ASSOCIATED PROGRAMME ON FLOOD MANAGEMENT

SELECTING MEASURES AND DESIGNING STRATEGIES FOR INTEGRATED FLOOD MANAGEMENT

A GUIDANCE DOCUMENT

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WEATHTER CLIMATE WATER

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ASSOCIATED PROGRAMME ON FLOOD MANAGEMENT

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To the reader

The Guidance Document *Selecting Measures and Designing Strategies for Integrated Flood Risk Management* is based on available literature and draws findings from relevant works wherever possible. The publication is considered as a resource guide/material for practitioners and not an academic paper. References used are mostly available on the Internet and hyperlinks are provided in the References section.

This publication is a "living document" and will be updated based on sharing of experiences with its readers. The Associated Programme on Flood Management encourages disaster managers and related experts engaged in management of flooding around the globe to participate in the enrichment of this guidance document. For this purpose, comments and other inputs are cordially invited. Authorship and contributions would be appropriately acknowledged. Please submit your inputs to the following email address: floodmanagement@wmo.int under Subject: *"Selecting Measures and Designing Strategies for Integrated Flood Risk Management".*

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A | Need for integrated flood management

1 Floods are the most common natural disaster with the largest impacts on society. Flood-impact records show that the number of flood fatalities is gradually decreasing, thanks, among others, to better early warning, although incidental devastating (coastal) floods may distort this trend. Flood damage, however, appears to be increasing because of insufficient attention to prevention, economic growth and lack of flood-sensitive land-use planning.

2 Integrated flood management **(IFM)** aims to maximize the productivity and efficient use of floodplains and coastal zones, while minimizing the loss of life and impact on livelihoods through protective measures. Absolute protection from flooding, however, is impossible. In planning for IFM, therefore, there is a need to decide what level of risk is acceptable, to decide how safe is safe enough.

3 Risk-informed decision-making on flood hazards is a key element of IFM. It comprises decision-making based on estimates of flood risk, as well as costs and benefits of flood mitigation and management. The approach looks for a "proportionate" response to risk, as well as a transparent process of estimating the risk and assessing the impacts of measures.

B | Planning for integrated flood management

4 Planning for IFM is approached as an iterative process towards risk-based decision-making. To this end, this guidance document presents a framework for policy analysis and planning to guide the steps of IFM. The framework reflects the policy cycle and consists basically of four steps which are to be followed in an iterative way: not only within one planning cycle, but also over the years to come.

5 Reaching agreement on problem assessment and policy objectives is the key to successful planning. That is why stakeholder engagement and communication through a process of joint fact-finding and decision-making are at the core of the framework.

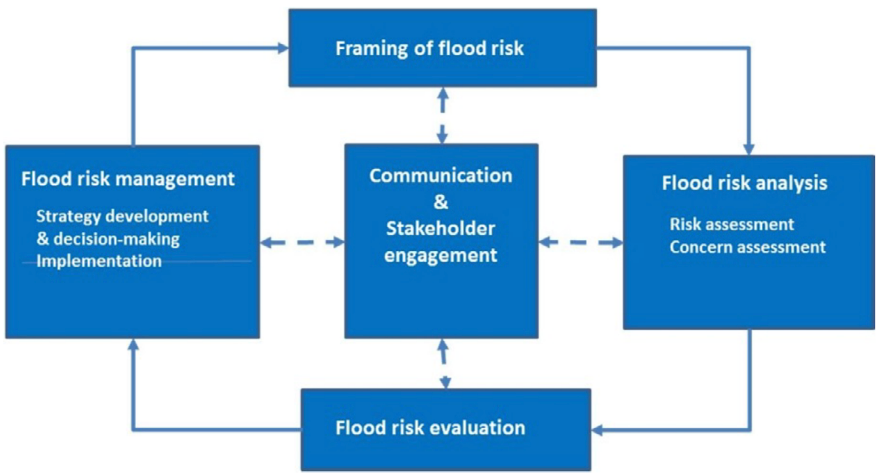

Figure 1 — Framework for integrated flood management

6 Floods vary in their extent and occur at irregular intervals. No two floods are the same. Development of a well-balanced strategy for IFM should start with a proper understanding of the flood risk: not only examining the characteristics of past floods but also looking into possible future situations.

7 Effective measures for reducing flood risk will be location-specific; there is no single solution for all flood problems. A variety of measures (a strategy) will be required to reduce flood risk to a societally agreed upon, acceptable level. Alternative strategies for IFM that outline how flooding can be managed for a particular region can inform such decisions.

C | Development of strategies

8 There is no general recipe for a successful development of strategies to reduce exposure to flood risk. Nevertheless, there are a few factors which will contribute to a successful development of IFM strategies.

9 It is important to base the development of strategies on a shared vision on regional development, which integrates flood risk with economic development and environmental sustainability. Embedding strategies in a vision for regional development will help to link the strategy to investment agendas from different fields, both public and private. The process of developing a successful strategy should be a blend of "top-down" and "bottom-up" approaches. A top-down approach will produce a strategic framework of coherent strategies, whereas a bottom-up approach will enhance stakeholder engagement and promote local linkages to other policy domains, such as urban development, nature restoration, etc. Linking the IFM strategy to the Sustainable Development Goals (SDGs) and the Sendai Framework for Disaster Risk Reduction will facilitate implementation of a strategy and provide added value to society.

10 The development of strategies should cover the full range of possible measures, including protection and mitigation measures, planning and building codes, emergency management, raising of risk awareness and preparedness, risk sharing, etc. Strategies to be developed should comprise a well-balanced mix of both structural and non-structural measures, including measures which can be implemented in the short term.

11 The development of strategies should take account of the many uncertainties associated with the development of basins or coastal regions. Adaptive flood-risk management encourages a flexible approach to increase resilience and limit the risk of over- or underinvestment. Integrated Flood Management can be viewed as an autonomous adaptation strategy to climate change and increased climate variability. "Green infrastructure" may contribute to the development of sustainable strategies for IFM, enhancing the capacity of natural systems to adapt to climate change through natural processes, enhancing the resilience of these systems.

D | Scope of this publication

12 This publication outlines the approach and steps to develop and evaluate well-balanced and well-motivated strategies to cope with the risk of floods. It starts with a few perspectives on flood risk and policy development which set the scene for developing a successful strategy for IFM. Next, the publication provides a comprehensive overview of measures arranged in the chain from flood hazard to flood impact. The characteristics and applicability of the different types of measures are briefly explained. The measures presented are the building blocks for the development of strategies for IFM. The publication concludes with some guidance on the development of coherent, alternative strategies for IFM within the context of interactive planning processes. This guidance document builds on policy and tool papers that have been published previously within the WMO/GWP Associated Programme on Flood Management (APFM).

1 INTRODUCTION

1.1 Impacts of floods on society: need for integrated flood management

13 Flood risk is commonly defined as the product of hazard, exposure and vulnerability. A hazard is understood as a potentially damaging physical event (in this case a flood) that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Whether a hazard leads to harm depends on the exposure of people, buildings, infrastructure, etc. to the hazard and their vulnerability.

14 Flood risk is a worldwide phenomenon. Over the last few decades, the world has experienced an increasing number of devastating floods. Tragic events, such as the Asian tsunamis (2004 and 2011) and Hurricane Katrina (2005), resulted in hundreds of thousands of people losing their lives or becoming homeless in a matter of hours. Heavy monsoonal rains displaced millions of people in Pakistan when the Indus river spilled over its banks in 2010. Flood disasters in various countries of Europe in the past decade were considered national crises, partly because of the huge amount of damage they caused. Floods in Thailand in 2011 caused even greater damage.

15 Losses due to natural disasters are increasing worldwide. A significant proportion of these losses is caused by floods. Flood impact records (CRED and UNISDR, 2016) suggest that the number of flood fatalities is gradually decreasing thanks, among others, to better early warnings, although incidental devastating (coastal) floods may distort this trend. Flood damaget appears to be increasing because of lack of attention to prevention, economic growth and lack of flood-sensitive land-use planning.

16 Climate change may cause a further increase in flood hazard probability and magnitude, while it is certain that demographic and economic development will be causing a continuous increase of the vulnerability of many floodplain and coastal areas. Even a modest 2% economic growth in flood-prone areas will double the economic damage of a given flood every 30–35 years.

17 In the wake of past disasters, governments have embarked on flood management, investing in measures such as flood prevention, early warning systems and evacuation planning, with the ultimate aim of better protecting their inhabitants and assets from flood hazards.

1.2 Flood types: their characteristics and consequences

18 According to their origin and characteristics, floods can be distinguished as being fluvial, pluvial, flash or coastal floods:

— Fluvial or riverine floods occur whenever water overflows the normal confines of a river or other water body (IFM Tool 2, UNESCO and WMO, 2012). Overflowing occurs when the river discharge exceeds the capacity of the main river channel;

— Pluvial or rainfall floods occur when heavy rainfall creates a flood event independent of an overflowing water body (IFM Tool 15). Pluvial flooding may occur in urban environments when the local drainage system is not capable of collecting and conveying surface runoff;

— Flash floods are floods of short duration with a relatively high peak discharge (IFM Tool 16, UNESCO and WMO, 2012). In areas with steep gradients, flash floods can occur within a few minutes or hours of excessive rainfall, thunderstorms and heavy rain from hurricanes and tropical storms. Flash floods may also originate from a dam or levee failure or from a sudden release of water held by an ice jam. Due to high flow velocities, flash floods often include mud and debris flow floods, sometimes further aggravated by concurrent landslides;

— Coastal floods occur when normally dry, low-lying land is flooded by seawater. Coastal flooding is mainly induced by storm surges (from a depression or hurricane) or by a combination of storm surges, high tide and elevated levels of river discharge leading to backwater effects in the river delta areas (UNESCO and WMO, 2012). Coastal floods may also originate from tsunamis, caused by a sudden rise or lowering of the ocean floor due to an earthquake or by large masses of earth falling or sliding into the water.

19 Coastal floods, especially tsunamis, can cause large numbers of fatalities, as these are often characterized by severe flood effects (large depths, flow velocities and waves). In addition, they often occur with a short warning time. This leaves little or no time for preventive evacuation and may result in large, vulnerable populations.

20 Riverine floods are generally less deadly than tsunamis and hurricanes, although dam-burst floods can be as devastating as a tsunami (though on a smaller geographical scale). Riverine floods tend to affect many people as huge areas of (arable) land can be inundated for a larger period of time (weeks to months).

21 Pluvial floods in urban areas may cause inundation of streets, basements, ground-level floors of buildings, etc. (IFM Tool 4). These urban floods tend to have a relatively short duration (in the order of hours or days) but may occur more frequently (for instance several times a year) and can result in loss of life, as well as significant disruption of economic and social activities.

1.3 Aim of this guidance document and target audiences

22 This publication outlines the approach and steps to develop and evaluate well-balanced and well-motivated strategies to cope with the risk of flooding. The design of strategies covers the full range of possible structural and non-structural measures, including structural protection and mitigation measures, planning and building codes, emergency management, raising of risk awareness and preparedness, risk-sharing, etc.

23 It builds on policy and tool papers that have been published previously within APFM. Due account is taken of the factors that may influence the design of coping strategies, such as climate change, financial constraints, socioeconomic developments, cultural values, stakeholder involvement and governance.

24 This guidance document is mainly intended for persons responsible for planning-flood management activities, designing flood-defence systems and operating flood-control systems in the public and private sectors. As the document advocates a multi-sector and multi-stakeholder approach to flood risk management, the target audience is wide-ranging:

— Flood managers, public officials of national and local governments, personnel of utility cotmpanies, those working in disaster management and land-use planning;

— Elected political leaders: decision-making on flood-management policies and planning;

— Local groups and NGOs that work in community-based flood management; and

— Private organizations, such as insurance companies and property developers.

1.4 Set-up of the guidance document

25 This guidance document covers a large array of subjects in a concise and comprehensive way. For various subjects, suggestions for further reading are given, especially from the IFM Policy and Tool paper series of APFM. The concept of IFM is briefly described in **Chapter 2**, which also presents different perspectives that set the scene for the development of IFM strategies. It includes perspectives on flood hazard and risk as well as on policy development and management.

26 **Chapter 3** presents an overview of measures, arranged in the chain from flood hazard to flood impact. The characteristics and applicability of the different types of measures are briefly explained. The measures presented are the building blocks for the development of coping strategies for IFM. The process of development and implementation of coping strategies is discussed in **Chapter 4**. One section deals with IFM within the context of interactive planning processes. Other sections discuss the design of alternative, coherent strategies or look into impact assessment of strategies and implementation aspects.

2 SETTING THE SCENE: KEY PERSPECTIVES ON INTEGRATED FLOOD MANAGEMENT

2.1 Integrated flood management concept in perspective

2.1.1 Context and concept of integrated flood management

27 Sustainable and effective management of water resources demands a holistic approach, combining social and economic development with the management of natural ecosystems. As flood disasters may adversely affect the sustainability of development, flood issues need to be addressed in the context of Integrated Water Resources Management (IWRM). Integrating flood risks in development strategies requires a move towards a culture of prevention by managing flood risk and living with floods.

28 The basic concept of IFM has been presented in the so-called Concept Paper (WMO, 2009). The concept employs strategies to maintain or augment the productivity of floodplains or coastal zones, while at the same time providing protective measures against human losses due to flooding. Integrated flood management integrates land and water resources development in a river basin or coastal zone as a whole. The approach aims to maximize the efficient use of these areas benefiting from normal and moderate flood waters that provide freshwater, nutrients and sediments, while minimizing loss of life and the impact on livelihoods due to the occurrence of extreme events. Like IWRM, IFM promotes an open, transparent and inclusive process with the involvement of stakeholders in planning and implementation.

2.1.2 Aim and key elements of integrated flood management

29 The aim of IFM for a specific river basin or coastal zone is to arrive at a well-balanced, optimal combination of measures, which is termed a strategy herein, providing a reduction of flood risk to an acceptable level of economic, societal and environmental costs.

30 Integrated flood management comprises five key elements:

— Adopting a best mix of measures, both structural and non-structural; to reduce flood risk and mitigate the consequences once a flood occurs;

— Managing the water cycle as a whole while considering all types of possible floods;

— Integrating land and water management, as both have impacts on flood risks;

— IFM should be part of a wider risk-management system, adopting integrated hazard management approaches, taking into consideration all related hazards such as landslides, debris flows, mudflows, avalanches, storm surges and tsunamis; and

— Ensuring a participatory approach to develop ownership of the strategy to reduce vulnerability.

31 Integrated flood management requires adopting a river basin, urban planning or coastal zone management approach to reduce flood vulnerability and risks and to preserve, restore and manage ecosystems. Environmental sustainability of flood-management options is one of the prerequisites of IFM. The IFM approach may also require collaboration across administrative boundaries. By doing so, IFM can significantly contribute to strengthening of the adaptive capacity of society to cope with climate variability and change.

2.1.3 Need for alternative strategies in integrated flood management to inform decision-making processes

32 The consequences of a flood will depend on the exposure and vulnerability of people and property to flooding. Measures to reduce flood risks will entail reducing the probability of flooding and/or reducing the adverse impacts of flooding. Traditionally, societies have tried to control floods through structural measures. As a 100% level of protection can never be guaranteed, non-structural measures are necessary to reduce the consequences in case protection fails and a flood occurs.

33 Effective measures for reducing flood risk are location-specific, as flood behaviour and hazard are spatially differentiated due to local geographical conditions. Moreover, the different magnitude of flood events will have different impacts on people, property and infrastructure. Hence, there is no single solution for all flood problems or at all locations; a variety of measures is required to reduce flood risk to a societally agreed upon, acceptable level. Alternative strategies for IFM that outline how flooding can be managed for a particular region can inform the selection of the preferred risk-management approach.

2.2 Perspectives on flood hazard and risk

2.2.1 Understanding flood risk

34 No two floods are the same. Floods can come suddenly such as flash floods in small basins or slowly build up during a period of many weeks. Floods occur at irregular intervals: several major floods may occur within a couple of years followed by a period of several decades with no significant flood. Floods vary in their magnitude and duration: planning for IFM should not deal with the previous flood, but look into possible future floods. To manage flood risk, it is important to know the probability of floods with different magnitudes. A proper flood-risk analysis, including hydrological, hydraulic and statistical analyses, is needed to better understand and quantify flood hazard and risk. The need for such a better understanding of hazard and exposure is fundamental to reducing risk and was also recognized and emphasized in the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNIDSR, 2015).

2.2.2 Future development of flood risk

35 Both population and economic growth exert considerable pressure on the natural resources of a region. Increasing population and growth of economic activities in floodplains and coastal zones, resulting in the construction of buildings and infrastructure, further increase the risk of losses from flooding.

36 Climate change will most probably cause an increase in flood risk. Research (Winsemius, et al., 2015) shows, however, that in many parts of the world, the increase in flood risk in the coming decades will mainly stem from demographic and economic growth. More and more people will tend to live and work in hazardous places, unless regional planning of future development takes better account of flood risk and adopts IFM approaches. The trend of rapid, ongoing urbanization, including the growth of megacities, adds to this challenge. This trend underlines the importance of sound and effective regulation of land-use development to limit the growth of flood risk.

2.2.3 Risk-informed decision-making for flood hazards

37 Absolute protection from flooding is technically unfeasible and economically and environmentally unrealistic. Hence, there is a need to decide what level of risk is acceptable, in essence, to decide how safe is safe enough. Risk-informed decision-making on flood hazards is a key element of IFM, comprising decision-making based on estimates of flood risk, as well as costs and benefits

of flood mitigation and management. The approach includes a "proportionate" response to risk, as well as a transparent process of estimating the reduction in risk and impact assessment. The risk estimates may be used to inform multiple decision-makers, including the general public. The development of alternative strategies will help to evaluate the contribution of different measures in reducing the flood risk, their side effects and costs and finally to define proportionate responses to risk.

2.3 Perspectives on policy development and management

2.3.1 Integrated approach to flood-risk management

38 The development of the preferred strategy should be based on a shared vision of regional development which integrates flood risk with economic development and environmental sustainability. Embedding strategies in a vision of regional development will help to link the strategy to investment agendas from different fields, both public and private. Linking the strategy to the SDGs and the Sendai Framework for Disaster Risk Reduction will facilitate implementation of a strategy and provide added value to society.

39 International initiatives have taken shape that promote an integrated approach to flood-risk management, adopting an integrated river-basin approach and promoting the coordination and exchange of information for transboundary rivers. It would be advantageous to adopt such policies when aiming for flood-risk reduction.

2.3.2 Disaster management and disaster risk reduction

40 Floods are the most common natural disaster with the largest impacts on society. With its holistic approach, the IFM concept includes disaster risk management principles applying it to floods. The disaster risk management cycle comprises four phases **(Figure 2)**:

— **Prevention/mitigation:** measures and activities, incorporated in regional and national development planning, that reduce the probability and/or the impacts of disasters;

— **Preparedness:** the aim of preparedness programmes is to reach an appropriate level of readiness to respond to any emergency situation that might arise, through programmes that strengthen the technical and managerial capacity of governments, organizations and communities to respond;

— **Response:** the aim is to provide immediate assistance to maintain life and improve health of the affected population during an emergency situation. The focus in this phase is on meeting the basic needs of people until permanent and more sustainable solutions are in place;

— **Recovery:** activities aimed at restoring livelihood and supporting infrastructure, making use of opportunities to reduce future vulnerability by enhancing prevention and increasing preparedness.

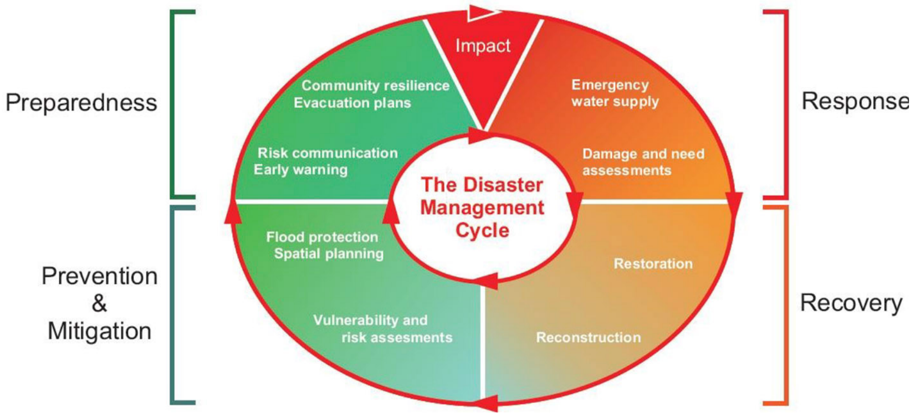

Figure 2 — Disaster management cycle (Deltares)

41 The Sendai Framework for Disaster Risk Reduction 2015–2030, which was adopted in 2015, provides a major worldwide contribution to disaster risk reduction. It articulates the need for improved understanding of disaster risk in all its dimensions of hazard, exposure and vulnerability. The framework aims at strengthening resilience through prevention of new, and reduction of existing, disaster risk, strengthening disaster preparedness for effective response and "building back better" in recovery, rehabilitation and reconstruction. The Framework also calls for enhancing disaster risk governance to better manage disaster risk. This includes a substantial increase of the availability of, and access to, multi-hazard early warning systems and disaster risk information and assessments by the general public.

2.3.3 Ecosystem-based management

42 In many natural systems, floods play an important role in maintaining key ecosystem functions and biodiversity. For example, flooding events serve to maintain fish spawning areas, to help fish migration and to flush debris and sediment. A large variety of flora, including agricultural crops, and fauna may depend on regular flooding. River and floodplain restoration offers opportunities to enhance ecosystem services of floodplains: not only to restore degraded habitats but also to optimize opportunities for society to benefit from controlled flooding. Maintaining and restoring the functionality of natural retention areas such as wetlands will reduce flood hazard and offer biodiversity co-benefits. Mangroves and salt marshes can play a significant role in reducing flood hazards in coastal regions.

43 The concept of ecosystem-based management, including green infrastructure, offers opportunities to develop sustainable strategies for IFM. Green infrastructure may also contribute to the capacity of natural systems to adapt to climate change through natural processes, thereby enhancing the resilience of these systems (WWF, 2016).

2.3.4 Strengthening flood resilience

44 Strengthening flood resilience is a common policy objective within IFM or disaster risk reduction. Flood resilience relates to:

— a) Maintaining, protecting and restoring the natural regulating capacities of wetlands to reduce the levels and duration of flooding;

— b)The ability to recover, in particular, the pursuit of building back better as well as increasing the coping capacity of inhabitants of flood prone areas; and

— c) The ability to adapt to changing conditions, including the impacts of climate change.

45 Resilience-oriented strategies generally involve a mix of both structural and non-structural measures, seeking a balance between prevention and mitigation on the one hand and response

and recovery on the other. Structural measures tend to dominate in traditional resistance-oriented strategies, while there are successful examples of non-structural measures such as floodplain monitoring and land-use planning to prevent inappropriate development.

2.3.5 Adaptive management

46 The design of strategies should take account of the many uncertainties associated with the development of basins or coastal regions. Adaptive management encourages an integrated and flexible approach to increase resilience, reduce vulnerability and limit the risk of over- or underinvestment in flood risk management. It links short-term decisions with long-term challenges concerning flood risk. Adaptive management is about minimizing future regret.

47 Adaptive management is also about monitoring to learn whether measures still meet expectations. If not, further adjustment to the plan will be in order. Climate change and increased climate variability will affect flood processes in several ways. Integrated flood management can be viewed as an autonomous adaptation strategy to climate change and increased climate variability (WMO, 2009).

3 OVERVIEW AND ASSESSMENT OF MEASURES

3.1 Integrated flood management measures in the chain from flood hazard to flood impact

3.1.1 Overview of measures for integrated flood management

48 This chapter presents an overview of measures for IFM, together with a short discussion of their scope and main characteristics. Different typologies may be considered for such an overview, for example:

— Structural vs non-structural;

— Strategy (resistance – resilience – adaptation);

— Engineering vs working more closely with nature/ecosystem-based management;

— Source to pathway to receptor (SPR).

49 The SPR concept allows the distinction between flood hazard, pathways resulting in exposure of "receptors" and consequences of flood to people and property (**Figure 3**, next page). As such, it offers a convenient way (a cascade) to arrange and present different types of measures for IFM (Marchand et al., 2012).

50 A plan for IFM will generally include measures from different steps of the cascade. Arranging different types of measures in a cascade aims at ensuring that all potential types of measures are consciously evaluated. The cascade does not imply a priority order of taking measures. It only reflects a logical sequence in evaluating them, starting at the source of flooding. Iteration will always be necessary to develop an optimal strategy for IFM.

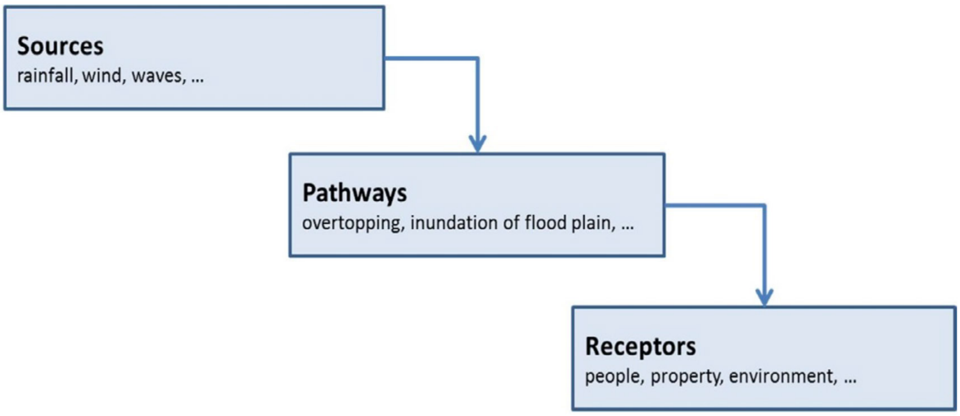

Figure 3 — The chain from flood hazard to flood impact (Deltares)

51 The types of measures related to the source and pathway part of the cascade will, in general, differ, depending on the type of flood, whereas the receptor part may differ from case to case, reflecting differences in economic situation, governance structure, etc. In the case of riverine floods, the cascade descends from rainfall and/or snowmelt in the upper catchment all the way

down to the individual or household that is impacted. Coastal floods may come from tsunamis, high tides or storm surges, as well as from backwater effects of surges on river stages.

52 The cascade can be elaborated in a number of guiding principles for categories of measures **(Figure 4)**:

— Reduce the flood hazard;

— Protect against floods (flood control);

— Regulate/adapt land use;

— Raise awareness /preparedness;

— Mitigate residual risk.

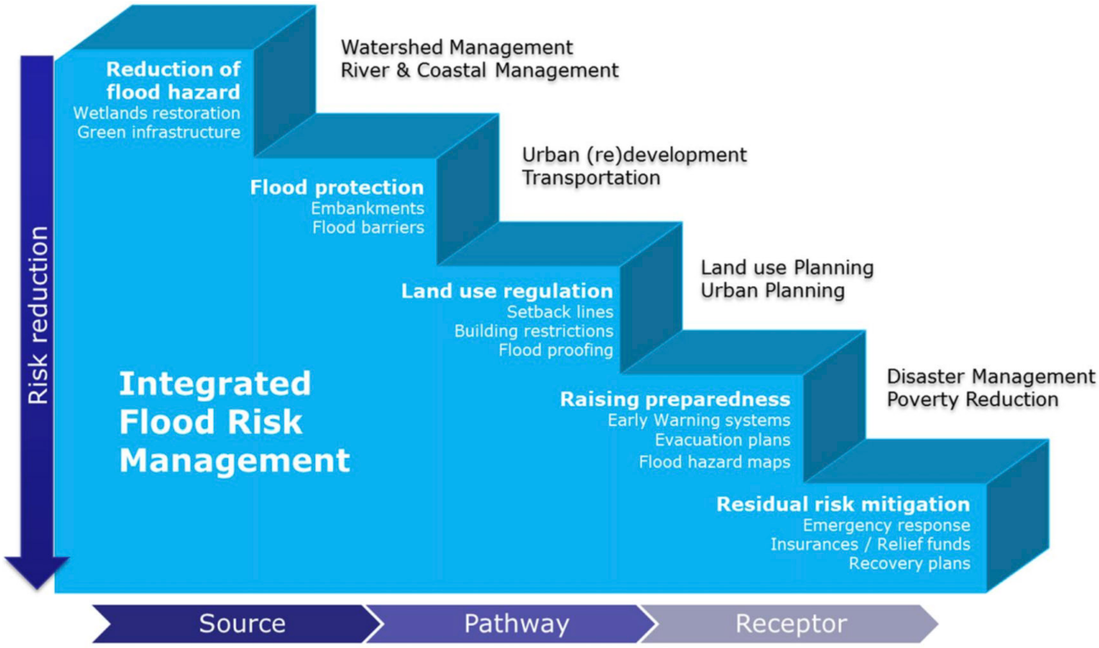

Figure 4 — Cascade with potential integrated flood management measures and associated policy and management fields (adapted from Marchand et al., 2012)

53 **Figure 4** also illustrates that for each category of measure, there is often a corresponding policy and management field and sometimes more than one, that is relevant (top of the figure). Since integrated flood management cannot be implemented in isolation, it is crucial to make linkages and agreements with these other policy domains.

54 The next sections discuss the measures typically associated with the various guiding principles for river and coastal floods. A brief outline is presented of the scope, characteristics and effectiveness of the measures. The description also contains suggestions for further reading, with particular reference to the relevant IFM policy and tool papers of APFM.

3.2 Reduction of flood hazard

3.2.1 Riverine floods

55 The hazard of riverine floods can be reduced by measures in the watershed area reducing the peak runoff to the river and measures in the river itself reducing the peak discharge or flood levels.

E | Reduction of (peak) runoff from watershed

56 Ecosystems play an important role in the regulation of surface and sub-surface flow. Vegetation can have a mitigating effect on the impact of heavy rains in catchments and urban areas. Foliage acts as an umbrella that reduces raindrop impacts on soils, thereby decreasing the risk of erosion and landslides. Roots strengthen the soil and improve soil texture, which increases the retention ("sponge") capacity. Organic matter from roots and leaves improves soil structure and increases both infiltration rates and water-retention capacity (Mirza et al., 2005).

57 The regulation function of vegetation in fact depends on many factors, such as catchment size, steepness, types of vegetation (age, species), soil condition, weather and climate (high precipitation areas).

58 Floods can be aggravated by human activities such as deforestation on hill slopes, shifting cultivation and overgrazing by domestic animals, removal of wetlands and installing drainage ditches and tile drainage systems. These factors cause quicker runoff from the steep hilly slopes resulting in flash floods and may increase the possibility of landslides.

59 Watershed management may comprise a combination of structural and non-structural methods for managing floods to reduce peak runoff. Measures, such as increasing natural water retention, afforestation, reforestation and wetland reconstruction and protection can help reduce the peak runoff discharge from a watershed. The impact of such measures on peak runoff is, however, generally hard to quantify accurately.

60 Change in vegetation cover and alterations to the natural channels (efforts to remove water from the landscape quickly) will affect the hydrological behaviour of a catchment (**Figure 5**, next page). Unabated loss of forests may increase the peak discharge for a given event, resulting in an increase in the number of flood-related disasters (Bradshaw et al., 2007).

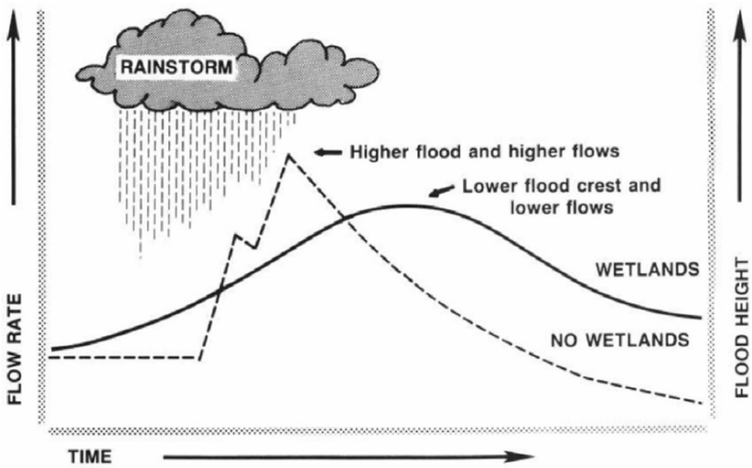

Figure 5 — Impact of wetlands on flow regime after a rainstorm (Tiner, US Fish and Wildlife Service, 1984)

61 The role of forests in minimizing the effects of catastrophic floods and landslides has long been debated (FAO, 2005). The conventional wisdom is that forests act as giant "sponges", soaking up water during heavy rainfall and releasing freshwater slowly when it is most needed, i.e. during the dry months of the year. The reality, however, is far more complex. It can be argued that it will certainly reduce the frequency and extent of moderate floods, when there is still soil storage capacity available. During a major rainfall event (like those that result in massive flooding), especially after prolonged periods of preceding rainfall, the forest soil becomes saturated and water no longer infiltrates the soil but instead runs off the soil surface, resulting in extensive flooding.

62 Hence, deforestation is not the only factor of importance. Much of the retention capacity depends on the types of land cover and land use that have replaced the forest. Watershed management should therefore:

- Pay specific attention to soil-conservation measures, to reduce the erosion and subsequent sediment transport downstream, which affects the river drainage capacity;
- Be careful with constructing forest roads and hard-surfaced roads, since the impermeable road network not only generates surface runoff but will also intercept and convey surface runoff quickly to the stream channel through its associated gutters and drains (Calder and Aylward, 2006).
- Be careful in implementing broad upstream basin drainage schemes to guide removal of water from the area, as this will increase downstream peak flows.

Further reading

- IFM Tool 13: *Conservation and Restoration of Rivers and Floodplains.*
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- Tiner, R.W., 1984: *Wetlands of the United States: Current Status and Recent Trends, US Fish and Wildlife Service.*
- World Wildlife Fund (WWF), 2016: *Natural and Nature-based Flood Management: A Green Guide.*

F | Regulation of river flow

63 Peak river flows may be regulated/reduced by temporary storage in reservoirs or diversion to detention schemes. The ability to reduce flood peaks depends on the capacity and operation of the infrastructure.

64 Reservoirs have been mainly developed for (irrigation) water supply and hydropower generation. To this end, they should be full of water at the start of the dry season. Effective hydropower generation also requires a reservoir to be as full as possible. For flood-control purposes, however, the reservoir should be as empty as possible to have sufficient storage to regulate peak flows. Multi-purpose operation aims to balance these conflicting demands in reservoir storage. Another aspect to incorporate in the operation is the structural integrity of the dam, which may force downstream releases when the full supply level is being approached or exceeded.

65 Apart from the envisaged socioeconomic benefits, reservoir development in the past has at times brought severe adverse environmental and social impacts, limiting the development potential of new large reservoirs. Instead there is a trend to develop more small or medium-sized reservoirs. Smaller reservoirs will, however, provide less opportunities for multi-purpose operation (both irrigation water supply and flood control) than larger ones.

66 Timely diversion of water is crucial for detention schemes, to make optimal use of storage. The diversion should not be too early and not too late. If water is diverted too early there might be no storage left at the time it is most needed. Such a situation may occur if the historical river flow data show the possibility of a couple of peaks during the wet season.

67 For detention schemes operated with low frequency (less than 1 per 10 years) it may be difficult to maintain their storage function. Farmers and urban developers may harvest and/or develop the area if they have the land rights, making it difficult to store peak floods when necessary.

68 Reservoirs and detention schemes, together with a proper operational plan, may provide a specific, quantifiable reduction in flood hazard. More storage capacity of reservoirs may replace more detention capacity or the other way around. Given a required or desired level of risk reduction, the optimal mix of detention and reservoir measures will depend on feasibility and costs, as well as on other impacts of these measures.

Further reading

– IFM Tool 10: *Reservoir Operation and Managed Flows(b)*
– IFM Tool 7: *Role of Land-Use Planning in Flood Management*

G | Enhancement of river-flow conveyance

69 Rivers have always been important carriers of economic development. Infrastructure has also been built along the river and in the floodplain to support transportation (navigation) and other economic activities. Infrastructure, such as bridges, piers and groins, may create obstructions to streamflow, thereby raising the stage or water level (for the same discharge). Also, urban expansion (human settlements at the river front or encroaching into the floodway) may have created bottlenecks that hamper a smooth discharge of river water, thus creating backwater effects, i.e. water level increases upstream of the bottleneck. In rivers with a mild slope, the removal or bypassing of these bottlenecks may reduce the upstream water levels over considerable lengths.

70 By making *"room for the river",* i.e. through smart river training and management, significant improvements in flow conveyance can be achieved which may reduce water levels in the river at locations of interest (e.g. urban centres along the river). It may include various channel improvements such as widening the channel, removing or altering obstructions that hinder the free flow of water and raising and/or widening of bridges and barriers that prevent free flow, as well as deepening the channel through dredging (see also **Figure 6**). These floodplain and channel measures require adequate maintenance to retain their effectiveness. Due consideration should be given to the impacts of such measures on downstream communities.

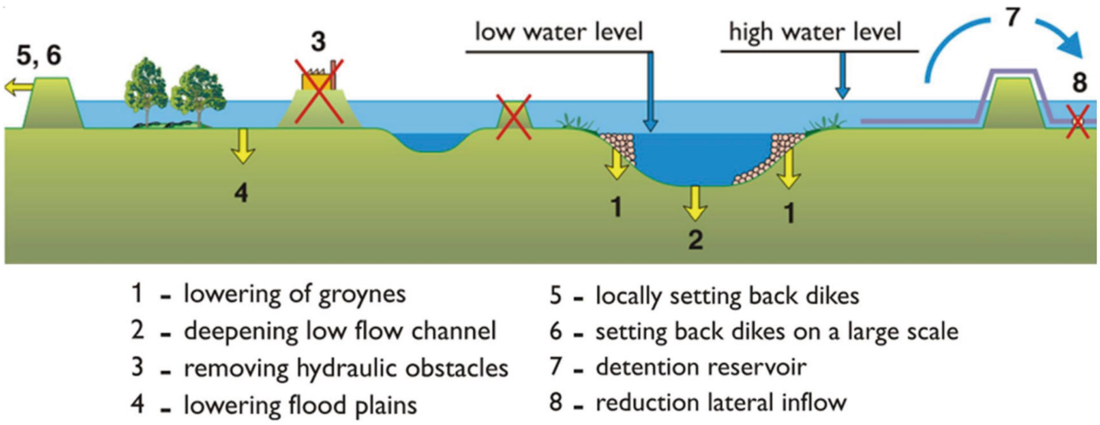


Figure 6 — Overview of "room for the river" measures to enhance conveyance (Deltares)

71 Another way of enhancing flow conveyance is through diversion of (part of the) flood waves by building bypass channels and floodways. Excess floodwaters can be diverted from the main river system by using bypass systems such as tunnels, open channels and/or green rivers (i.e. rivers that only convey water during flood events).

Figure 7 — Enhancing flow conveyance: Red River Floodway at Winnipeg, Canada (left) and side-channel of Waal River at Lent, Netherlands (right)
(Manitoba Floodway Authority, Canada, left; Ministry of Infrastructure and Environment, Netherlands, right)

72 Measures in floodplains or development of green rivers may have large spatial implications which may not always be acceptable to land owners. Adequate compensation may facilitate land acquisition. On the other hand, combining green measures with urban development may create attractive waterfronts and increase their value. Measures to enhance river-flow conveyance will have a direct link with the design of new or additional flood-protection systems. Such measures help to accommodate larger design flood waves without raising the embankment levels. Increasing river conveyance – the ability to carry water downstream – may prove more cost-effective than other structural measures.

Further reading

- IFM Tool 13: *Conservation and Restoration of Rivers and Floodplains*
- World Wildlife Fund (WWF), 2016: *Natural and Nature-based Flood Management: A Green Guide*

3.2.2 Coastal floods

A | Dissipation of wave energy

73 Reduction of high waves is especially important in coastal environments, where storm surges and tsunamis are among the most destructive forces of nature. Coastal ecosystems, such as mangroves, coral reefs, seagrass beds and saltmarshes, can physically exert an effect on waves. They cause a hydraulic resistance that can break the waves and reduce their velocity, thereby reducing their energy. Mangroves are especially able to reduce significantly the energy of huge waves such as storm surges that accompany cyclonic depressions. It is one of the main reasons for substantial mangrove rehabilitation efforts all over the world.

74 The role of coral reefs as submerged breakwaters has been extensively studied (Kench and Brander, 2006; Möller et al., 1999). This research shows that reefs constrain ocean swells, thereby transforming wave characteristics and consequently attenuating wave energy. In temperate areas, services similar to coral reefs are provided by reef-building shellfish species, such as mussels or oysters. These species act as ecosystem engineers in that they modify their local hydrodynamic and sedimentary surroundings.

75 They may also be viewed as a foundation species, as they are able to construct hard substrate reefs in soft sediment areas. In general, however, shellfish reefs are considerably lower in height than a full-grown coral reef. As a result, effects on reducing current velocities and wave dampening are more modest.

B | Coastline stabilization

76 Coastal vegetation plays a significant role in mitigating coastal erosion and promoting sediment deposition. Mangroves and salt marshes are especially capable to grow with rising sea levels, provided the tidal movement is not restricted by human interference. Beach nourishment may be applied to compensate for coastal erosion.

77 Managed realignment is an alternative measure that usually entails moving the coastal embankment landward in order to reduce the maintenance cost of a coastal defence. It creates a new shallow foreshore which can effectively reduce the wave energy. The measure can only be implemented if sufficient space can be made available at the landward side at acceptable economic and social cost.

Further reading

– IFM Tool 17: *Coastal and Delta Flood Management*

3.3 Protection against floods

3.3.1 Riverine floods

78 Many flat, lowland and delta rivers are embanked to protect agricultural fields and urban areas from flooding. Protection of an entire area by building embankments, levees or dykes has been and is being practised in many flood-prone areas, often in response to disastrous flooding.

79 Apart from embankments, the protection system may also include movable flood barriers, to prevent the inland propagation of high water levels through inland streams and channels.

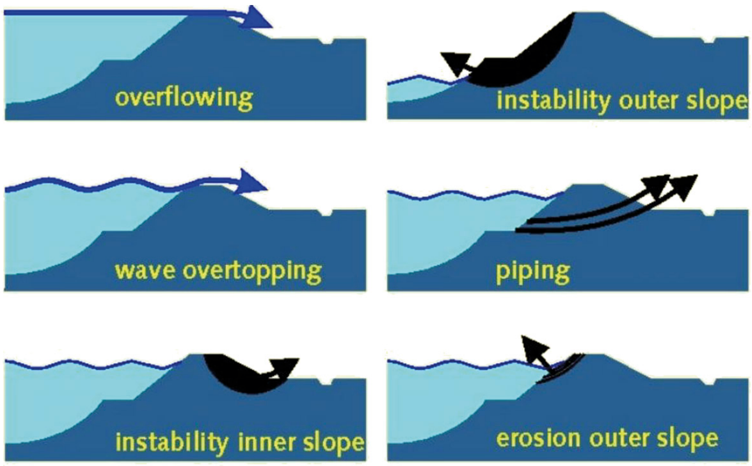


Figure 8 — Failure mechanisms of an embankment
(Netherlands Ministry of Infrastructure and Environment)

80 Embankments are often built according to the highest known flood level or up to a particular design flood wave, e.g. the 1:100 year flood, plus freeboard[1]. The protection of an entire area will depend on the proper functioning of protection systems as a whole. Embankments may fail either because a flood exceeds the design conditions or because breaches occur at weak spots in the embankment system. Such breaches may cause large impacts, in particular if the protection has produced a sense of safety which has stimulated economic development. Hence, this places great importance on continuously monitoring and maintaining the structural integrity of embankments **(Figure 7)**. In addition, there is the need for flood early warning systems to allow

1 As defined in the WMO/UNESCO Glossary for Hydrology, the freeboard is the "Vertical distance between the normal maximum level of the surface of a liquid in an open-flow conduit, reservoir, tank or canal, and the top of the sides of the structure"

for emergency measures, such as placing sandbags for emergency raising of design height and evacuation if the water level is expected to approach or exceed the design water-level height.

Figure 9 — Protection of an area by building embankments, levees or dykes: ring dyke at Red River, Canada (left); a levee protects a home surrounded by floodwater from the Yazoo River near Vicksburg, Mississippi, USA (Manitoba Floodway Authority, left; Getty images, right)

81 Furthermore, the construction of embankments along a river generally results in higher river-water levels during high discharges in both the embanked area of the river, as well as upstream, simply because the water cannot expand laterally as the embankments act as a constriction. In heavy, silt-laden rivers, the embankments could lead to significant riverbed aggradation which can result in higher risk of overtopping. Embankments could also lead to waterlogging of the areas that they are intended to protect, if natural drainage channels from the floodplain behind the embankment back to the river are blocked.

82 Building embankments is generally not a flexible measure. Some flexibility may be created through the application of different protection levels to different zones. Higher protection level may be achieved, for example, through ring dykes around cities or through placement of critical infrastructure on mounds. Such critical infrastructure may be provided with a higher level of protection against floods (e.g. 1:500 or 1:1,000 year flood) than less crucial infrastructures (e.g. 1:100 year flood).

83 Embankments are designed to protect areas from flooding by confining the water to the river, thus protecting the areas immediately behind them. Building embankments may have significant impacts on the hydrological and morphological regime of rivers and floodplains with a loss of environmental services provided by the latter.

84 Embankments also offer opportunities for multi-functionality. An obvious example is the use of an embankment for transport purposes. Dykes and roads are almost the perfect symbiosis in infrastructure. But there are opportunities for other combinations as well, e.g. with urban (re) development. In urban areas, embankments may be combined with housing or parking areas.

Figure 10 — Dyke enhancement at an urban waterfront in the Netherlands (De Urbanisten)

85 Many societies are showing a growing aversion to risk and are adopting strategies which aim to further reduce the probability of failure so as to avoid the impacts of failure. This trend of risk aversion, together with the expected impacts of climate change, has triggered the development of more robust flood-protection works to help protect society by almost preventing flood losses. Such dykes (super levees, delta dykes), thanks to their height, width or structural reinforcements, should be designed so that the possibility of a breach in the embankment with uncontrolled flooding is practically zero.

Further reading

– CIRIA, 2013: *International Levee Handbook, London*

In terms of preparedness:

– IFM Tool 11: *Flood Emergency Planning*
– IFM Tool 4: *Organizing Community Participation for Flood Management*

3.3.2 Coastal floods

A | Seawalls, dykes and dunes

86 Engineering solutions such as groynes, detached breakwaters and artificial reefs are built to significantly reduce coastal beach erosion and to maintain a minimal beach for recreation. Seawalls and revetments are usually built in regions (along boulevards of beach resorts) where natural dunes are absent or have been removed for recreational purposes. These structures are, however, no remedy for structural sediment deficiencies due to sea-level rise, nor for dune erosion during conditions with relatively high surge levels (above the dune-toe level). Under such circumstances, sand nourishments are needed to replenish or maintain the volume of sand in the littoral system. The method is relatively cheap if the source of the sand is not too far away (i.e. less than 10 km). It should be noted that these kinds of measures need to be repeated every few years, owing to wave and current forces. Such artificial nourishments will be gradually spread to the onshore and offshore directions.

B | Storm surges barriers and dams

87 Coastal floods may propagate inland over long distances through tidal rivers and estuaries. Protecting the areas along rivers and estuaries against such floods may require raising and strengthening embankments over considerable lengths. In such cases, it can be effective to shorten the length of the coastline by closing off the river mouth from the sea – temporarily or permanently – with a storm surge barrier or dam. Such structures will prevent extreme surge levels to propagate land inward. These structures often involve large investments and are designed for a lifetime of 100–200 years. This design should therefore consider future climate change conditions such as sea-level rise.

Figure 11 — Thames Barrier at London, United Kingdom (left),
Maeslant Barrier of Rotterdam Waterway, Netherlands (right)
(Environment Agency UK, left; Netherlands Ministry of Infrastructure and Environment, right)

3.4 Regulation/adaptation of land use

88 Placing restrictions on use of land through land-use zoning with building restrictions and flood proofing are all measures that aim to reduce the impact of flooding. Regulation of new building developments will generally be easier to implement than adaptation or regulation of current land use. New regulations may, however, inhibit any further development that could be damaged from the exceedance of the design event.

89 Adaptation of land use refers to a wide range of measures that can be taken to reduce the impact of a flood. It includes measures and coping mechanisms by which people have adapted their way of living and their livelihood to regular or incidental flooding, such as houses on raised land (mounds) or on poles, growing flood-resistant crops, diversifying livelihood, etc.

90 Traditionally, people used to live in areas which were relatively safe from flooding. Due to growing population pressure, urbanization and marginalization, as well as unregulated development, more and more people are living in hazardous places. Zoning regulations aim to tune the land use to the flood hazard and to keep the most hazardous places, i.e. the floodway, uninhabited (see **Section 4.2.1**). In less hazardous areas of the floodplain, certain uses of land can be allowed with prescribed or restricted use conditions (e.g. parks, golf courses, cropland). Enforcement of such regulations is often difficult, requiring constant vigilance. Zoning is not effective when enforcement is not undertaken or is perceived as restricting development.

91 Insurance premiums may also be related to zoning systems and provide incentives for better tuning of land use to flood hazard. Furthermore, banks may be required not to issue loans on such occasions and re-investments in flood zones may be prohibited as a way of avoiding growth in the future values of goods at risk.

Figure 12 — Different methods of floodproofing (adapted from FEMA, 1986)

92 Floodproofing includes permanent or temporary measures to either prevent floodwater reaching buildings and infrastructure, or minimize the damage should water touch or enter the building. Some methods of floodproofing can be distinguished **(Figure 12)**:

— **Elevation:** raising a building or the ground level so that the base floor is higher than the design flood level;

— **Dry floodproofing:** ensuring that water does not enter a building by making the walls, doors, windows and other openings of the building watertight; and

— **Wet floodproofing:** a design that allows floodwaters to enter the house freely, but minimizes impact by reducing structural damage from the force of the water. House contents can be temporarily stored on elevated levels or removed. The measure may include having a second place in which to live that is not exposed to the flood hazard during times of flooding.

93 In unprotected and inhabited floodplains, floodproofing might be an initial step in reducing vulnerability to flooding.

Figure 13 — Other methods of floodproofing: raising (top and bottom left); retaining wall (top right); removable structural dyke (bottom right) (Paul Pilon)

Further reading

- IFM Tool 7: *The Role of Land-Use Planning in Flood Management*
- IFM Tool 15: *Flood Proofing*
- Federal Emergency Management Agency, 1986: *Design manual for retrofitting flood-prone residential structures*

3.5 Raising of awareness/preparedness

94 Flood early warning can provide sufficient lead time to put in place temporary or emergency measures to reduce potential losses. Short- to medium-term measures can be taken prior to the arrival of flood events to reduce the risk of loss of life and damage by means of minimizing exposure to flooding. Such measures can range from placement of pre-designed floodwalls for protecting the city and for closing the access points in ring-dyke communities or moving people and belongings, including livestock, to safety. Such emergency measures require timely information on when and where the flood will come, how extensive the flood will be, how long it will last, etc. For this purpose, flood early warning systems **(FEWSs)** are being developed and used on an increasing scale. These systems are an essential tool to identify when a flood hazard is imminent. They can also be part of a multi-hazard early warning system (WMO, 2011).

95 The main goal of an FEWS is to complement other measures that have been taken and prevent hazards from becoming disasters. By providing end-users with meaningful warnings, they have the opportunity to take risk-mitigating actions, such as moving assets to higher ground, laying sandbags, and preparing for evacuation. Warnings should ultimately be provided by local authorities because they know the local conditions, as well as vulnerable people and assets. It is beyond the capability or capacity of local governments, however, to operate a unified, multi-channel, nationally standardized system for delivering warnings to their citizens. This is often the responsibility of the national or provincial/state government. Although the ability to predict floods has improved through a combination of real-time data collection and model application, false alarms may still be given and some events missed as early warnings cannot be fully accurate.

Figure 14 — Flood early warning systems: evacuation route at New Orleans, USA (left); flash-flood warning, Hong Kong (right)
(Jos van Alphen)

96 When forecast levels exceed design level, warnings should also make clear how much time people will have to evacuate the area at risk. Evacuation requires sufficient time and adequate organization. If such time is not available, people should find shelter in nearby refuge areas. Evacuation of a large number of people may create chaos, in particular when the evacuation is not properly planned and guided. Evacuation plans and refuge areas should be known to the population at risk prior to the event as part of preparedness measures and are of equal importance as the warning system itself. While FEWSs provide information about "when" the flood will happen, flood-risk maps tell us "where" the flood will hit.

97 Flood-hazard maps are also useful tools to raise people's awareness. They also comprise important input for emergency management, i.e. for planning the response to the flood event. Flood-hazard mapping may also play a role in local capacity-building, including the planning and execution of drill exercises. It is also very important that flood-risk information comes from a trustworthy source, as some may provide wrong information or instructions (IFM Tool 22).

98 Improved community preparedness is important to allow people to respond to the forecast flood risk and minimize adverse consequences of the flood. Besides an effective flood-warning system, community preparedness includes community disaster management programmes to increase their resilience. Local or regional disaster-management committees are essential to assist communities to prepare themselves before, during and after flood events, since the organization of (inter)national response usually takes time. The resilience of households and communities can be further enhanced by improving their economic status. This allows them to recuperate more quickly after the flood. Improving economic well-being may also lead to better houses and reduced hazard exposure that, when combined, make them more resistant to floods.

Further reading
– IFM Tool 20: *Flood Mapping*
– IFM Tool 2: *Conducting Flood Loss Assessments*
– IFM Tool 11: *Flood Emergency Planning*
– IFM Tool 4: *Organizing Community Participation for Flood Management*
– IFM Tool 22: *The Role of the Media in Flood Management*
– IFM Tool 24: *Public Perception of Risk and Social Impact Assessment*

3.6 Mitigation of residual risk

99 Once it is known that a flood will occur – or is in the process of occurring – emergency measures can be taken to help mitigate its impacts. Effective and efficient emergency response is based on adequate flood preparedness. Such activities include planning for various emergency flood scenarios, simulation exercises, demonstrations and drills, as well as training and education in specific skills (e.g. sandbagging). Good coordination and management of organizations and activities are essential for containing the flood disaster and minimizing loss of life and injury during and after the event. Specific activities can also be planned to quick-start economic recovery through assistance and stimulus measures for businesses.

100 Flood recovery plans are important to enable people to take up their lives again more quickly after the flood. Recovery and rehabilitation is a process that aims to restore public services and create conditions for socioeconomic activities and should aim at increasing the resilience of communities. Recovery provides opportunities to integrate risk reduction and preparedness measures into development planning. Such measures will help to reduce the impacts of future flood events: build back better or rebuild by design. Recovery also provides opportunities for institutional strengthening of disaster risk-management activities.

101 The financial burden of flood impacts may be relieved somewhat by relief funds and flood insurance. Many countries have some form of flood insurance coverage, which differ widely between countries in their treatment of risks. Insurance against floods are mainly limited to urban properties, although crop insurances do exist (e.g. in India). If residents in flood-risk areas expect the government to compensate them for their flood disaster loss, they will not be inclined to buy flood insurance. However, if governments are constantly making flood-related loss payments, they might consider taking proactive measures to reduce exposure of their citizens to risk. Moreover, relief funds do not always reach those who most need it, whereas insurance is often too expensive for the poor.

Further reading

– IFM Tool 8: *Risk Sharing in Flood Management*

4 DEVELOPMENT AND IMPLEMENTATION OF INTEGRATED FLOOD MANAGEMENT STRATEGIES

4.1 Introduction: scope of strategy development

102 The nature and consequences of floods in a particular river basin or coastal plain will depend on the climate, the hydrological and hydraulics characteristics of the area and the socioeconomic conditions. These linked factors and the governance situation will strongly influence the development of an appropriate strategy for IFM. Obtaining agreement on problem assessment and policy objectives is the basis for a successful development and implementation of IFM strategies. Stakeholder engagement within the context of an interactive planning process will help to develop a shared perception and promote ownership of problems and potential solutions.

103 Strategies relate to a situation which is bound to change over time. In light of the uncertainty about the future, flood-management plans should adopt strategies that are flexible, resilient and adaptable to changing conditions. Individual flood-management measures cannot be planned in isolation. The development of strategies should look into the opportunities for integration with socioeconomic developments through land-use planning.

104 There is no general recipe for a successful design of strategies to reduce exposure to flood risk, but some elements can be considered as essential building blocks. That is why this chapter presents some considerations for the design of coherent and well-balanced strategies for IFM, including a thorough examination of all relevant options and a search for an optimal balance of structural and non-structural measures.

4.2 Development of strategies within an interactive planning process

105 Planning integrated flood management can be approached as an iterative process towards risk-informed decision-making. **Figure 15** (next page) presents a framework for policy analysis and planning to guide the steps of IFM. This framework, adapted from the Risk Governance Framework of the International Risk Governance Council (IRGC, 2005), reflects the policy cycle. The framework consists basically of four steps, which are to be followed in an iterative way; not only within one planning cycle, but also over the years as flood plans need regular updating.

106 Reaching agreement on problem assessment and policy objectives is the key to successful planning. Hence, stakeholder engagement and communication are at the core of the framework: a process of joint fact-finding to develop a shared perception and common knowledge base.

4.2.1 Framing of flood risk

107 A planning process generally starts with an inception phase in which the scope and objectives of the planning process are defined. This includes the problems to be addressed and which

objectives are to be pursued. Ideally, problems and objectives will be embedded in a vision of future regional development.

108 Relevant stakeholders will be identified through a stakeholder analysis. The level of participation of the different stakeholders in the planning process may depend on their knowledge, interest or executive roles and responsibilities (legal, financial, human resources).

109 Starting points will be defined for the next steps in the cycle. This includes the system description, which reflects what aspects and dimensions are to be considered in the flood-risk analysis. It is beneficial to establish a socially acceptable level of risk. This process is facilitated through the definition of scenarios of plausible future situations.

110 Scenarios play a central role in defining adaptive strategies. By developing multiple scenarios, it becomes easier to define and prioritize no-regret measures. Having multiple scenarios also helps explicitly to take into account various uncertainties, including the possible impacts of climate change.

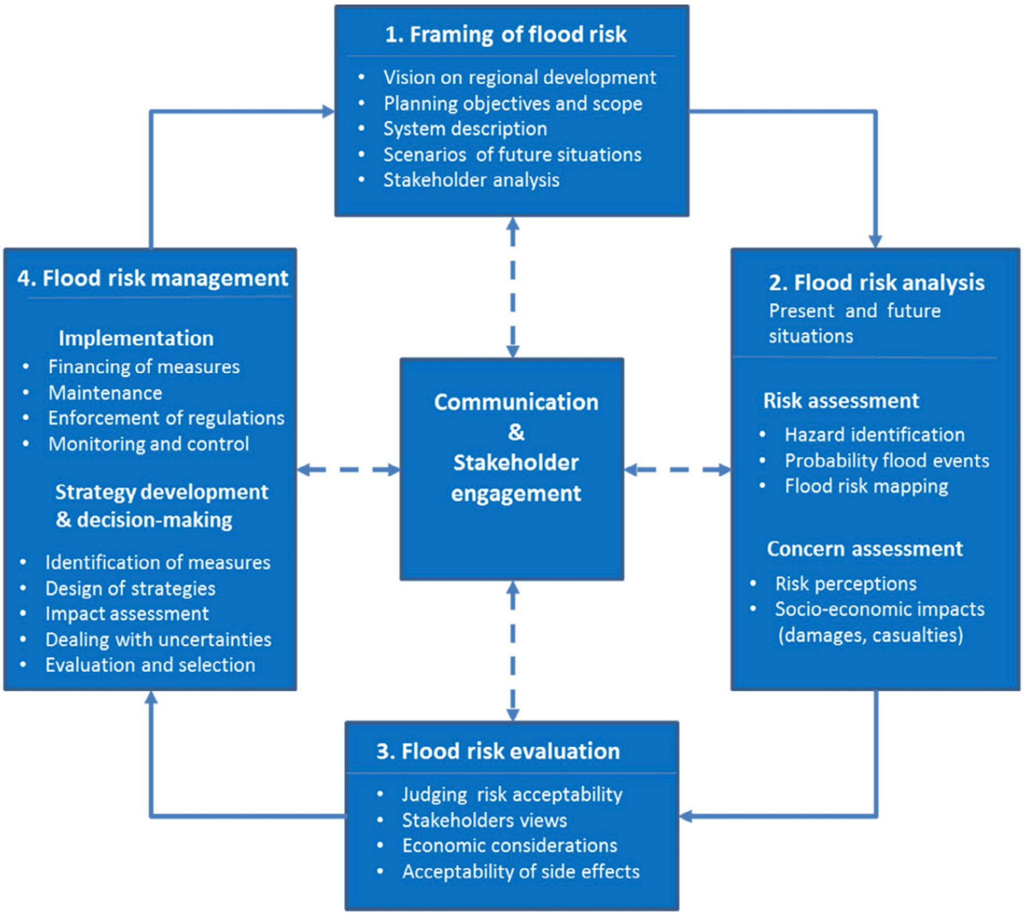


Figure 15 — Framework for policy analysis and planning of integrated flood management (adapted from the Risk Governance Framework of the International Risk Governance Council)

4.2.2 Flood-risk analysis

111 Flood risk analysis includes the identification of flood hazards and the assessment of flood probabilities and impacts for both the current situation and scenarios of future situations. Modelling is often part of the analysis to quantify hazard and exposure, including the probability of different extents of flooding. A flood-risk analysis also looks into the different types of impacts of floods, including the functioning of critical infrastructure.

112 The assessment of concerns may include risk perceptions of different stakeholders. Through flood-risk mapping, a comprehensive overview can be compiled of hazards, impacts and risks in the project area, which serves as input to flood-risk evaluation and management.

4.2.3 Flood risk evaluation

113 Flood-risk evaluation is essentially a societal and policy process which should answer the question: what flood risk is acceptable or how safe is safe enough? The inputs to this discussion are flood-risk maps, the potential measures to reduce the risk and their costs. It includes stakeholder views and local risk perceptions, as well as economic considerations regarding the acceptability of side effects and damage and the benefit–cost ratio or cost-effectiveness of risk- reducing measures.

114 The new flood protection standards in the Netherlands include the concept of a basic level of safety. The associated threshold value for the risk criterion of local individual risk has been decided in a motion of the Netherlands Parliament. The recommended set of risk or safety level(s) guides the further planning and design of measures and strategies (Van Alphen, 2015).

4.2.4 Flood-risk management

115 Strategies to be developed should comprise a well-balanced mix of both structural and non-structural measures, including those which can be implemented in the short term. The strategies will be assessed on economic feasibility, social and cultural aspects and environmental considerations. An environmental impact assessment will sometimes be required when considering structural measures.

116 Implementation of strategies will look into the financing of measures, as well as considering their ongoing long-term operation and maintenance costs. Good governance should also create the conditions for effective enforcement of regulations and public awareness campaigns.

117 Development of strategies in an interactive setting could be supported with decision-support systems (DSSs) or planning kits. A planning kit will generally be built on the results of numerous simulations with hydrological and hydraulic models, which are used to quantify flood risk and assess the impacts of measures. It allows combining measures into strategies and provides direct feedback on the impacts of these strategies.

118 A planning kit generally presents a dashboard from which a user can select measures and learn about their impacts, including an indication of how well particular targets are being met.

119 **Figure 16** (next page) shows an example from the *Room for the River* project that was undertaken in the Netherlands (Schijndel, 2006).

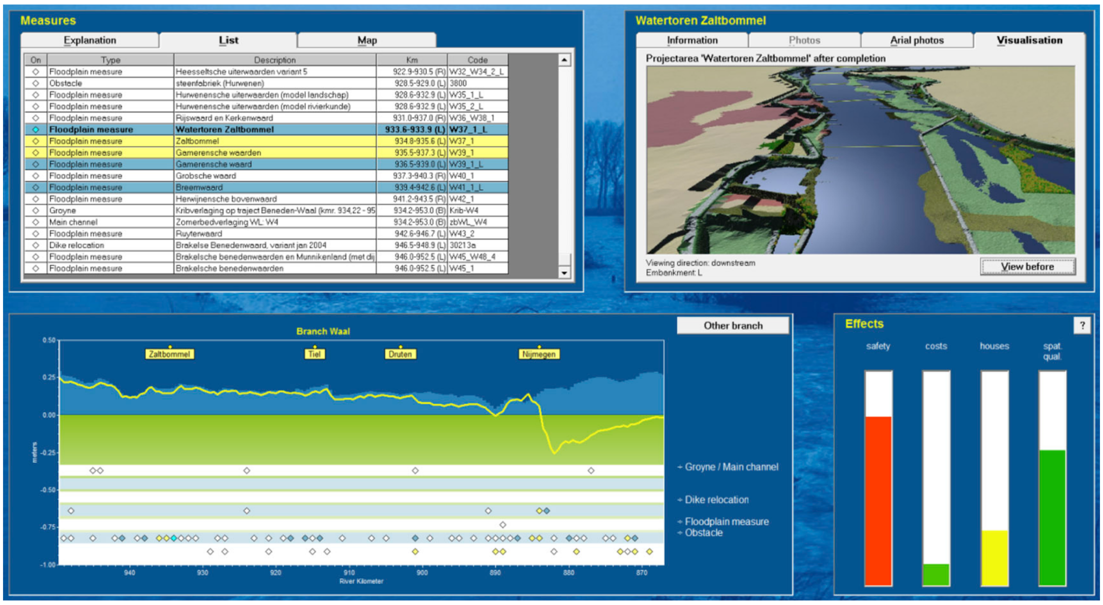


Figure 16 — Example of planning kit dashboard for Room for the River project, showing measures, reduction of design flood levels and other impacts (Deltares)

120 The development and use of a DSS or planning kit is attractive in situations with different levels of objectives and where many possible measures or combinations of measures could be considered. Planning kits especially play a role in designing strategies, by reducing the long list of potential measures to a set of the most promising ones. For a planning kit to be helpful in developing a strategy, it is important that it contains a complete overview of all potential measures with their impacts. This allows the creation of a common information and knowledge base for strategy development. The planning kit should also be relatively easy to use and provide quick response to user interactions to facilitate learning processes on the flooding problem and its possible solutions. Such quick response requires a simplified representation of relationships between measures and their impact on the water system, especially in view of synergetic effects of measures.

4.2.5 Joint fact-finding for shared perception and common knowledge base

121 Stakeholders will enter a planning process with their own views on what is the actual problem and what might be effective solutions. Not all stakeholders will hold the same views. There may also be knowledge gaps to properly assess (future) flood risk or the impacts of IFM measures. Obtaining agreement on problem assessment and policy objectives is the basis for successful development and implementation of IFM strategies. A process of joint fact-finding with frequent interactions will help to create a common knowledge base. In this process, perceptions of stakeholders may be altered or refined when new knowledge becomes available. Stakeholder engagement will help to develop a shared perception of problems and potential solutions and will promote ownership of the redefined problem and its solutions.

Further reading

- IFM Policy 4: *Social Aspects and Stakeholder Involvement in Integrated Flood Management*
- IFM Tool 2: *Conducting Flood Loss Assessment*
- IFM Tool 20: *Flood Mapping*

4.3 Design of coherent, alternative strategies

122 Policymakers need to select a "best strategy' for a particular area, taking into account technical feasibility, financial constraints and environmental considerations, as well as political and societal

acceptability. Sometimes it may very hard to attain an agreed-upon solution because specific instruments of a particular sector might be in conflict with others (e.g. a flood wall blocks shore residents' views). A compromise is therefore often required between needs and preferences of different stakeholders. Policymaking can be supported by analyses to show how different alternative strategies perform and what they cost, as well as their positive and negative effects. These alternatives should span the relevant "playing field".

4.3.1 Thorough examination of all relevant options

123 Integrated Flood Management should avoid isolated perspectives and assess the problem to determine which measures may be the most appropriate and effective. Successful implementation of IFM looks at the flood-risk situation as a whole – now and in the future –compares the available options and selects a strategy that is most appropriate to a particular situation.

124 It would often be best to reduce the peak magnitude and duration of a flood **(Section 4.2)**. More or less traditional flood-control measures, such as dykes or embankments, may reduce the probability of flooding below the design level. Zoning measures help to reduce the potential impact should a flood nevertheless occur, by trying to keep society away from the water. There are also other impact-reduction measures, such as floodproofing houses.

125 Early warning systems and emergency measures can reduce damage or casualties when flooding cannot be avoided. The implementation of such measures requires the active involvement of stakeholders. Finally, there is the residual risk when all measures taken were not sufficient to prevent damage, such as when their design capacity is exceeded. When the damage is done, all that remains is to help people out and assist them with relief and recovery (Marchand et al., 2012).

126 Although the flood risk at hand determines what measures will be appropriate, some types of measures can be generally qualified as "low regret". These include:

— Establishing early warning systems and risk-management plans;

— Identifying and mapping "hot spots" for flash flooding;

— Restoring and maintaining the functionality of natural retention areas;

— Safeguarding retention areas in local and regional spatial planning;

— Limiting "inappropriate" development of land use in flood-prone areas; this may include defining zones where development should be considered totally off-limit (e.g. floodways) and zones which could be developed if specific protective measures are adopted (e.g. floodplains); and

— Relocating "inappropriate" land-use activities to low-risk areas.

127 Such preventive measures to reduce flood risk are consistent with the Sendai Framework for Disaster Risk Reduction. The avoided losses in case of a flood generally offer a good return on investment.

Small steps vs "grand" new strategy

128 The success of a strategy will depend on stakeholders receiving an immediate reassurance of increased safety through short-term measures, especially those stakeholders who were or will be directly affected by the flood. Flood management plans need to include both long- and short-term interventions. Often it might be best to begin planning integrated flood management by taking a few concrete small steps. Sometimes, however, it may be feasible to formulate and implement a "grand" new strategy for reducing flood risk. This might be the case shortly after a major flood disaster has occurred, when people are more willing to accept and finance flood-risk

management measures. Such a new strategy should then be already thought out and ready to implement. This requires that options are thoroughly studied beforehand.

4.3.2 Optimal balance of structural and non-structural measures

129 Many societies cannot afford the cost of reducing flood risk through the adoption of high-cost structural measures or through policies which relocate vulnerable land use at high risk of flooding. The side effects of structural measures may be too damaging to the environment or may place a disproportionate burden on a sector of society without suitable or adequate compensation, whereas adoption of certain restrictive land-use regulations may hamper economic development goals of society. In such cases, an appropriate strategy might be to reduce vulnerability through floodproofing, a design of critical infrastructures with transparent coordination, disaster preparedness and flood emergency responses and to avoid future developments that are not floodproofed or protected.

130 Too frequent flooding and its associated agricultural damage may lead to a lack of investment in the agricultural sector. In such cases, a more diversified approach might be necessary, for example the construction of agricultural levees which provide a minimum safety level (e.g. 1:10 year). These may provide sufficient protection for agricultural use but not necessarily for residential or higher value uses.

131 Loss of life and some property damage can be reduced if appropriate disaster response plans are put in place and well-rehearsed. Disaster response should be supported by reasonably accurate and reliable forecasts. Flood-hazard maps should present affected areas, evacuation routes and refuge areas. They should also show information on likely hazardous areas and help society to decide on how best to invest in flood-prone areas. Floodplain zoning and land-use planning are critical to stemming and reversing the trend of escalating economic losses.

132 Effective implementation remains a challenge, particularly in developing economies with population pressures and unplanned developments, and inadequate institutional capacity for enforcement. Society needs to make a concerted effort to change its previous approaches, otherwise disasters which could have been averted through implementation of appropriate measures will repeat themselves, time and time again.

133 Strategies aiming at reduction of flood hazards – through structural measures such as flood embankments or non-structural measures, including afforestation – can only bring partial safety for people inhabiting floodplains. There is no such thing as absolute safety. Floodplain users who assume they have total protection may decide to increase their investments.

134 In such cases, they may experience heavier losses when the protection fails, than they would have otherwise. Taking measures may also cause users to further encroach onto hazardous lands due to the perception of reduced exposure to the hazard and lack of appropriate floodplain zoning and enforcement. This underlines the importance of raising awareness of the flood hazard, making clear that absolute safety for flooding is a myth **(Tool 22)**.

4.3.3 Promoting coherent strategies

135 There are many ways to compile alternative strategies for a certain area from the large portfolio of available measures. Just combining measures which do not conflict in space or effect may produce hundreds of sets of combinations of measures. Such an approach to support policymaking would not be very practical. It is like building a house from materials that are conveniently at hand, instead of asking an architect to make a design and advise on materials to use (FLOODsite, 2009).

136 To promote a coherent strategy, a top-down approach is needed, in which certain principles may guide its design. A top-down approach may produce a strategic framework which can be further

elaborated through a bottom-up approach. A top-down approach will look for coherent strategies, whereas a bottom-up approach will enhance stakeholder engagement and ownership and promote local linkages to other policy domains, such as urban development, nature restoration, etc. In the Netherlands Delta Programme, a top-down and bottom up approach were combined, supervised by the Delta Commissioner, an independent senior government official.

137 Another approach to arriving at design alternatives may correspond to clearly distinguished policies, such as "hold-the-line", "retreat" or "advance the defence line" in flood and coastal plain situations, or by enhancing the resilience or the resistance of the flood-risk system along large rivers.

4.4 Impact assessment of strategies

138 The policy series of APFM provide, through a number of Technical Documents, guidance for assessment of environmental, economic, social and institutional aspects of IFM measures and strategies. There are in addition a number of aspects which may require special attention in both development and impact assessment of strategies:

- Development of strategies should not include measures that create new hazards or shift the problem in time and space, without provision of adequate compensation. Efforts should be made to reduce or compensate for the negative effects of measures on downstream or upstream settlements;
- A strategy should look into and reflect the needs of displaced people. Their vulnerability prior to flooding should be addressed to boost their resilience and well-being after the flood. A cost–benefit analysis that includes social welfare and equity may lead to a different strategy than one based solely on economic efficiency;
- Culture, tradition and religion can play an important role in shaping people's perceptions and actions and should be taken into account in the design and appraisal of strategies, otherwise socially acceptable solutions will not be attained, nor will they be locally supported;
- Gender issues must be acknowledged and incorporated into flood-risk management strategies, in particular in their implementation.

Further reading

- IFM Tool 21: *Effectiveness of Flood Management Measures*
- IFM Policy 4: *Social Aspects and Stakeholder Involvement in Integrated Flood Management*
- IFM Tool 3: *Applying Environmental Assessment for Flood Management*

4.5 Implementation of strategies

A | Institutional arrangements

139 Agreement among stakeholders on the preferred strategy is an important achievement for the project, but does not guarantee its implementation. Besides willingness to cooperate, implementation also requires assignment of tasks to specific organizations, which are subsequently in need of resources. Arrangements and resources should also have been considered while evaluating the alternative strategies. Arrangements are needed that specify these tasks. Moreover, an assessment is needed to ascertain if the organizations have the mandate to cover all project aspects.

140 Once a strategy is selected, it is important that the legal and institutional settings are in place to enable its implementation. The effective enforcement of regulations and maintenance of

infrastructure require an appropriate governance structure. While the use of existing organizations in the strategy is sometimes considered advantageous, new entities may be created to help focus activities and raise the strategy's strategic profile. In the end, it does not matter exactly where a responsibility is located, as long as there is agreement on mandate, information, capacity and financial resources and an incentive exists to communicate efficiently and effectively among all the different actors involved.

B | Financial resources

141 Implementation of measures requires financial resources and hence political commitment at the highest level. There may be a need to bring financial resources together from different governmental departments, donor organizations, international funding institutions or the private sector. Public–private partnerships are cooperative approaches in which financial risks are shared. Private actors will require a return on investments. This means that, in addition to showing that a measure is economically sound, a business case is also required that details the rate of the return and its sources of revenue and expenditure. Such a business case may be supported by strategic flood-loss assessments (see IFM Tool No. 2). If financial resources turn out to be a limiting factor, alternative options should be sought which require less funding (e.g. adopting community-based flood-management strategies).

C | Monitoring

142 Implementation of the strategy may take a long time. Regular communication on progress made, based on monitored results, will help to maintain the commitment created among stakeholders in the planning stage. A well-developed monitoring programme can serve different purposes and should have already been designed during the planning stage. Stakeholders can be actively involved in the monitoring programme to promote interest in the management of their local environment.

Figure 17 — Hydrological monitoring: staff gauge (left) and data-collection platform (right) (Paul Pilon)

143 Because system functionality and its feedbacks are not always well understood, especially when it concerns the impacts of innovative measures or the response of ecosystems or of societal charge, monitoring can also contribute to learning and to establishing if adjustments to the strategy are required. Over time, stakeholders and decision-makers may also revise their perceptions of what the desired situation should be. Monitoring of the physical and socio-economic conditions is thus an important part of adaptive management.

D | Reporting and communication

144 Reporting of monitoring results may be required at both local, national and international levels. For example, the targets and indicators under development of the Sendai Framework for Disaster Risk Reduction 2015–2030 and the SDGs will require national reporting of aggregated local data on many aspects, ranging from loss of life and damage to critical infrastructure or preventive measures taken to reduce flood risks. Communication needs adequate access to data and results of analyses. Such data and information should be shared with the public in a timely and understandable way.

Further reading

- OECD, 2015: *Principles on water governance*
- UNISDR, 2015: *Sendai Framework for Disaster Risk Reduction 2015–2030*

4.6 Reflection and outlook

145 Floods have always occurred and will continue to do so. We may, however, influence their extent and may certainly influence their impact on society. Because of economic development and climate change, flood risk is likely to increase in the future, unless societies make a concerted effort to change their previous approaches. If not, where losses could have been greatly averted through implementation of appropriate measures, disasters will repeat themselves, time and time again.

146 Policymakers need to decide on a best strategy for a particular area, taking into account technical feasibility, financial constraints and environmental considerations, as well as political and societal acceptability. A compromise will often be required between needs and preferences of different stakeholders. Policymaking can be supported by analysis which shows how alternative strategies may perform.

147 The planning of IFM should be approached as an iterative process towards risk-informed decision-making. Reaching agreement on problem assessment and policy objectives is the key to successful planning. Development of a well-balanced strategy should always start with a proper understanding of the flood risk. Not only examining the characteristics of past floods but also looking into possible future situations. The planning process should also answer the question: what flood risk is acceptable and how do we get there?

148 The trigger to such interactive planning process may be an update of an existing flood-risk management plan or a comprehensive response to a recent flood disaster which calls for action. There is not one particular best moment to start an interactive planning process. The important thing is to make a start with the development of well-balanced and well-motivated strategies for IFM. Any time will do: so why not start today!

APFM-RELATED REFERENCES[2]

Concept Paper
APFM Technical Document No. 1

Integrated Flood Management – Concept Paper (third edition)

Flood Management Policy Series
APFM Technical Documents No. 1-5

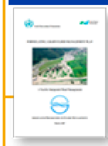
IFM Policy 2: Legal and Institutional Aspects of Integrated Flood Management

IFM Policy 4: Social Aspects and Stakeholders Involvement in Integrated Flood Management

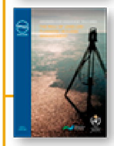
IFM Policy 3: Environmental Aspects of Integrated Flood Management

IFM Policy 5: Economic Aspects of Integrated Flood Management

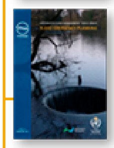
Flood Management Tool Series



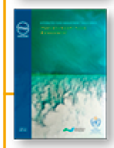
IFM Tool 1: Formulating a Basin Flood Management Plan



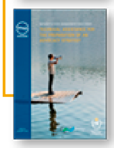
IFM Tool 7: The Role of Land-Use Planning in Flood Management



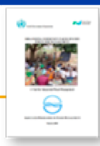
IFM Tool 11: Flood Emergency Planning



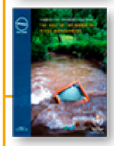
IFM Tool 18: Transboundary Flood Management



IFM Tool 24: Technical Assistance for the Preparation of an Advocacy Strategy



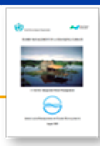
IFM Tool 4: Organizing Community Participation for Flood Management



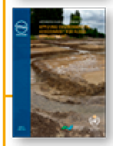
IFM Tool 22: The Role of the Media in Flood Management

IFM Tool 23: Health and Sanitation Aspects of Flood Management

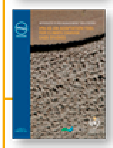
IFM Tool 25: Public Perception of Flood Risk and Social Impact Assessment



IFM Tool 9: Flood Management in a Changing Climate



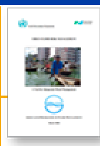
IFM Tool 3: Applying Environmental Assessment for Flood Management



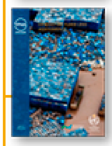
IFM Tool 10: IFM as an Adaptation Tool for Climate Change: Case Studies

IFM Tool 13: Conservation and Restoration of Rivers and Floodplains

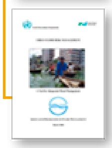
IFM Tool 14: Urban Flood Management in a Changing Climate



IFM Tool 6: Urban Flood Risk Management



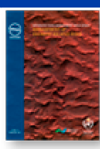
IFM Tool 2: Conducting Flood Loss Assessment



IFM Tool 8: Risk Sharing in Flood Management

Technical Tools

IFM Tool 5: Reservoir Operations and Managed Flows

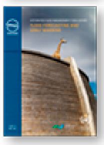


IFM Tool 12: Management of Sediment- Related Risks

IFM Tool 15: Flood Proofing

IFM Tool 16: Management of Flash Floods

IFM Tool 17: Coastal and Delta Flood Management



IFM Tool 19: Flood Forecasting and Early Warning

IFM Tool 20: Flood Mapping

IFM Tool 21: Effectiveness of Flood Management Measures

2 APFM publications are available at www.floodmanagement.info/publications

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For more information, please contact:

Associated Programme on Flood Management
c/o Climate and Water Department
World Meteorological Organization

phone +41 (0) 22 730 83 58
fax +41 (0) 22 730 80 43
e-mail floodmanagement@wmo.int
www.floodmanagement.info

World Meteorological Organization
Communications and Public Affairs Office
7 bis, Avenue de la Paix — P.O. Box 2300
CH-1211 Geneva 2 — Switzerland

phone +41 (0) 22 730 83 14/15
fax +41 (0) 22 730 80 27
e-mail cpa@wmo.int
public.wmo.int

GWP Global Secretariat
Linnégatan 87D — PO Box 24177
SE-104 51 Stockholm — Sweden

phone +46 8 1213 86 00
fax +46 8 1213 86 04
e-mail gwp@gwp.org
www.gwp.org

Deltares
PO Box 177
2600 MH Delft — The Netherlands

phone +31 (0)88 335 8273
fax +31 (0)88 335 8582
www.deltares.nl