Chapter 7: Structural Measures for Flood Management in the Context of Integrated Water Resources Management

The basis of integrated water resources management (IWRM) is that different uses of water are interdependent. Managers, whether in the government or private sectors, have to make difficult decisions on water allocation. More and more they have to apportion diminishing supplies between ever-increasing demands. Drivers such as demographic and climatic changes further increase the stress on water resources. The traditional fragmented approach is no longer viable and a more holistic approach to water management is essential (UN-Water 2008).

In the words of the Global Water Partnership: "IWRM is a process which promotes the coordinated development and management of water, land, and related resources, in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment. ... It is a cross-sectoral policy approach, designed to replace the traditional, fragmented sectoral approach to water resources and management that has led to poor services and unsustainable resource use. IWRM is based on the understanding that water resources are an integral component of the ecosystem, a natural resource, and a social and economic good" (GWP 2012).

The concept of IWRM offers solutions to the water crisis by linking water to other vital resources in a holistic manner and viewing the whole water cycle together with human interventions as the basis for sustainable water management. The specific approaches used need to be tailored to the individual circumstances of a country or local region.

Integrated Flood Management

Sustainable and effective management of water resources demands a holistic approach, linking social and economic development with the protection of natural ecosystems and appropriate management links between land and water uses. Therefore water-related disasters such as floods and droughts that play an important part in determining sustainable development also need to be integrated within water resources management.

Flood management plays an important role in protecting people and their socioeconomic development in floodplains. Unfortunately, strategies that rely on structural solutions (dams and reservoirs, embankments, bypass channels) alter the natural environment of the river, resulting in losses of habitat, biological diversity, and productivity of natural systems. The need for sustainable development has highlighted the importance of addressing the negative consequences on the environment of these flood-protection measures. Environmental degradation has the potential to threaten human society in the areas of safety of life, economic wellbeing, and food and health security. Thus it is essential to consider environmental impacts in flood management activities (WMO 2006b).

There are no universal solutions that determine environmentally-friendly flood management practices. Practices should be adopted that suit the particular circumstances of a basin using the three-way approach of avoiding, reducing, and mitigating adverse environmental impacts without compromising the flood management objective. This, in essence, is integrated flood management (IFM), a process that promotes an integrated – rather than fragmented – approach. IFM integrates land and water resources development in a flood plain within the context of IWRM, and aims to maximize the net benefits from flood plains while conserving the environment and minimizing loss to life, infrastructure, and property from flooding (APFM 2004; WMO 2006a). An integrated approach means considering all the impacts in a holistic manner by looking at linkages and interdependencies between upstream and downstream areas as well as between the river course and the flood plain. This means looking at the whole river basin with its natural boundaries in line with the flow patterns of water, rather than individual administrative areas.

IFM uses a multidisciplinary approach to flood management and involves a wide range of stakeholders, including professionals from different agencies and fields directly or indirectly related to flood management, and representatives of those most likely to be affected by flooding, as well as by anti-flooding measures. This chapter describes some integrated basin wise approaches to flood management, using some of the techniques described in the previous chapters and taking into account human and environmental needs.

Passive Flood Control Measures

Passive flood control measures refer to the avoidance of activities that accelerate flood discharge. The main purpose is to favour natural flow retention through the interdisciplinary management of water and land resources along watercourses and preserving and improving the general environmental conditions. The main control measures are as follows (Colombo et al. 2002: 29–30):

- adaptation of cultivation in the neighbourhood of watercourses to flooding, taking into account the resistance and susceptibility to damage of different crops;
- development of forms of cultivation suitable for the local conditions in river plains;
- transfer of local cultivation to safer areas;
- public acquisition of land and structures that are more frequently subjected to floods;
- safeguarding of available lowland run-off zones covered by woods, coppice, and grassland;
- cessation of construction in flood plain areas;
- restoration of retention areas through withdrawal and displacement of dams as well as reactivation of old arms;
- preservation of natural-like trenches, and environmentally-friendly development of already trained water systems;
- promotion of land suitable for water retention or needed for building flood protection structures in land use plans;
- setting up integral land consolidation procedures both to favour passive control and foster sustainable agricultural practices; and
- building or preservation of structures to slow runoff.

Flood Storage Reservoirs

Flood storage reservoirs or basins control floods or flash floods by detaining and storing water and then releasing it slowly at a controlled rate, thus reducing the destructive flood peak. In this method, effective flood mitigation is obtained by having an adequately-sized reservoir or group of reservoirs immediately upstream from the area to be protected. The most effective reservoirs for flood control are those located in a broad floodplain. However, these require the construction of a very long dam or embankment bounding the area where the flood water is to be stored, and a large area of valuable agricultural land would have to be flooded. Such a reservoir would catch most of the run-off water that would cause flooding to the nearby area. Sites further upstream require smaller dams and less valuable land, but they are less effective in reducing flood peaks (ADPC/UNDP 2005).

The terms ‘detention’ and ‘retention’ basins are sometimes used interchangeably, but there are some differences between them.

A detention basin is an area where excess storm water is stored or held for a short time before it drains out to a natural watercourse, or for a longer time for agricultural, consumptive, aesthetic, recreational or other uses. The water retention also helps reduce the amount of pollutants transported by runoff (Colombo et al. 2002). Detention basins are sometimes called dry ponds or holding ponds because they eventually empty out to downstream.

In some cases water remains in the basin almost indefinitely, reduced only by the net amount lost by evaporation and absorption at the surface. Such basins are called retention basins, wet ponds, or wet detention basins.

The design of water detention or retention basins includes a number of factors such as the size, stability, and impermeability of the dam or embankment, the design of the elevation and capacity of the outlet for releasing the water, and the storage volume required. Diversions are often required to channel the flow from the main river to the basin area. A variety of engineering work is required to install flood storage reservoirs.

Some of the specific considerations in the planning, design, operation, and maintenance of water retention basins have been summarized by Colombo et al. (2002):

- Hydrological elements such as the basin capacity and spillway should not be undersized. However, large retention facilities might have a high ecological impact.
- Correct hydraulic dimensioning of the operation facilities is needed similar to that for conventional dams, including correct design of the bottom outlet, the spillway, and the bypass.
- The geological setting must be taken into account, including the geotechnical properties of soils and groundwater conditions, especially for permanent lakes.
- Ecological aspects should be considered, for example the ecological continuity of the flowing water, sediment accumulation, and channel shaping downstream of the basin. The bottom outlet should be designed so as to minimize interruption of the ecological continuum of the water flow. Wherever possible, the construction of retention installations should be accompanied by ecological compensating measures. Limnological development and successional use has to be analysed if a permanent lake is to be planned.
- Bioengineering criteria should be adopted that favour restoration of the natural condition of the river course and thus the increase of biodiversity within the riparian habitat, especially in urban areas.
- The commissioning, operation, and maintenance phases should consider safety of the population in connection with urban and industrial development, land reclamation, and new traffic routes, which usually emerge in the vicinity of retention basins.
- Areas subject to flooding during events with a return period of five years or less should not be used as arable land. At best, they can be used as grassland.
- Forest management should take into account the resistance of the tree cover against floods as well as its fitness for the site. Storage of timber in the retention area should be forbidden.
- Recreational facilities must either be positioned outside the retention area or be designed to withstand floods, or appropriate safety measures should be taken.
- Use of basins for power generation, water replenishment, and/or storage of drinking and service water must be secondary to the use as a flood retention basin. In general, any secondary use of such basins should have no noticeable influence on the main purpose.
- If provision for habitats and nature conservation is made in the basins, natural succession should be the prime objective. Again, this use must be secondary to flood reduction.
- Existing retention basins should be kept in good condition and adjusted to current engineering standards based on revised hydrological and slope stability conditions.
- A qualified inspector should be appointed for major retention basins and an overseer (e.g., a water licensee) for other basins.
- The earth dam surfaces should be protected against erosion and infiltration by surface water. A dense vegetation cover such as turf can be effective.
- Dams or embankments, emergency spillways, and outlets should be checked periodically (and always after each storm) for erosion damage, piping, settling, seepage, or slumping along the toe or around the barrel. Regular maintenance should be carried out. Maintenance on the outside of the dam includes removing debris from around the inlet, mowing the embankment to keep bushes and trees from becoming established, checking the outlet pipe for cracks or other damage, and removing rodents that burrow into the dam.
- Sediments within the basin must be periodically removed and disposed of in order to maintain the volume for storage of flood water. As a rule of thumb, accumulations over one-half the design volume should not be allowed.
- The longitudinal structures enclosing the basin must be planned or adapted with maintenance roads in order to guarantee accessibility to people and machines.

In addition to the general recommendations above, there are some specific recommendations for lateral retention basins (i.e., basins constructed on flat areas close to the water course).

- Locate in central or lower portions of the catchment, where the existence of flat areas enables identification of large surfaces for the storage of significant volumes of flood water.
- Land planning of river catchments should identify bonds and prescriptions for preservation of areas that can potentially be used for lateral retention basins.
- The entrance and exit points between the river course and the basin must have protective structures installed in order to avoid erosion.
- Construction of artificial lakes and islands, and plantation of small wooded areas may favour the colonization of many different plant species.

River Corridor Rehabilitation and Restoration

River corridor enhancement, rehabilitation, and restoration is a concept that involves different activities with a degraded river or stream in order to return it to its natural condition. In practice, restoring a river or stream to its original state is almost impossible. However, some limited enhancement works can be done to restore the river corridors.

The general environment of the riparian zone and the ecological role of the riparian vegetation must be taken into account in interventions on fluvial systems. In addition to its ecological function for aquatic habitats and terrestrial wildlife, this vegetation provides important socioeconomic benefits (e.g., flood defence, scenic and aesthetic quality, and leisure) as well as regulation of ecosystems (e.g., riverbed stability, erosion control, filtering/retention of sediments, flood defence, wastewater treatment, and pesticide control).

Ecologically oriented interventions in the riparian vegetation should consider the following criteria (Colombo et al. 2002: 32):

- keeping a structure of vegetation of different ages that allows the presence of both shrub and tree layers;
- periodic cutting and selective thinning of adult trees that present problems of stability, and elimination of invading species in favour of autochthonous species and, possibly, valued species; and
- keeping shrubby vegetation where possible, since it can bend easily during floods and does not obstruct bridge sections.

The influence of periodical flooding processes, sedimentation, and erosion can be felt in the transition areas of riparian vegetation. Structural measures to regulate the river, such as large hydraulic infrastructures that aim to improve water flow conditions, usually cause environmental changes throughout the fluvial ecosystem. These can be reflected in the destruction of habitats and vegetation, alteration of physico-chemical water characteristics, and other modifications at the level of the whole ecosystem.

The overall interventions on river corridors should focus on maintenance, rehabilitation, and restoration of well-structured corridors consisting of wide lateral strips containing varied topographical elements and populated by autochthonous grass, shrub, and tree species.

Table 16 summarizes some of the main measures used to enhance, rehabilitate, and restore river corridors. The most common efforts focus on enhancing riparian zones by planting grasses, bushes, and trees; stream bank stabilization; the removal of dams and other man-made structures; and stocking the river with fish or other living organisms.

The following principles related to the ecology of river systems can help practitioners when planning and undertaking rehabilitation projects (Cottingham et al. 2005).

- Riverine ecosystems are structured hierarchically, with important processes operating at a range of spatial scales, from large regional and catchment scales, to sub-catchment and reach scales, and ultimately down to smaller site and micro-habitat scales.
- Riverine ecosystems can also be highly dynamic and variable in space and time. As such, stream ecosystems in good condition are resilient to periodic natural ecological disturbances, such as droughts, floods, and fires, which can help drive important physical and biological processes.
- Hydrological connectivity provides strong spatial connections along river networks and between rivers and their floodplains, and plays a key role in ecological processes such as nutrient and energy cycling (spiralling), and the recovery of populations and communities following natural and human induced disturbance.

Table 16: Measures to enhance, rehabilitate and restore river corridors

Riverbed	Margin	Flooding area
Cleaning and removal of obstructions	Cleaning and removal of obstructions, managing damaged trees	Cleaning and removal of obstructions
Recovery and restoring of natural conditions	Recovery and restoring of natural conditions	Recovery and restoring of natural conditions
Ecological and aesthetic valorization	Ecological and aesthetic valorization	Ecological and aesthetic valorization
River-bed modification	Revegetation planting and seeding	Revegetation planting and seeding
Meandering	Stabilization, protection, and/or natural, semi-natural, and artificial revetments	Increasing hydrological communication with the river bed and margins
Narrowing/widening	Plaiteds, reed rhizomes	Level lowering
Ecological flow regime	Gabions, geo-textiles, foundation-stones, and similar, used with or without vegetal materials	Humid zones and increase of habitat diversity
Substratum modification	Flow deflectors	Flood retention basins
Silt traps	Slope modelling	Compartmentalization systems
Alternative river-beds	Buffer strips	

Source: Colombo et al. 2002: 35

- Stream rehabilitation activities are embedded in the hierarchical organization mentioned above, and should begin with an examination of large-scale factors that might constrain processes acting at smaller spatial scales. Longitudinal processes should also be considered, as the source of degradation can be some distance from the locations where ecosystem impacts are evident and rehabilitation is proposed, and loss of connectivity may constrain the biotic response to physical changes in the channel.
- The most effective form of rehabilitation is to prevent degradation of river ecosystems in the first place. The highest priority should go to protecting the remaining high quality river systems (or parts thereof), particularly those that serve as important refugia and are a potential source of colonizing organisms.
- Rehabilitation should aim to increase the resilience of river ecosystems to natural (and further human-induced) disturbances so those ecosystems become self-sustaining and capable of responding to large-scale processes such as climate change and the condition of catchments.
- Where possible, rehabilitation efforts should aim to work with natural processes. This means considering rehabilitation at broader scales than is often practised and choosing realistic rehabilitation targets. Given the nature of human impacts, it is unlikely that degraded streams can be returned to their pre-disturbance condition. In such circumstances it can be inappropriate to adopt 'return to natural' as the target for rehabilitation.
- The fragmentation of populations, coupled with sometimes low levels of connectivity (whether because of human interventions such as barriers or naturally poor dispersal abilities), means that many plant and animal species will respond to habitat restoration only very slowly. Isolation may therefore be a major constraint to biotic recovery, and in some cases this could take years or decades. Further, local extinctions may preclude full population recovery.

For rehabilitation to be successful, proper planning and interaction with stakeholders must complement the ecosystem perspective listed above. Socioeconomic considerations will play a large role in determining where and when different rehabilitation measures are applied.