Mitigating the Effects of Floods and Erosion In the Niger South Catchment Area through Integrated Flood Management (IFM)

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Abstract

Natural disasters, such as the occurrence of floods, cause much misery, especially in developing countries where low-income earners undergo great stress. Losses due to floods reduce the asset base of households, communities and societies through the destruction of standing crops, dwellings, infrastructure, machinery and buildings, in addition to tragic loss of life.

The goal of IFM is to identify and maximize the net benefits from floodplains, reduce flood risks, and minimize loss of human life due to flooding in a sustainable manner, thereby shifting the emphasis from flood control to flood management. The method integrates land and water resources management in the river basin, through the adoption of a three-fold approach: i) avoiding; ii) reducing; and iii) mitigating adverse environmental impacts, without compromising flood management objectives. These approaches are put into perspective in the Niger South Catchment Area, which constitutes parts of the lower Niger River and where erosion and the associated flooding constitute serious environmental hazards. The dominant types of erosion, as well as the human activities and natural occurrences that constitute erosion menace in the catchment are identified and used as a guide to recommend erosion and flood management strategies. Use of flood control dams and reservoirs, as a means of attenuating flood peaks downstream, are recommended. Based on hydrological forecasts, the reservoirs can be regulated to minimize the chances of coincident peaks from floods in different tributaries and synchronize with the main stem of the river downstream. Public education and flood warnings, with clear and accurate messages, as well as timely emergency preparedness are recommended as complements to all forms of intervention.

Keywords: Floods, Erosion, Niger South Catchment, Integrated Flood Management, Environmental Impact

Introduction

The goal of IFM is to maximize the net benefits from floodplains, to reduce flood risks, and to minimize loss of human life due to flooding in a sustainable manner. The need for a paradigm shift in thinking from flood control to flood management is the catalyst behind the concepts of IFM. It integrates land and water resources management in the river basin. Integrated Flood Management adopts a threefold approach of i) avoiding; ii) reducing; and iii) mitigating adverse environmental impacts without compromising flood management objectives. It is desirable to minimize the negative impacts of flood management interventions that limit natural productivity, health and services provided by the ecosystem, including flood alleviation processes, to a reasonably practical level.

Natural disasters cause much misery, especially in developing countries where they cause great stress among low-income earners. Approximately 70 per cent of all global disasters are linked to hydro-meteorological events Flooding poses one of the greatest natural risks to sustainable development. Flood losses reduce the asset base of households, communities and societies through the destruction of standing crops, dwellings, infrastructure, machinery and buildings, quite apart from the tragic loss of life. In some cases, the effect of extreme flooding is dramatic, not only at the individual household level, but in the country as a whole. There is a need, therefore, to find ways of making life sustainable in the floodplains – even if there is considerable risk to life and property. The best approach is integrated management of floods.

An understanding of the interplay between floods, the development process and poverty is vital to ascertain the way in which current and future development processes can and do increase flood risk. A population might be poor because it is exposed to flooding or it might be exposed to flooding because it is poor and occupies the most vulnerable land. The appropriate method of intervention will differ according to which diagnosis is correct. Further, a community with a weak asset base and few multipliers of community well-being is exposed to many different disturbances, some of which may have a greater impact than floods. Decision-makers and development planners at all levels need to be sensitive to this prospect.

Extreme demands on natural resources due to population growth have forced people and their property to move closer to rivers in many parts of the world. Flood control and protection measures have encouraged people to utilize newly protected areas extensively, thereby increasing flood risks and consequent losses. At the same time, various other activities for development and improvement of life, livelihoods and human security are drivers of environmental and ecosystem degradation. Flood management policies and practices have to be viewed within the overall context of such drivers. It is, therefore, extremely important to balance development imperatives, flood risks, social and economic vulnerability, as well as sustainable development vis-à-vis the preservation of ecosystems.

Defining Integrated Flood Management

Integrated Flood Management is a process of promoting an integrated – rather than fragmented – approach to flood management. It integrates land and water resources development in a river basin, within the context of Integrated Water Resources Management (IWRM), and aims at maximizing the net benefits from the use of floodplains and minimizing loss of life from flooding. Globally, both land – particularly arable land – and water resources are scarce. Most productive arable land is located on floodplains. When implementing policies to maximize the efficient use of the resources of the river basin as a whole, efforts should be made to maintain or augment the productivity of floodplains. On the other hand, economic losses and the loss of human life due to flooding cannot be ignored. Treating floods as problems in isolation almost necessarily results in a piecemeal, localized approach.

Integrated Flood Management calls for a paradigm shift from the traditional fragmented approach of flood management. Integrated Flood Management recognizes the river basin as a dynamic system in which there are many interactions and flux between land and water bodies. In IFM, the starting point is a vision of what the river basin should be. Incorporating a sustainable livelihood perspective means looking for ways of working towards identifying opportunities to enhance the performance of the system as a whole. The flows of water, sediment and pollutants from the upper catchments of the river into the coastal zone (ridge to reef) – often taken to extend dozens of kilometres inland and to cover much of the river basin – can have significant consequences. As estuaries embrace both the river basin and the coastal zone, it is important to integrate coastal zone management into IFM. Figure 1 depicts an IFM model.

It has to be recognized that the objective in IFM is not only to reduce the losses from floods but also to maximize the efficient use of floodplains with the awareness of flood risk – particularly where land resources are limited. That is, while reducing loss of life should remain the top priority, the objective of flood loss reduction should be secondary to the overall goal of optimum use of floodplains. In turn, increases in flood losses can be consistent with an increase in the efficient use of floodplains in particular and the river basin in general.

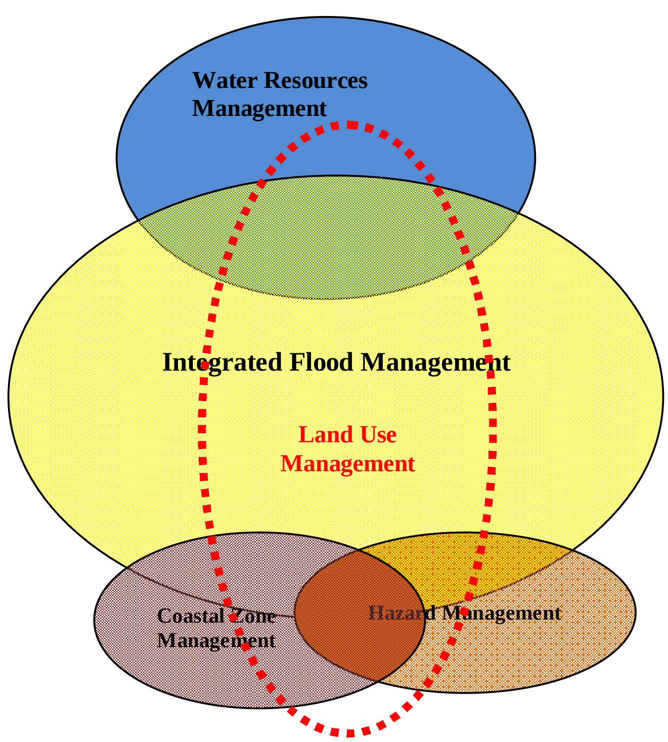

Figure 1: Integrated Flood Management Model

The Niger South Catchment

Nigeria is the final downstream country through which the Niger River flows, and contains 28.3 percent (424,500 km^2) of the basin area. The Niger Basin extends across 20 of the 36 States of Nigeria and comprises two main rivers, the Niger and the Benue, and 20 tributaries. Of Nigeria's major rivers, more than half are in the Niger River Basin. Their combined length accounts for almost 60 percent of the total length of all important rivers in Nigeria (Figure 2). Almost 60 percent of Nigeria's population, or about 67.6 million inhabitants, live in the Basin. These Nigerians comprise 80 percent of the population of the entire Basin. Given Nigeria's size and location, its agricultural production, both rain fed and irrigated, is substantial.

The Lower Niger River and the Niger Delta hydrographic region of the Niger River Basin is approximately the Hydrologic Zone 5 in Nigeria. States in the Niger South Catchment include Delta, Rivers**,** Bayelsa, parts of Edo, Anambra and Kogi States. At Lokoja, the Niger River enters the Lower Niger River segment, which includes the Niger Delta (Figure 2). Also at Lokoja before reaching the Niger Delta, the Niger River is joined by its major tributary, the Benue River, which originates in the highlands of Cameroon's Adamawa Plateau. From Lokoja, the Niger River takes a north to south direction for 200 km; it receives only a few small tributaries, including the Anambra, on the left bank, which drains a basin with significant rainfall. Onitsha is the last monitoring station on the river. The Lower Niger flows for another 100 km and the lower valley progressively transforms into the vast Niger Delta covering approximately 30,000 km^2, with no fewer than 30 outlets to the ocean. The main course of the Niger takes the name of Nun as it crosses the Niger Delta and discharges to the Gulf of Guinea, 4,200 km from its source in Guinea.

Soil Erosion and Flooding

For many communities in the Niger South Catchment, erosion and the associated flooding constitute serious environmental hazards. Different types of erosions, such as sheet, rill, and gully, are pervasive in Anambra and Edo States, and to a lesser extent in Kogi State. However, gully erosion constitutes the most significant threat to the survival of individuals and communities (Figure 3). Human activities, such as bush burning, deforestation, improper farm practices, and, more importantly, construction activities (building of roads, houses, industries), that undermine natural landscape or drainage systems account for much of the erosion menace plaguing the States. However, given the unconsolidated underlying geologic formations in these areas, rainfall intensity and duration is the most important natural cause of soil erosion (Okpara, 1993). Increase in the frequency of heavy rains and flooding had lead to widespread erosion and siltation with more dramatic impact on the areas. Its impacts include destruction of valuable property, loss of farmland and livelihood, loss of soil nutrients and biodiversity, productivity collapses, and loss of flora and fauna (e.g. fishes in rivers and streams) due to the transportation of sand deposits or pollutants to other natural ecosystems (Figure 4). Loss of productivity and valuable property undermine food security, personal security, and social order in a community with consequences for internal displacement. Although climate change may not be the cause of soil erosion in the catchment, it is already amplifying its impact due to severe precipitation. Consequently, unchecked or severe erosion has lead to increased demand by local people on governments (Federal, State and Local) and has precipitated conflicts.

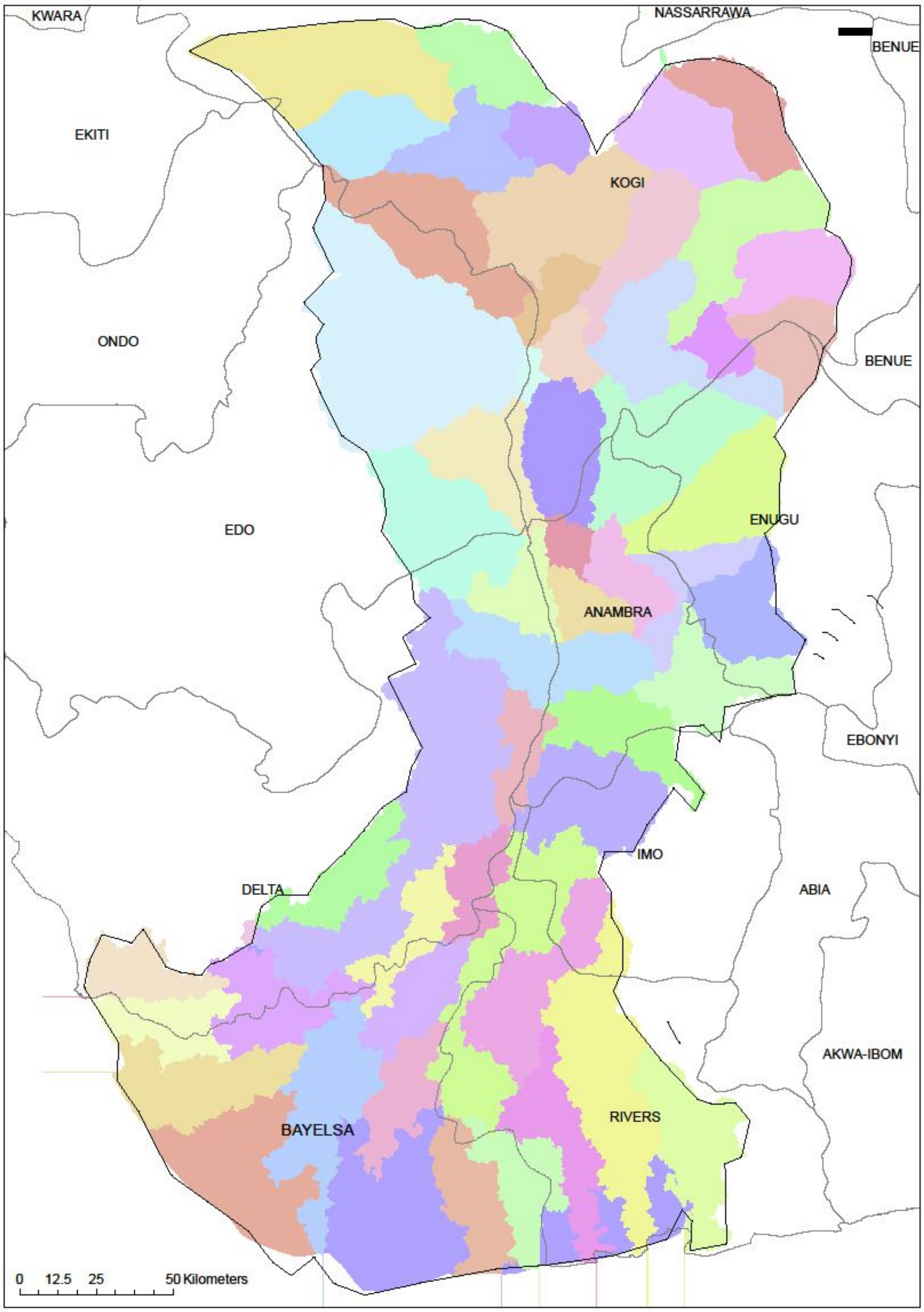

Figure 2: The Niger South catchment

Figure 3: Farm erosion in Anambra State, Nigeria

Coastal Erosion and Flooding

Coastal erosion and flooding is the most important environmental problem pervasive in the Niger Delta segment of the Niger South Catchment (Figure 4). Nigeria has a coastline of approximately 853 km, and the Niger Delta accounts for about 450 km of the coastal zone. Over 75% of the 30 million inhabitants of the Niger Delta region live along the coastal area and survive mainly on fishing and agriculture. The problem of coastal erosion and flooding due to sea-level rise and storm surges constitute a significant source of threat to life, property, livelihoods, and infrastructure in the Niger Delta region (Ezirim, 2008b). This is made worse by the destruction of mangrove forests due to oil exploitation activities. Flooding is widespread in the Niger Delta because of low relief, the reduced hydraulic capacities of water channels, and high rainfall. In the mangrove swamp forest areas, diurnal tidal movements result in floods, exacerbated by rising sea levels, coastal erosion and land subsidence (UNEP, 2006).

Figure 4: Urban flooding in Yenagoa, Balyesa State, Nigeria

Interestingly, it has been noted that severe flooding in the Niger Delta has become more frequent with floods wiping out crops and disrupting traditional farming practices (Best and Lawson, 2008). Worst still, a UN report has estimated that about 30% of Africa‘s coastal infrastructure, including coastal settlements in the Gulf of Guinea, Senegal, the Gambia, and Egypt, could be inundated by 2085 due to climate change (UNEP, 2006). Although scientists generally dispute the warning that sea levels will rise by 2 m by the year 2010, it is strongly estimated that a 0.2 meter rise in sea level would lead to displacement of about 200 villages in the Niger Delta region. A projected sea level rise of more than 1 m could flood much of the Niger Delta and force up to 80 percent of the delta‘s population to higher ground, with a consequent property damage that the IPCC estimated at $9 billion (World Bank, 1996).

General Methods of Controlling Floods

Flood Control Dams and their Reservoirs

Flood control dams store all or a portion of the flood waters in the reservoir, particularly during peak floods and then releases the water slowly. Typically, the principal use of such dams is to store a portion of the flood volume in order to delay and attenuate flood peaks downstream. Space within a reservoir is generally reserved to store impending floods. Based on hydrological forecasts, the reservoir is regulated in a way to minimize the chances of coincident peaks from floods in different tributaries synchronizing in the main stem of the river downstream. Small to medium floods generated from the catchment are fully captured by the reservoirs. However, extreme flood events are only partially attenuated and their transformation downstream is delayed. The extent of attenuation depends on the available storage capacity vis-à-vis the magnitude of the flood event. The main performance parameter in assessing the flood control benefits of a reservoir is, therefore, the extent of the flood peak reduction during extreme events.

Many dams have multiple purposes and flood management may be required only for a few days or weeks in any particular year. Potential conflicts between flood management objectives (where storage space in the reservoir is required) and hydropower and irrigation (where it is desirable to keep the storage capacity as filled as possible) make it difficult to operate a multiple purpose reservoir. While allocating water for various uses, the need to maintain environmental flows should also be addressed. This should not only be guided by the percentage of the total flows released, but also by the need for variability of outflows in the downstream of a storage reservoir to be mimicked to maintain near-pristine conditions.

Sediment and Organic Material

Dams also disrupt the natural flow of sediments and organic materials. As stream flow slackens in the reservoir, the sediment transport decreases and suspended sediment along with the organic material, which provides vital nutrients for downstream food webs, also drops out and is lost to the downstream ecosystem. The organic silt is mostly retained in the reservoir, instead of fertilizing the downstream flood plains, estuarine and coastal ecosystems. The elimination or reduction of high flood events changes the structure and functioning of the downstream floodplain ecosystems. As the river remains within its channel for long periods of time, the lateral connectivity between the river channel and their fringing wetlands is lost.

The availability of resources to the food chain downstream is affected in various ways. The reservoir exports plankton and algae in the flow releases. On the other hand, there is a lack of organic matter such as wood and leaves, which are retained in the reservoir. In most cases, the turbidity of downstream water is decreased below a reservoir, which may lead to increased primary productivity in the reach. Algal growth may occur in the channel immediately downstream from dams because of the nutrient loading of the reservoir releases. With a decrease in flood magnitudes downstream of a dam, there is an invasion of new varieties of plants into the river sand bars and islands, resulting in reduced conveyance capacity of the river during flooding.

Sediment-depleted water released from dams can erode finer sediments from the receiving channel, thereby scouring the downstream streambed and banks until the equilibrium bed load is re-established. It may also result in coarsening of the streambed which, in turn, reduces habitat availability for many aquatic species living in or using interstitial spaces. Without new sources of sediment, sand and gravel bars alongside and within streams are eventually lost, along with the habitats and species they support. In addition, as the stream channel becomes incised, the water table underlying the riparian zone also lowers, thereby affecting the composition of vegetative communities within the stream corridor.

Other methods of controlling floods are detention and retention basins, bye-pass and diversion channels, and channelization.

The traditional management response to a severe flood was typically an ad hoc reaction – the quick implementation of a project that considered both the problem and its solution to be self-evident, and that gave no thought to the consequences for upstream and downstream flood risks. Thus, flood management practices have largely focused on reducing flooding and reducing the susceptibility to flood damage. Traditional flood management has employed structural and non-structural interventions, as well as physical and institutional interventions. These interventions have occurred before, during and after flooding, and have often overlapped.

Source controls intervene in the process of the formation of runoff from rainfall or snowmelt, and take the form of storage in the soil or via the soil. The use of this strategy normally considers the consequential effects on the erosion process, the time of concentration in the soil and the dynamics of evapo-transpiration. The assessment of the likely effectiveness of source control also considers pre-flood conditions such as the state of saturation of the soil, and whether or not the ground is frozen. Thus, a potential drawback with some forms of source control, and other forms of land-use modification such as afforestation, is that the capacity to absorb or store rainfall depends on the antecedent conditions of the catchment.

Surface water storage, through such devices as dams, embankments and retention basins, is a traditional approach to attenuating flood peaks. Water storage modifies floods by slowing the rate of rising waters, by increasing the time it takes for the waters to peak and by lowering the peak level. More often than not, such storage serves multiple purposes, and flood storage can be the first casualty in any conflict among purposes. Moreover, by completely eliminating the low floods, such measures can give a false sense of security. Storage has to be used in an appropriate combination with other structural and non-structural measures.

Seemingly self-evident, but regularly overlooked in practice, is the need to make flood management a part not only of the planning and design, but also of the operation of reservoirs. Releases from reservoirs can create risks, and the careful operation of reservoirs can minimize the loss of human life and property due to such releases. In this context trans-boundary cooperation is indispensable. Increasing the carrying capacity of a river changes its natural morphological regimes and ecosystem, affects other river uses and has a tendency to shift the problem spatially and temporally. Deepening of channels may also affect the groundwater regime in the region. Dikes or flood embankments are most likely to be appropriate for floodplains that are already intensely used, in the process of urbanization, or where the residual risks of intense floodplain use may be easier to handle than the risks in other areas (from landslides or other disturbances, for example).

Flood warnings and timely emergency action are complementary to all forms of intervention. A combination of clear and accurate warning messages with a high level of community awareness gives the best level of preparedness for self-reliant action during floods. Public education programmes are crucial to the success of warnings intended to preclude a hazard from turning into a disaster. Evacuation is an essential constituent of emergency planning, and evacuation routes may be upward into a flood refuge at a higher elevation or outward, depending upon the local circumstances. Outward evacuations are generally necessary where the depths of water are significant, where flood velocities are high and where the buildings are vulnerable.

Integrated approach to flood management therefore calls for a best mix of structural and non-structural measures. An isolated flood management option may achieve a certain objective, e.g. protection of a certain area, but cannot address the various objectives that should be addressed at the river basin level. The residual risks associated with structural solutions, for example due to uncertainty in the input information for analysis of these options or due to a series of chain failures of structural control and protection works, have to be taken into account.

Challenges of Flood Management

Key challenges of flood management that need to be addressed in an integrated approach include:

- Population growth and economic growth exert considerable pressure on the natural resources system;
- Increased population and enhanced economic activities in floodplains further increase the risk of flooding;
- Designing for large floods must account for the likelihood of failure in cases of floods of magnitude below the notional design standard;
- Riverine aquatic ecosystems provide such benefits as clean drinking water, food, materials, water purification, flood mitigation and recreational opportunities;
- The magnitude and variability of the flow regime needed within a basin to maximize the benefits to society and to maintain a healthy riverine ecosystem must strike a balance between competing interests in the river basin;
- Intensity and duration of precipitation events are likely to increase due to climate change, resulting in an increase of the frequency of major floods in many regions.

Elements of Integrated Flood Management

Integrated Flood Management takes a participatory, cross-sectoral and transparent approach to decision-making. The defining characteristic of IFM is integration, expressed simultaneously in different forms: an appropriate mix of strategies, carefully selected points of interventions, and appropriate types of interventions (structural or non-structural, short- or long-term). An IFM plan should address the following six key elements that follow logically for managing floods in the context of an IWRM approach (Figure 1).

- Flood management plans should include drought management, and should take measures to maximize the positive aspects of floods such as by retaining part of flood flows for use in crop production.
- IFM recognizes the need to manage all floods and not just those floods up to some design standard of protection. Flood plans must consider what will happen when a flood more extreme than the design standard flood occurs, and must foresee how such a flood will be managed.

- Urban flood plans must manage both storm water quantity and the effects of storm water on water quality.

Integration of Land and Water Management

Hydrological responses to rainfall strongly depend on the local characteristics of soil, such as water storage capacity, infiltration rates and preceding rainfall conditions. The type and density of vegetation cover and the land-use characteristics are also important in understanding a catchment's response to rainfall. Human alterations to catchments can play a significant role in increasing flood hazards if the runoff generation process is changed, especially when the infiltration capacity of the soil decreases or a change in soil cover occurs. Environmental degradation and uncontrolled urban development in high-risk zones, such as historical inundation plains and the bases of mountain ranges, lead to an increased vulnerability to catastrophic events for those communities on the floodplains. Changing pervious natural surfaces to less pervious or impervious artificial surfaces, leads to an increase on storm water runoff rates, and the total volume of runoff may also affect water quality. Changes in natural water storage as a consequence of urbanisation also cause significant changes to the temporal characteristics of runoff from an urbanized area, such as shortening the runoff travel time, and can result in an increased incidence of flash flooding.

Land-use planning and water management should be combined in one synthesized plan with a certain common field, such as the mapping of flood hazards and risks, to enable the sharing of information between land-use planning and water management authorities.

Flood management needs to recognize, understand and account for linkages between upstream and downstream to realize synergies in improving river basin performance.

Management of Risk and Uncertainty

Risk and uncertainty in flood management should take the following into consideration:

- Flood risks are related to hydrological uncertainties which are subordinate to social, economic and political uncertainties: the biggest and most unpredictable changes are expected to result from population growth and economic activity.
- Flood risk management consists of systematic actions in a cycle of preparedness, response and recovery, and should form a part of IWRM.
- Risk management calls for identification, assessment, and minimization of risk, or elimination of unacceptable risks through appropriate policies and practices.

Adoption of a Best-Mix of Strategies

Table 1 displays the strategies and options generally used in flood management. The adoption of a strategy depends critically on the hydrological and hydraulic characteristics of the subject river system and region. Three linked factors determine which strategy or combination of strategies is likely to be appropriate in a particular river basin: the climate, the basin characteristics and the socioeconomic conditions in the region. The nature of the region's floods and the consequences of those floods are functions of these linked factors. Optimal solutions depend upon knowledge that is complete, precise and accurate. In light of the uncertainty about the future, flood management plans should adopt strategies that are flexible, resilient and adaptable to changing conditions. Such strategies would be multi-faceted with a mix of options. Successful IFM looks at the situation as a whole, compares the available options and selects a strategy or a combination of strategies that is most appropriate to a particular situation. In addition, flood management plans need to include both long-term and short-term interventions.

Table 1. Strategies and Options for Flood Management

Strategy	Options
Reducing Flooding	Dams, levees and flood embankments. High flow diversions. Catchment and managements.
Reducing Susceptibility to Damage	Floodplain regulation Development and redevelopment policies. Design and location of facilities Flood proofing Flood forecasting and warning
Mitigating the Impacts of Flood	Information and education Disaster preparedness Post-flood recovery Flood Insurance
Preserving the Natural Resources of Flood Plains	Floodplain zoning and regulation

Participatory Approach

Identification and involvement of all stakeholders is an important component of IFM. The following are important in ensuring participatory approach:

- IFM should encourage the participation of users, planners and policy-makers at all levels and should be open, transparent, inclusive and communicative; this requires the decentralization of decision-making, and includes public consultation and the involvement of stakeholders in planning and implementation.
- IFM has to keep gender, religious and culture differences in perspective.
- It is important to make use of strengths of both "bottom-up" approach and "top-down" approach in determining the appropriate mix.
- River basin committees or organizations, at basin or sub-basin levels, can provide appropriate coordination and cooperation across functional and administrative boundaries.

Adoption of Integrated Hazard Management Approaches

- A holistic approach to emergency planning and management is preferable to a hazard-specific approach, and IFM should be part of a wider risk management system.

- Integrated Hazard Management Approach consequently ensures consistency in approaches to natural hazard management in all relevant national or local plans.
- Early warnings and forecasts are key links to the series of steps required to reduce the social and economic impact of all natural hazards, including floods.

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