-structural measures is lagging behind, but there are already a few important outcomes like the Hydraulic Interpretation Centre, launched in October 2009, which is open for public consultation.

Component 3: Project Implementation and Auditing

The existing project implementation unit, under the administration of the city, would progressively transfer the operation of hydraulic assets and non-structural programs to permanent agencies based on their institutional capacity, complemented by training programs.

Phase 2

Phase 2 targets six provinces, and it aims at strengthening the country's risk management capacity by supporting institutional development and flood management infrastructure investments. This phase was prepared within the framework of the Federal Water Agreement under the leadership of the provinces and in close coordination with inter-jurisdictional Federal Hydraulic Committee (COHIFE). COHIFE was responsible for developing nationwide water management principles that has been adopted by provincial governments and they are the basis for coordinated action. Within the COHIFE framework, the most flood prone provinces were selected. This phase focuses on:

- Institutional strengthening by providing flood risk reduction instruments to the provincial institutions
- Improving flood preparedness for vulnerable areas not benefited from structural defenses. This provided improved housing in safe areas for lower income families living in flood prone areas and for those that were resettled from for the works
- Developing key defense structures to protect important urban areas against flood effects.

Lessons learned from past operations in the country

- Investments are affected by unpredictable allocations of public funds to infrastructure investment programs, which are subject to modifications that delay progress of project implementation
- Flood protection projects in Argentina are designed with limited consideration to financing recurrent costs and the institutional support to maintain assets which hare built. To address this issue, the City of Buenos Aires has contracted the maintenance of existing drainage works to the private sector, and committed itself to extend the contract for the newly built network and to prepare a separate maintenance contract for the tunnels due to their technical specificity
- Inadequate collection of solid waste compromises the performance of drainage systems. Unfortunately, effective solutions to this problem are still challenging
- The existing coordination procedures, across government jurisdictions, were agreed in a context of weak provincial institutional capacity— they should be updated to improve efficiency and effectiveness.

Policy lessons

- Water basin strategies have helped prioritize interventions in the rural and urban areas.
- The non-structural measures added to the protection effects of the physical interventions at the city level are essential to build resiliency to floods
- Flood protection projects are designed and implemented with limited consideration to maintenance. Experience has shown the importance of including comprehensive maintenance strategies to sustain the overall condition of the infrastructure
- Lengthy procurement procedures and the timing of local elections explain most of the slow progress of some components of the program. In Buenos Aires, once the main contracts were awarded, works have proceeded as planned.

Sources: World Bank 2005; World Bank, 2006; Halcrow, 2011. Buenos Aires drainage master plan: http://www.halcrow.com/Our-projects/Project-details/Buenos-Aires-drainage-masterplan/.

7.5.2. Germany: Cologne flood prevention

Cologne, with a population of one million, is the fourth largest city in Germany. Flooding is not something new in the city, as flood events have been reported from as far back as in 792 CE.

The Group of Municipal Drainage Operations Cologne (Stadtentwässerungsbetriebe Köln or StEB) is a municipal corporation responsible for the city's water management activities, including sewage disposal and drainage, flood control and prevention, and management of surface waters.

With regard to flood protection, StEB provides protection against 100 and 200 year flood levels along 67 kilometers of the banks of the River Rhine. In addition to structural flood protection such as retention areas, StEB provides floodwater management and ensures that the population is well informed about flood risk management activities in their area. More details with regards to flood risk management in Cologne are presented below.

Structural and mobile flood protection

Work carried out along 67 kilometers of the Rhine's banks enabled protection levels to be raised to that appropriate to a 1:100-year event, for the most part, and to a 1:200-year event in particularly critical areas. In addition, two retention areas were created for receiving and holding back the river water. The total cost for these measures was about US$ 600 million. Given that a flood level of a 100-year event would affect more than 150,000 inhabitants, the investment is considered as both effective and efficient.

For the structural measures, StEB sought a design concept that would be compatible with the city's appearance. For this reason, StEB conducted individual architectural competitions for the new flood pumping stations, and furthermore, Cologne's design advisory council, as well as individual citizens, took an active part in designing many flood protection installations. This aspect was also important to ensure that the new structures would be accepted among the citizens.

Photo 7.1: Pumping station in Cologne. Source: Peter Jost, pj-photography.de

A fundamental element of Cologne's new flood protection system is the 'mobile walls' (also termed demountable defenses) which, if necessary, can be deployed in less than 10 hours along a total length of 9.5 kilometers of riverbank within the city area. In total, 350 people drawn from StEB, THW (Germany's technical relief organization) and contractors are available for the loading, transportation and erection of the walls.

Figure 7.3: Raising and enhancing the existing flood protection with mobile walls. Source: Heinz Brandenburg, StEB

Flood management and risk prevention

Structural measures, including drainage systems, flood protection walls and dykes, together with the construction of bridges for flooded settlements, are important components of the city's flood protection strategy. These are complemented by measures improving both flood prevention and management of flood hazards. These approaches include management of traffic, setting up ferry services for flooded areas, and the provision of pumping deployments.

A flood protection center has also been formed to ensure that these management tasks can be achieved quickly and efficiently. The centre's activity is triggered whenever the Rhine reaches a level of 4.50 meters at the Cologne water gauge (KP). Citizens and others involved with flooding are kept informed of developments and of countermeasures both taken and yet to be taken, once levels reach this height. This is done via internet or telephone. In addition, a citizen's hotline is set up to answer questions directly.

If the river reaches a height of 7.5 meters, the Major Centre for Flood Protection, which includes all authorities, services and other relevant institutions, will take action. The Centre is responsible for coordinating and reconciling all measures between the involved agencies.

A constant flow of information and coordination of protection measures is essential for the Centre to perform its work. FLIWAS, the 'FLood Information and WArning System' which was first tested during a flood protection drill in 2009, enables the collection of all information relevant to a flood emergency. In its basic version, FLIWAS monitors water levels, communications, organizational, operational, and evaluation plans as well as providing testing and training.

To enable individuals to determine whether their property or residential area could be affected by flooding, risk maps are available on the internet. These maps show flood levels and how floods could spread in the affected area, including a comparison of developments with and without flood protection facilities. To make sure emergency personnel are well prepared, regular flood emergency drills take place. In addition, StEB conducts campaigns to raise the population's awareness to flood hazards and impacts, and also involves citizens through consultation with regards to structural measures.

Policy lessons

- StEB's approach considers the entire water cycle in all of their activities.
- The overall strategy is not focused on short-term targets but considers quality, overall economic viability and ecological sustainability.
- Response to flood risk is not focused only on structural protection measures but includes non-structural flood management and prevention activities.
- Policy makers were convinced of the necessity of implementing these flood protection measures only after the catastrophic flood events in 1993 and 1995 had caused damages of more than US$ 120 million.
- Information availability, such as the development of risk maps, is an issue which StEB prioritizes.

To most effectively manage all these activities, StEB carries out research and analysis of future challenges, including the possible impacts of climate change and the consequences of urban demographic shifts.

Sources: Brandenburg 2011. StEB nd.

7.5.3. Mozambique: Integrated flood management in Mozambique's cities and towns

Mozambique is located on the confluence of many major Southern African rivers including the Zambezi River and the Limpopo River. The country has been hit by 34 significant cyclones and four major flood events in 2000, 2001, 2007 and 2008.

Maputo, the capital of Mozambique, houses 45 percent of the total Mozambican urban population, 36 percent of which is considered to live below the poverty line. Recent data indicate increasing rural-urban migration, contributing to higher poverty and vulnerability levels. Throughout Mozambique, both urban and rural areas are at risk from flooding. However during the 2000 floods 70 percent of the lives lost were recorded in urban areas near to Maputo, mainly in the cities of Xai-Xai and Chokwe.

The Cahora Bassa Dam, together with the Kariba Dam in Zimbabwe, serves several Southern African nations as a dual purpose system which generates electricity and also helps to control river flow. Previous regular flooding of the river basin was much reduced by the controlling of the output from the dams. Although these dams are not primarily flood control mechanisms, their impacts on river flow clearly affects flood frequency and severity. Nevertheless, heavy rainfall in the region often raises the water level in the rivers thus increasing flood risk. In addition, many cities on or close to the Indian Ocean, including Maputo, are particularly vulnerable to sea level rise.

Flood risk mitigation efforts in Mozambique, and in Maputo in particular, involve multiple initiatives, with the majority of these being non-structural measures. A Disaster Risk Reduction (DRR) strategy which incorporates climate change concerns has been in place since 2003.

The National Institute of Disaster Management (INGC) is a government entity responsible for disaster prevention, response, and recovery. The institute is guided by a medium and long term 'Master Plan for Prevention and Mitigation of Disasters', which focuses on vulnerability reduction and strengthening the disaster preparedness of people living in areas highly exposed to natural hazards. Awareness-raising tools were introduced to local communities, through schools and government organizations, aimed at enhancing people's capacity to cope with flooding. In addition, field-testing activities for the implemented measures take place through the training of Local Disaster Management Committees, as well as simulation exercises.

Flood preparedness is also facilitated by an early warning system, coordinated by the National Directorate of Water, together with the National Institute of Meteorology and the National Disaster Management Institute. The system provides forecasts of flood risk; detects and monitors flooding; and issues flood warnings when necessary, paving the way for a coordinated response.

In 2003, UN-HABITAT produced a manual based on the concept of 'living with floods', and presented issues around water using simple and realistic ways: for example, showing simple adaptation measures for buildings and introducing a cards game (as illustrated in Figure 7.4). These recommendations were derived from real situations, easily recognizable by the local communities.

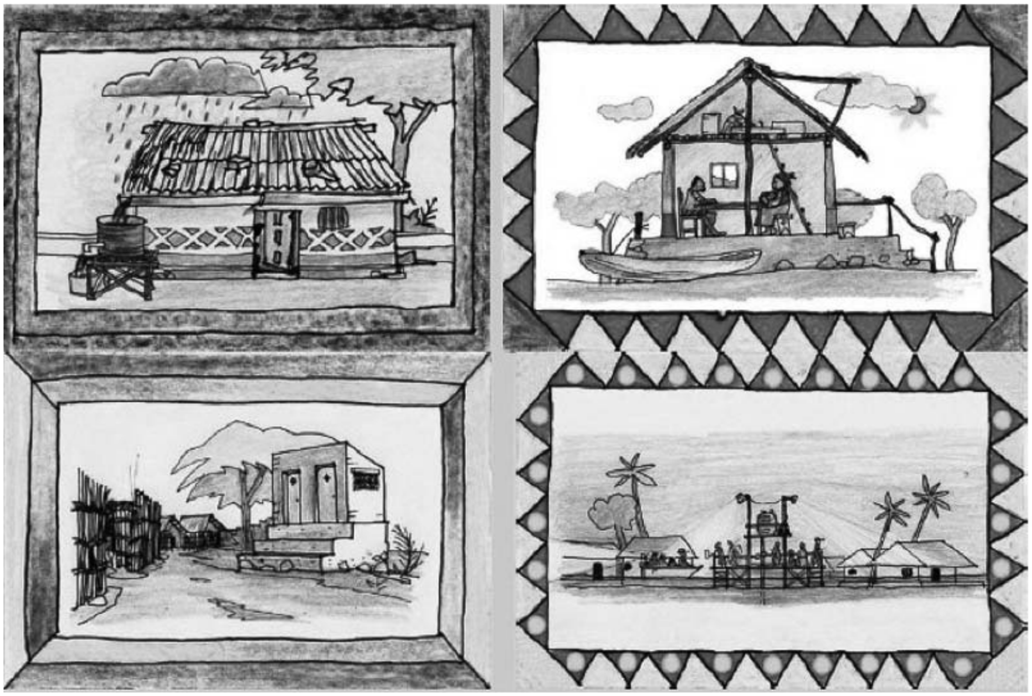

Figure 7.4: Examples from manual on 'living with floods' - rainwater harvesting, ideal house, elevated latrine, and supporting platform for temporary evacuation and protection of goods. Source: UN-HABITAT.

Other measures included the construction of flood resilient buildings: one example is in Ihangoma, a village located at the confluence of Zambezi and Shire Rivers, which experiences frequent flooding. The building serves as temporary refuge during floods but is otherwise used as a school or for other community services.

During the 2000 and 2001 flood events, despite the fact that some affected areas had land use plans, including measures to mitigate against erosion and landslides, these were often not followed or enforced. Insecurity of land and shelter tenure was also a major issue for flood-affected communities. GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) reported that some people refused to leave low-lying land, despite efforts to move them to safer locations. In response to this the United Nations Environment Program (UNEP), UN-HABITAT and the Government of Mozambique developed a project aimed at improving the security of land tenure in flood affected areas. This was approached through:

- Providing the necessary equipment for institutions to deal with land registration
- Improving the technical capabilities of relevant authorities to prepare maps of urban settlements affected by the floods

– Reviewing the legal and institutional framework with regards to land rights.

Urban drainage projects have also been carried out, including the construction of urban drainage channels, for example in the Mafalala district of Maputo and at the border of the Mafalala and Urbanização districts.

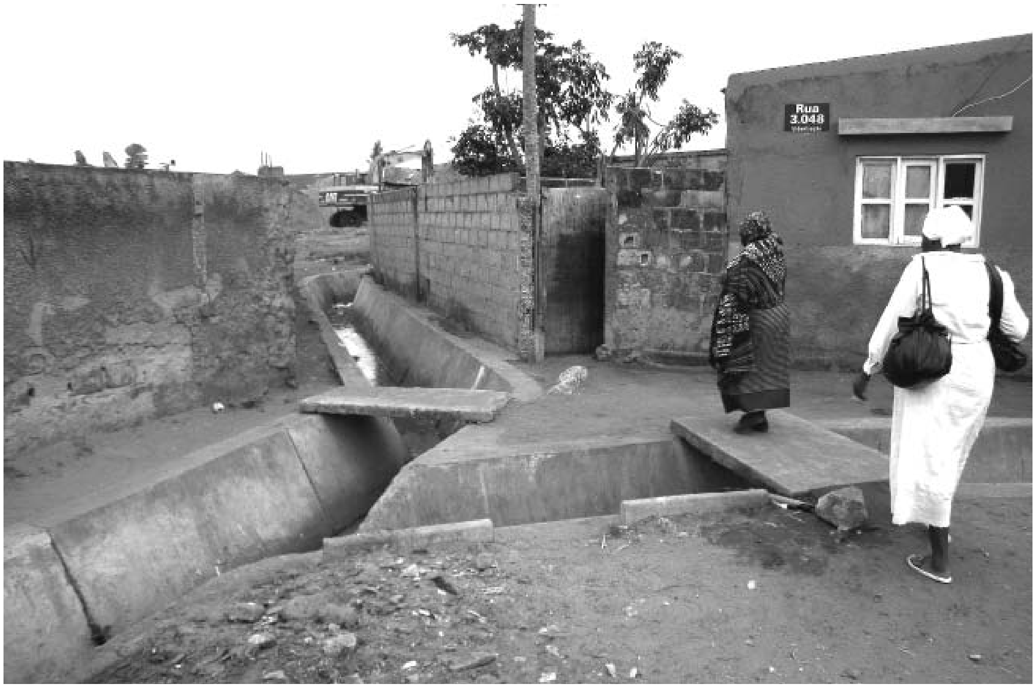

Photo 7.2: Drainage in Maputo Bairro Urbanização, Well-functioning drainage is very important for preventing that sanitary systems overflow during heavy rainfalls. Source Sustainable sanitation/Åse Johannessen

In 2010, however, despite the improved drainage system solid waste caused blockages resulting in flash flooding and necessitating emergency clearance of the drainage channels This happened despite the fact that the government implemented an improved citywide solid waste management system, financed by a 'garbage tax' levied upon electricity bills.

Policy lessons

– Following the Mozambique flood in 2000, the World Bank highlighted that consultation had improved the nature of the interventions, but participation leading to empowerment was rare

– Awareness-raising tools were introduced to local communities in order to enhance people's coping capacity. These tools were derived from real situations, easily recognizable by the local communities

– Construction of flood resilient buildings which can serve as temporary refuges during flooding, but otherwise used for other community services, is an innovative and cost-effective response to flood hazard risk

– Floods may expose problems of poor land management prior to a disaster.

Sources: ALNAP and Provention 2008; ADPC 2006 ; UN-HABITAT 2007; OCHA 2001; Hellmuth et al. 2007; Kruks-Wisner 2006; Magaia 2011; UNDP and ECHO 2010; UN-HABITAT n.d.

7.5.4. Indonesia: Flood management in Jakarta

Greater Jakarta is the political and economic centre of Indonesia. It has an estimated population of about 28 million and accounts for a quarter of the Indonesia's non-oil GDP. Jakarta is located in a flat low-lying fan-shaped region intersected by thirteen rivers originating from the mountains to the south. Around 40 percent of the city is between one to one and a half meters below sea-level. Every year, large parts of the city are flooded during the rainy season.

Floods were especially severe in February 2002 and February 2007. During the latter event, 36% percent of Jakarta was inundated with floods up to seven meters deep, causing over 70 deaths and displacing 340,000 people. In November 2007 rising sea tides created "little tsunamis" with gushing water inundating hundreds of houses in the low-lying neighborhoods in the northern part of the city. The floods in 2008 caused 30 deaths and shut down Jakarta's international airport for three days. Floods have caused severe disruption in the city: BAPPENAS, Indonesia's National Development Planning Agency, estimated the financial losses from the 2007 flood at US$900 million. However, the total socio-economic losses are significantly higher, and include loss of human life, health costs, labor and school days lost.

In the past few years, significant efforts towards flood mitigation have been undertaken which has resulted in a system of canals and polders (low lying areas that act as temporary storage) which discharge into the sea. In the future, it is expected that sea level rise, land subsidence and storm surges, due to unpredictable weather patterns, will cause even more disruption.

History of flood control measures

Previous flood control measures were installed to protect the main city areas to a design level of a 1:100 year flood. This resulted in the construction of two major floodways: the Western Floodway and Eastern Floodway. These channels were designed to intercept flood flows from all rivers before they entered lowland areas (the city area as it was at that time) and to convey the water directly to the sea. There are also sea walls protecting Jakarta from flooding from the sea.

The Western Floodway was planned as an extension of a previous floodway (constructed in 1924), which intercepted the Ciliwung, Cideng and Krukut rivers. The extension was designed to cope with the Grogol, Sekretaris and Angke rivers as well. It was completed in 1992 at a cost of around US$ 100 million mainly financed by Japan's ODA.

The objectives of the West Jakarta Flood Control System Project were:

- To construct the Sarinah/Thamrin Drainage Pumping Station and the Grogol/Sekretaris Interceptor in order to better control floodwaters in the west Jakarta region.
- Construction of the Cengkareng Floodway (non-ODA loan project).
- Repairs to Melati Regulating Pondage, Cideng Thamrin Waterway, and Krukut Waterway.
- Improvement of outlet works for Pluit Regulating Pondage.

Embankment improvement works were also added to the construction of the Sarinah/Thamrin Pumping Station, and this helped to improve the capacity of the drainage network for this region

The Eastern Floodway was designed to intercept all other remaining rivers (Cipinang, Sunter, Buaran, Jatikramat and Cakung) and to discharge to the Java Ocean. Conceived originally in 1973, the project commenced in 2002.

The objectives of the East Flood Canal Project were to:

- Excavate and construct a 23.57 kilometer canal, running from Cipinang in East Jakarta to Marunda in North Jakarta, discharging into the Java Ocean.
- The canal measures an average of 100 meters to 300 meters in width and 3.7 meters in depth.
- Canal flow capacity was designed to be 390 cubic meters per second.

The project was funded by the Jakarta administration and central government and has progressed very slowly due to the complicated process of land acquisitions. The project finally reached the sea on December 31, 2009, but there are still unfinished works in several spots. In the aftermath of the 2010 flood, the government planned to connect the Ciliwung River to Cipinang River (which is now intercepted by the East Flood Canal) to provide connection between the East and West Flood Canals.

The floodways were planned to contain 1:100-year floods (290–525 cubic meters per second) for the Western Floodway and 101–340 cubic meters per second for the Eastern Floodway. Areas located downstream of the two floodways were divided into six drainage zones covering about 240 square kilometers. Most of the land (about 150 square kilometers) with an elevation of less than two meters is considered as polder; the rest is treated as gravity drainage areas, with pumps and reservoirs releasing flood water from the polders. The existing old river channels were considered as primary drainage, and only designed to contain 1:25-year floods.

Evaluation of measures

The floodways have been judged to be partly effective in preventing flooding in Jakarta. According to records there were six major floods in the ten years prior to the construction of the Western floodway. However, in the ten years that followed the completion of the project in 1992 there were only two major floods, one in January and one in February of 1996. During this period there were no particular changes to weather patterns for Jakarta and the regions upstream, and there were still periods of very heavy rains in which more than 100 millimeters of precipitation fell in one day. Further, no other flood control projects were being conducted from the upstream regions to the project target area, and therefore it is apparent that this project made a major contribution to flood control.

However, other factors have ensured that flood risk remains high in Jakarta despite the completion of these structural projects.

Population pressures

Since 1980 the population of Greater Jakarta has doubled from 11.9 million to 28 million. Every year, due to rural-urban migration an estimated 250,000 people relocate to the city. Due to population pressures half of the city's small lakes (waduk) have been converted into residential or commercial areas, leading to severe reductions in retention capacity and increases in peak discharge. Jakarta's flood control systems are also adversely affected by weak enforcement of urban and spatial plans and building regulations, as well as uncontrolled abstraction of groundwater.

Insufficient maintenance and improper operation of flood control systems

The Ministry of Public Works (MoPW) and DKI (i.e. City of Jakarta administration) are responsible for maintaining flood control infrastructure. However, due to lack of financial resources the maintenance of the system is insufficient. This has resulted in huge sediment build-up in primary floodways and drains, reducing protection levels from 1:25 years to less than 1:5 years.

Limited coverage of solid waste collection services

The rapid population increase resulted in an increase in solid waste. DKI collects less than 40 percent of the solid waste generated, and about 15 percent of Jakarta's total solid waste (about 1,000 tons per day) is discarded into the city's canals. Waste water discharge into the canals adversely affects water quality and contributes to water-borne diseases.

Lack of coordination between authorities responsible for flood management

MoPW and DKI are responsible for managing Jakarta's flood control system. MoPW is responsible for floodways that cross provincial boundaries, while the Public Works Department of Jakarta is responsible for drains and retention basins within its boundaries. Nevertheless, MoPW do not adequately allocate financial resources to maintain floodways under its control, and as a result DKI needs to allocate its resources to maintain the floodways as well. In term of spatial planning, there is also a lack of coordination between regencies in Jabodetabek (Greater Jakarta). In the case of flooding, water resources planning and coordination within Jabodetabek become the key aspect that needs to be taken into account.

Land Subsidence

Recent evidence confirms that some areas of Jakarta are subsiding rapidly, with future minimum subsidence predicted to be five to 10 centimeters per year. This has resulted in an increased risk of coastal inundation and necessitated the construction of a new stretches of sea wall, as well as increasing the height of the existing defenses. Subsidence also results in lowering reduction of clearances of structures over the canals (such as bridges) which also obstruct flows. Recent study conducted by DKI shows that subsidence in Jakarta is mainly caused by deep ground water extraction; in addition the load of structures and tectonic activities also contributes to the sinking of the city.

Jakarta Comprehensive Flood Management

Further flood control and mitigation projects are planned covering the whole spectrum of structural and non-structural measures. Some of these projects are regarded as urgent while others are longer term and are now the subject of extensive risk assessment and scenario evaluation. For example, the speed of construction of an elevated toll road to the airport was increased, in order to safeguard its accessibility. The scheme is designed to use the expected revenue from the tolls to finance the construction of the flood protection. Figure 7.5 below shows the range of existing and planned activity regarding Flood Risk Management in Jakarta.

Major initiatives include the Jakarta Urgent Flood Mitigation project/Jakarta Emergency Dredging Initiative Project (JUFMP/JEDI Project), Jakarta Coastal Defense Strategy and the Jakarta Comprehensive Flood management plan which are tackling flood risk respectively within the city, upstream of the city and at the city-coastal interface. Other more local initiatives are also cutting across these strategic projects and tackle issues such as waste management and ecological issues.

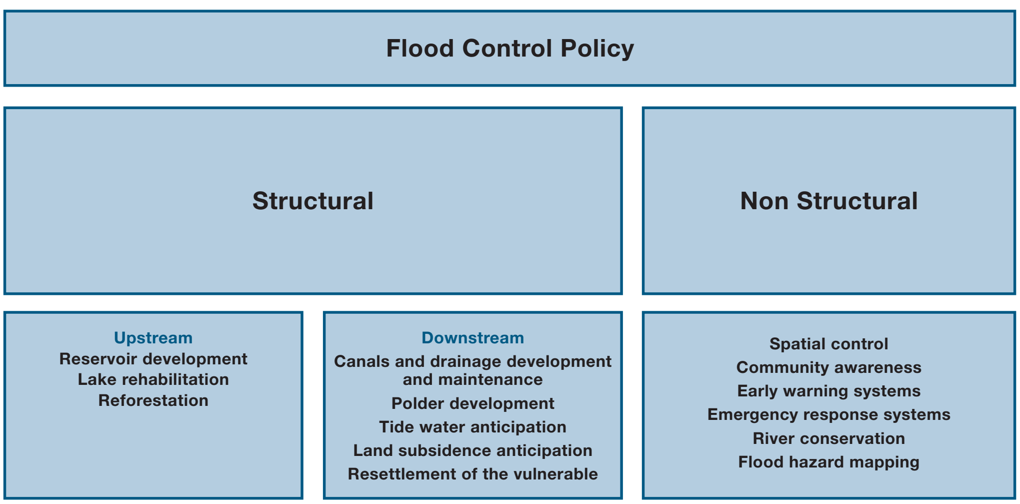

Figure 7.5: Flood control policy elements for Jakarta.

Jakarta Urgent Flood Mitigation Project/Jakarta Emergency Dredging Initiative (JUFMP/JEDI Project)

The objective is to improve the operation and maintenance of priority sections of Jakarta's flood management system. There is also a need to upgrade the management information systems and early warning systems, and to introduce a scheme for safe disposal of dredged material using a combination of sorting, disposal in land reclamation sites and a licensed hazardous waste disposal facility. The project is run by Central Government (Ministry of Public Works) and DKI Jakarta supported by the World Bank. Challenges with resettlement and the need to conduct open and transparent consultations and negotiations over compensation and redress have delayed the program which is now planned to start physical works in early 2012.

Jakarta coastal defense strategy

This project is aimed towards building flood risk strategy which can protect Jakarta, in the long term, from the dual impact of sea level rise and land subsidence. Short term coastal defense is also re-evaluated in the study. In the short term, urgent coastal defense actions include new and heightened seawalls and redesign of coastal pumps and gates. These will need to continue. At the same time, long term climate projections and the expected impact of continued groundwater extraction are combined to give scenarios of future flood risk. Options have been identified as suitable to mitigate future flooding under various climate and subsidence conditions. As these include major offshore coastal defenses, groundwater controls and the building of new and larger retention areas in the city, all of the options identified will require preparation or lead time. Therefore the project aims to provide a clear direction as to the transition triggers from one future defense strategy to the other, in terms of sea level and the subsidence actually observed.

Photo 7.3: Scavenging on Jakarta's Waste. Photo from JUFMP/JEDI, Source: WB/Asnaap

Jakarta Comprehensive Flood Management.(JCFM): The Project for Capacity Development of Jakarta Comprehensive Flood Management

This JICA-funded project includes facilitating the implementation of the Zero delta Q policy – that construction of new buildings should not result in increased water discharge (Government regulation 26 on national spatial planning). This is only possible with a comprehensive plan involving cooperation between upstream and downstream areas and including zoning of areas, construction of infiltration measures to recharge groundwater and regulations on upstream areas to solve a downstream problem. The project will build on existing catchment wide modeling of run off to design a sustainable system of run-off allocation.

Insurance schemes – Insurance is available for flooding in Indonesia. However in the aftermath of a major flood event in the city it is sometimes difficult and expensive to obtain. A micro-insurance scheme was designed to offset the cost of flood damage for the poor in Jakarta. However this innovative product was discontinued as the cost of the policy was too high. Adequate risk financing for Jakarta is an area where more effort may be directed.

Community based FRM initiatives includes:

- Pilot projects in canal and gutter cleaning services and solid waste management, producing marketable products such as organic compost.
- Flood preparedness training.
- Practical handbook for the community.

Capacity building to prevent and manage future flooding also includes:

The provision of an integrated waste management facility. Located in Bantar Gerbang and Ciangir Tangerang, this will divert municipal solid waste from Jakarta.

Waste management and recycling schemes

Community flood early warning system in Kebon Baru. This project strengthens the existing Jakarta wide Flood Early Warning System for local action. This includes the corroboration of flood warnings by local wardens using flood warning poles.

Dashboard Jakarta: is an innovative pilot project looking at the way in which meteorologically based forecasts of flooding can be combined with local intelligence via social media such as Facebook and Twitter to provide a mobile application suitable for alerting the residents and managers of Jakarta about upcoming and existing patterns of flooding in the city.

Mangrove Plantation recovery program

Groundwater extraction controls - are being introduced slowly, as cutting off all extraction would leave large parts of the population without any supply. Tariffs for hotels and businesses have been increased in line with piped water prices.

Policy lessons

- Past structural measures have reduced risk but significant residual risk remains
- A diverse approach including non structural and structural measures is necessary
- Urbanization and land subsidence are more urgent issues for Jakarta than future sea level rise
- It is a challenge to implement a truly integrated approach given that at least 30 organizations have been involved in recent studies and projects.
- Experience shows that it is not easy to scale up community-based activities to a city scale. Some examples of best practice at a local level could be spread more widely around the city,
- The experience of previous structural projects demonstrate that, in a megacity such as Jakarta, the scale of city-wide projects to install

structural measures suffer from very long lead in times. Forward planning needs to be flexible and incorporate scenario testing as in the JCDS.

– On the other hand, an even more comprehensive integrated solution combining downstream, midstream and upstream retentions would be more effective in order to anticipate possible intense rainfall within this large catchment, subsidence along the coast, and sea level rise.

Sources: Mercycorps (2011); Handhayani (2009); Fook Chuang Eng (2011); Brinkmann (2011); Nasir, H. 2008, Rukmana 2010.; Haryanto, U. (2009); Jakarta Post, the (2003). Japan International Cooperation Agency (JICA). World Bank (2008); Tucci (2009); WHO (2007); BAPPENAS;

7.6. Final remarks

This guide has addressed the challenge of integrated flood risk management to prevent and recover from large and increasing flood risk in urban areas. Living with flood risk is a devastating reality for a large and growing number of people in the world, but it is not the only or even the most urgent challenge which they face day to day. There are many reasons that may result in the priority of flood risk management being ignored in favor of more immediate demands. There are financial, practical and psychological factors that come into play here, including the common perception that flooding will not happen.

As the guide advocates an integrated approach to flood risk management, it follows that in a successful system, flood risk awareness, perception and good practice will be high. Moving from the current situation to the integrated ideal will often involve a painful process necessitating changes of mindsets and motivations for multiple stakeholders, and the balancing of their relative needs and priorities. The benefits of the integration of flood risk management into wider urban management, urban planning and climate change adaptation are clear but there are also dangers involved when flood management becomes subsumed as part of a larger role and there has not been a flood for a while.

Flood risk management therefore needs champions at the city, regional, national and international level in order for it to be brought to the table, as appropriate, in major developmental decision making processes. Issues with a strong champion in a position of influence tend to be more successfully addressed in general

(Bulkeley et al. n.d.). For an often high impact, low frequency risk like flooding, the need for advocacy is even more critical. A body with an oversight role is also helpful, as is the timetabling of regular reviews of national disaster, emergency, resilience and adaptation planning if the consideration of flood management is embedded in those plans.

It must be recognized that even repeated awareness campaigns, flood warnings and general advice will not always engender actions. Inertia is common to institutions and populations at risk and the situation is made worse by the future uncertainty which is perceived to dominate decisions in this area. The most successful long-term flood risk management strategies will balance the implementation of short-run, quick gain, non- structural measures with a vision of the best suite of structural and non- structural measures to be implemented for the longer term. Understanding the required resources, the best and worst case scenarios and the tipping points at which action becomes imperative, rather than justified, can lead to better decisions. In addition acknowledging those actions which will simply never be feasible can help in producing real practical solutions day to day.

As the case studies in this volume reveal and research has often shown, concerted effort and financing applied towards flood risk reduction is often only triggered after a major flood event – and for a relatively short time afterwards. Other opportunities to make significant investment can arise through less reactive and more proactive initiatives such as urban regeneration projects, flagship buildings or climate adaptation programs (Bulkeley et al. 2009). A change of administration, international agreements or major disasters elsewhere can also spark initiatives. Global networks such as city associations or even the potential for investment by global international businesses can create impetus and funding streams.

Whatever the source of the window of opportunity, the timescale to plan and implement change on the back of heightened awareness is generally short. Conversely the best practice in relation to evaluating options, undertaking consultations and stakeholder engagement has a relatively long lead time. Having the vision for integrated flood risk management in place in advance of when circumstances for change are favorable can be a factor in successfully exploiting any such opportunity as it arises.

7.7. References

ALNAP and Provention. 2008. "Learning from previous relief and recovery operations."

ADPC (Asian Disaster Preparedness Center). 2006. "Integrated Flood Risk Management in Asia." ADPC

Brandenburg, H. 2011. *Cologne Flood Prevention*. Presentation in the BBL on the River Flood Protection Experience from the City of Cologne. Washington DC. USA. 19 July 2011.

Brinkmann, J. J. 2011 " Towards a public-private partnership for the coastal development and protection of Jakarta" Urban resilience workshop May 26, 2011, Jakarta.

Bulkeley, H., Schroeder, H., Janda, K., Zhao, J., Armstrong, A., Chu, S. Y and Ghosh, S. 2009. Cities and Climate Change: the role of institutions, governance and urban planning. Report prepared for the World Bank Urban Symposium on Climate Change. University of Durham and Oxford.

Fook Chuang Eng 2011 "Jakarta Urgent Flood Mitigation Project" (JUFMP). Urban resilience workshop May 26, 2011 Jakarta.

Halcrow. 2011. Buenos Aires drainage master plan. Available online: http://www.halcrow.com/Our-projects/Project-details/Buenos-Aires-drainage-masterplan/.

Handhayani, S., 2009 "Ciliwung - Jakarta: Delta Dialogue From Fighting Floods to Living in Harmony with Water" Aquaterra Second Forum on Delta & Coastal Development Amsterdam, 10-12 February 2009.

Haryanto, U. 2009. "East Flood Canal Finally Reaches Jakarta Bay." The Jakarta Post

Hellmuth, M. E., Moorhead, A. and Williams, J. 2007. *Climate risk management in Africa: Learning from practice*. The International Research Institute for Climate and Society (IRI).

Jakarta Post, the. 2003. "Special team proposed for East Flood Canal project." Jakarta Post

Kruks-Wisner, G. 2006. "After the Flood: Crisis, Voice and Innovation in Maputo's Solid Waste Management Sector." Massachusetts Institute of Technology (MIT).

Magaia, S. 2011. *Didactic Tools: A Fundamental Part of the Strategy for Vulnerability*

Reduction in Mozambique. Presentation in the Preparation of a Global Handbook for Urban Flood Risk Management Workshop, Accra, Ghana 17-18 May 2011.

Mercycorps (2011) presentation Jakarta workshop

Nasir, H. 2008. , "Flood since Batavia until Jakarta (1614-2008) problems and solutions. Available from http://www.eu-changde.com/english/download.asp

OCHA. 2001. "Mozambique Floods 2001 – Lessons Learned" Workshop 26-27 July 2001 Beira. Summary Report produced by the Office of the United Nations Resident Coordinator Maputo.

Rukmana, D., 2010. "Jakarta Annual Flooding in February 2010." Indonesia's Urban Studies.

StEB. Nd. *Your professional partner for wastewater, water management and flood protection*. The Stadtentwässerungsbetriebe Köln, AöR, (StEB).

Tucci C. 2009 "LAC Water Bean Retreat." PowerPoint Presentation February 12, 2009 , World Bank.

UNDP and ECHO. 2010. *Community-Based Best Practices for Disaster Risk Reduction*. Prepared under the United Nations Development Programme (UNDP) and the European Commission Humanitarian Office (ECHO) through the Disaster Preparedness Programme (DipECHO).

UN-HABITAT. n.d. "Scoping Report: Addressing Land Issues after Natural Disasters." Available from http://www.gltn.net/images/stories/downloads/utf-8nat_disaster_scoping_paper_jan_08.pdf.>

UN-HABITAT. 2007. *Enhancing urban safety and security: global report on human settlement*, London, Earthscan.

World Bank 2008. "Project Information Document (PID). Concept Stage." WB Report No.: AB4043.

World Bank. 2007. "Flood Management in Jakarta: Causes and Mitigation" February 2007. World Bank.

World Bank 2005 Argentina Urban Flood Prevention and Drainage Project Project Information Report, Appraisal Stage No.: AB1399

World Bank. 2006. Argentina - Urban Flood Prevention and Drainage Project. Project Appraisal Document. Report Number: 34001.

WHO (World Health Organization). 2007. "Emergency Situation Report No. 6." 19 February 2007.

Abbreviations

ACCCRN	Asian Cities Climate Change Resilience Network
ADPC	Asian Disaster Preparedness Center
ADRC	Asian Disaster Reduction Centre
AEP	Annual Exceedance Probability
AfDB	African Development Bank
AIP	Annual Investment Program
ALARP	As Low As Reasonably Practical
ALERT	Automated Local Evaluation in Real Time
ALPHALOG	L'Association Libre pour la Promotion de l'Habitat et du Logement
AR4	Fourth Assessment Report (of the IPCC)
ASP	Alandur Sewerage Project
BAPPENAS	Indonesia's National Development Planning Agency
BCPR	Bureau of Crisis Prevention and Recovery
BCR	Benefit Cost Ratio
BDCCs	Barangay Disaster Coordinating Councils
BGCP	Business and Government Continuity Plan
BMP	Best Management Practices
BMTPC	Building Materials and Technology Promotions Council
BOM	Bureau of Meteorology (Australia)
BOQ	Bill of Quantities basis (contractual term)
BOT	Build, Operate and Transfer basis (contractual term)
CBA	Cost Benefit Analysis
CBDRM	Community Based Disaster Risk Management
CBO	Community Based Organization
CDERA	Caribbean Disaster Emergency Response Agency
CFMC	Community Flood Management Committee
CIDA	Canadian International Development Agency
CPNI	Centre for the Protection of National Infrastructure

CRED	Centre for Research on the Epidemiology of Disasters
CWC	Central Water Commission (India)
DaLa	Damage Loss Assessment methodology
DFID	Department for International Development (UK governmental body)
DGPC	Algerian Civil Protection Agency
DGPS	Differential Global Positioning System
DipECHO	Disaster Preparedness Programme of the European Commission's Humanitarian Aid department
DRF	Data Request File
DSC	Data Storage Centre
DSM	Digital Surface Model
DSS	Decision Support System
DST	Decision Support Tools
DTM	Digital Terrain Model
DWF	Development Workshop France
ECHO	EU Humanitarian Aid Department
EFFS	European Flood Forecasting System
EM-DAT	Emergency Events Database
EPM	Environmental Planning and Management
EROS	Earth Resource Observation System
ESA	European Space Agency
EWS	Early Warning System
FAO	Food and Agriculture Organisation of the UN
FEMA (US)	Federal Emergency Management Agency
FEWS	Flood Early Warning System
FMU	Flood Management Unit
FRM	Flood Risk Management
GCM	Global Climate Models
GDIN	Global Disaster Information Network

GDP	Gross Domestic Product
GDPFS	Global Data Processing and Forecasting System
GFDRR	Global Facility for Disaster Reduction and Recovery
GHGs	Greenhouse Gases
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GLOF	Glacial Lake Outburst Floods
GNP	Gross National Product
GOY	Government of Yemen
GPS	Global Positioning System
GUI	Graphical User Interface
GWP	Gross World Product
HEC-RAS	Hydrologic Engineering Centers River Analysis System
HEPS	Hydrological Ensemble Prediction Systems
ICHARM	International Centre for Water Hazard and Risk Management
IFMS	Integrated Flood Management Strategy
IFRC	International Federation of Red Cross and Red Crescent Societies
IIRS	Indian Institute of Remote Sensing
ILWIS	Integrated Land and Water Information System (a software package from ITC)
INGC	National Institute of Disaster Management (Mozambique)
IOC	Indian Ocean Commission
IP-CCTV	Internet-protocol closed-circuit television
IPCC	Intergovernmental Panel on Climate Change
IRIN	Integrated Regional Information Networks
IUCN	International Union for Conservation of Nature
IWPDC	*International Water Power and Dam Construction* (periodical title)

KBMS	Knowledge Based Management System
KDRRI	Kailali Disaster Risk Reduction Initiatives
LGU	Local Government Units
LID	Low Impact Development
LIDAR	Light Detection And Ranging
MBES	Multi Beam Eco-Sounder Surveying
MBMS	Model Base Management System
MCA	Multi Criteria Analysis
MDGs	Millennium Development Goals
MFI	Market-based Financial Institution
MMDA	Metropolitan Manila Development Authority
MRC	Mekong River Commission
NADI	GFDRR funded IFM project in the Philippines
NASA	National Aeronautics and Space Administration
Nat-CatSERVICE	Munich Re database of natural catastrophe losses and associated services
NATMO	National Atlas and Thematic Mapping Organization
NFIP	National Flood Insurance Program (USA)
NFIs	Non Food Items
NGO	Non Governmental Organization
NHWC (US)	National Hydrologic Warning Council
NMHS	National Meteorological and Hydrological Services
NOAA (US)	National Oceanic and Atmospheric Administration
NSIDC (US)	National Snow and Ice Data Centre
NWS (US)	National Weather Service
O and M	Operation and Maintenance
OECD	Organisation for Economic Co-operation and Development
Ofwat	Official body regulating water and sewerage providers in England and Wales
ORT/ORS	Oral Rehydration Therapy/Oral Rehydration Salts
PDNA	Post Disaster Needs Assessment

Periperi	Partners Enhancing Resilience to People Exposed to Risk (South Africa)
PLA	Participatory Learning and Action
PPP	Public-Private-Partnership(s)
PRA	Participatory Rural Appraisal
PREDES	Network for social studies on disaster prevention in Latin America
PROMISE	Program for Hydro-Meteorological Disaster Mitigation in Secondary Cities in Asia
PROSAM	Sanitary program of Brazil
PTSD	Post Traumatic Stress Disorder(s)
PWRI	Public Works Research Institute (Japan)
RCM	Regional Climate Model
RTK-GPS	Real Time Kinematic GPS
SAR	Synthetic Aperture Radar
SFM	Stream Flow Model (S Africa)
SHOALS	Scanning Hydro-Graphic Operational Airborne LIDAR Survey
SINAGER	Sistema Nacional de Gestion de Riesgos
SMART	Stormwater Management and Road Tunnel
SRES	Special Report on Emissions Scenarios (of the IPCC)
StEB	Group of Municipal Drainage Operations Cologne (Stadtentwässerungsbetriebe Köln)
SUDS	Sustainable Urban Drainage Systems
SWAN	Simulating Waves Nearshore
TE2100	Thames Estuary 2100 project (UK)
TFP	Total Factor Productivity
TRCA	Canadian flood forecasting system (Toronto and region Conservation)
UN-ECLAC	UN Economic Commission for Latin America and the Caribbean
UN-HABITAT	United Nations Human Settlements Programme

UNCHS	Also known as the UN-Habitat organization
UNDHA	United Nations Department of Humanitarian Affairs
UNEP	United Nations Environment Programme
UNEP/SEI	United Nations Environment Programme/Stockholm Environment Institute
UNFCCC	United Nations Framework Convention on Climate Change
UNOCHA	UN Office for the Coordination of Humanitarian Affairs
UNOSAT	UNITAR'S Operational Satellite Applications Programme
UNISDR	UN International Strategy for Disaster Reduction
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USVI	United States Virgin Islands
VSL	Valuation of a Statistical Life
WASH	Water Supply, Sanitation and Hygiene promotion
WDR	*World Development Report*
WGCCD	Working Group on Climate Change and Development
WHO	World Health Organization
WMO	World Meteorological Organization
WRC	Water Resources Commission (Ghana)

Glossary

Actuarial: pertaining to statistical computations, such as those used for mortality rates and insurance calculations

Algal bloom: (or marine bloom or water bloom) is a rapid increase in the population of algae in an aquatic system; may be of concern as some species of algae produce neurotoxins

Aquifer: an underground bed or layer of permeable rock, sediment, or soil that yields water.

Attenuation: reducing the peak of flood flow, typically by slowing discharge rate (via storage in ponds, balancing lakes or similar)

Barnier Law/Barnier funds: special valuation scheme for flood-prone and flood-damaged properties found in French legislation

Bioaccumulation: the accumulation of substances, such as pesticides, or other organic chemicals in an organism

Biomass: biological material derived from living, or recently living organisms. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material

Bourn(e): stream or brook that only flows for part of the year

Cadastral Map: map showing registered property with ownership, tenure, precise location, dimensions (may include GIS coordinates) and values etc – eg UK Land Registry records. (Alternate spellings of root word include 'cadaster' and 'cadastre')

Catchment: see Watershed

Coping Capacity: the means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster. In general, this involves managing resources, both in normal times as well as during crises or adverse conditions. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and human induced hazards

Culvert: covered channel, or large pipe, to convey water below ground level (for example, under a road, railway or urban area, also beneath a building or other structure)

Disdrometer: instrument used to measure the drop size distribution and velocity of falling precipitation (rain, hail, snow, sleet)

Downstream: that part of a channel nearer to the sea than the reference point; travelling with the normal direction of flow

Ex ante flood measures: actions taken in advance of flooding (to prevent damage occurring)

Ex post flood measures: actions taken after flooding has occurred (eg to mitigate damage, prevent further damage occurring)

Exposure: people, property, systems, or functions at risk of loss exposed to hazards

Filter strip: gently sloping area of vegetated land, delaying and reducing stormwater peaks, and trapping pollutants and silts

Floodplain: area of nearly flat land bordering a river that is partly, or wholly, covered with water during floods

Gabion: container made of wire, plastic mesh (or similar material), filled with stones, used to form retaining wall or provide protection against scour

Geotextile: permeable fabric (synthetic or natural) used in conjunction with soil for the function of filtration, separation, drainage, reinforcement or erosion protection

Giorgi regions: sub-continental regions of the world as defined by Giorgi and Francisco (2000):

A: Australia

B: Amazon Basin

C: Southern South America

D: Central America

E: Western North America

F: Central North America

G: Eastern North America

H: Alaska

I: Greenland

J: Mediterranean Basin

K: Northern Europe

L: Western Africa

M: Eastern Africa

N: Southern Africa

O: Sahara

P: Southeast Asia

Q: East Asia

R: South Asia

S: Central Asia

T: Tibet

U: North Asia

Giorgi, F. and Francisco, R. 2000. “Uncertainties in regional climate change prediction: a regional analysis of ensemble simulations with the HADCM2 coupled AOGCM.” Clim. Dyn. 16: 169-182.

Groundwater: water that collects or flows beneath the Earth’s surface, filling the porous spaces in soil, sediment, and rocks. Groundwater originates from rain and from melting snow and ice and is the source of water for aquifers, springs, and wells. The upper surface of groundwater is the water table.

Groyne: wall or embankment built out from the coast, or a river bank, to inhibit erosion of the shore or river bank (and in some cases to encourage accretion)

Hazard: an act or phenomenon that has the potential to produce harm or other undesirable consequences to some person or thing

Internally displaced persons (IDPs): someone who is forced to flee his or her home but who remains within his or her country’s borders (sometimes incorrectly termed refugees)

Kabari: scrap dealer (term used in Pakistan)

Kanungkong: a bamboo instrument traditionally used to call community members to assemble, to alert people or call children home, now used for flood early warning system as well (term used in Philippines)

Levee: an embankment raised to prevent a river from overflowing.

Meander: natural process of deviation of a river or stream from a straight course, in which silt is deposited on the inside of the bend (accretion) and erosion occurs on the outside

Mitigate/mitigation: the use of reasonable care and diligence in an effort to minimize or avoid injury; to take protective action to avoid additional injury or loss

Polder: regions of land that are inundated when the capacity of the soil to absorb water is saturate

Rainwater harvesting: accumulating and storing rainwater for reuse before it reaches the aquifer

Re-profiling (of a river bank, or embankment): change the degree of slope (for example, to make a flood bank flatter and more stable)

Resilience: the capacity that people or groups may possess to withstand or recover from emergencies and which can stand as a counterbalance to vulnerability

Return period: average interval of time between years in which events occur that equal, or exceed, a given magnitude

Riparian owner: owner of land bordering a watercourse; may have legal rights and responsibilities relating to water flow or water quality because of this

Riparian: land bordering a watercourse

Risk: the probability of harmful consequences or expected losses resulting from a given hazard to a given element at danger or peril over a specified time period

River Basin: see 'Watershed'

Scour(ing): erosion resulting from the shear forces associated with flowing water and wave action (typically river bed scouring downstream of structures such as bridges or outflow pipes)

Seiche: standing wave in an enclosed or partially enclosed body of water

Soakaway: depression into which surface water percolates

Staff gauge: graduated scale placed in a position so that the surface level of a water body relative to a fixed point (eg sea level) can be read off

Sustainability: forms of progress that meet the needs of the present without compromising the ability of future generations to meet their needs

Swale: grass-lined channel which allows the infiltration, storage and conveyance of stormwater

Swale: low-lying depression or 'ditch' typically in moist/marshy area; does not convey water, but allows it to be absorbed by the ground (infiltrate) gradually

Tahsil: administrative divisions (term used in some areas of Asia especially parts of India)

Tributary/tributaries: smaller watercourse(s) joining a larger one, thus adding to total flow (the meeting point is a 'confluence')

Upstream: that part of a channel nearer to the source of the watercourse than the reference point; travelling opposite to the normal direction of flow

Urban heat island effect: urban areas are significantly warmer than the surrounding rural areas; temperatures can vary across a city depending on the nature of the land cover, such that urban parks and lakes are cooler than adjacent areas covered by buildings

Vulnerability: the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard

Wadi: a dry channel except in the rainy season/winter season (North African regional term)

Watershed: is an extent, or an area of land, where surface water from rain and melting snow, or ice, converges to a single point, usually the exit of the basin, where the waters join another waterbody (such as a river, lake, reservoir, estuary, wetland, sea, or ocean). Other terms include catchment area, catchment basin, drainage basin, drainage area, river basin and water basin

Note: technical definitions derived from CIRIA 2002. C551 Manual on scour at bridges and other hydraulic structures. London: CIRIA.

ECO-AUDIT

Environmental Benefits Statement

The World Bank is committed to preserving endangered forests and natural resources. The Office of the Publisher has chosen to print *Cities and Flooding* on recycled paper with 50 percent postconsumer fiber in accordance with the recommended standards for paper usage set by the Green Press Initiative, a nonprofit program supporting publishers in using fiber that is not sourced from endangered forests. For more information, visit www.greenpressinitiative.org.

Saved:

- 60 trees
- 25 million BTUs of total energy
- 6,125 pounds of net greenhouse gases
- 27,619 gallons of waste water
- 1,750 pounds of solid waste

green press INITIATIVE









Urban flooding is a serious and growing development challenge. It is a global phenomenon which causes widespread devastation, economic damages and loss of human lives. *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century* provides forward-looking operational assistance to policy makers and technical specialists in the rapidly expanding cities and towns of the developing world on how best to manage the risk of floods. It takes a strategic approach, in which appropriate risk management measures are assessed, selected and integrated in a process that both informs and involves the full range of stakeholders.

ISBN 978-0-8213-8866-2

SKU 18866