# Flood Risk Management in the People's Republic of China

## Learning to Live with Flood Risk

Yoshiaki Kobayashi and John W. Porter

Asian Development Bank

ADB

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# Currency Equivalents

(as of 27 March 2012)

| | | |
|---|---|---|
| Currency Unit | – | yuan (CNY) |
| CNY1.00 | = | $0.1586470579 |
| $1.00 | = | CNY6.303300 |

# Abbreviations

| | | |
|---|---|---|
| ADB | – | Asian Development Bank |
| CBFRM | – | community-based flood risk management |
| CSIRO | – | Commonwealth Scientific and Industrial Research Organisation |
| FCDH | – | flood control and drought relief headquarters |
| FFMWS | – | flash flood monitoring and warning system |
| GIS | – | geographic information system |
| IWHR | – | Institute of Water Resources and Hydropower Research |
| MWR | – | Ministry of Water Resources |
| NFMS | – | national flood management strategy |
| PRC | – | People's Republic of China |
| RBC | – | River Basin Commission |
| TA | – | technical assistance |

# Foreword

The People's Republic of China (PRC) has had a long history of serious loss of life and damage to property due to flooding, costing 1% of gross domestic product per year on average.

The Government of the PRC has traditionally relied on structural measures to control floods. However, as floodplains have become more densely settled due to population pressure, flood damage has risen, despite major public investment in structural flood control measures. The traditional PRC approach to flood control, which relies solely on structural measures, is no longer practically or economically feasible. A more integrated flood management approach is necessary to adapt to changing social, hydrological, and environmental conditions along the nation's major waterways. The government, recognizing the need for a more integrated approach to flood management, passed the Flood Control Law in 1997. In addition, in the wake of the catastrophic floods of 1998—when the Yangtze and Songhua–Liao river basins inundated more than 2.5 million hectares of land, damaged 7 million houses, killed 3,500 people, and resulted in $30 billion in monetary losses—the government announced a new policy emphasizing the importance of an integrated approach to natural resources management, including flood management. Furthermore, the Ministry of Water Resources prepared a national flood management strategy in 2005. This strategy reflects a shift from dependence on structural measures to a balanced approach using both structural and nonstructural measures.

The core of the new concept of flood management in the PRC is flood risk management. Flood risk management is based on an analysis of flood hazard, exposure to flood hazard, and vulnerability of people and property to danger. This is followed by identification, assessment, and implementation of appropriate structural and nonstructural measures to manage or reduce flood risks to levels regarded as acceptable.

A key lesson of flood risk management is learning to live with flood risks. People and governments need to recognize that flood risks cannot be eliminated entirely. Instead, people should learn to accept some degree of the risks and, in return, derive benefits from floods such as improved soil fertility, provision of opportunities for food and materials, sustenance of aquatic and riparian ecosystems, and richness of the whole river environment. These benefits will be possible if people in flood-affected areas learn to live in harmony with the flood cycle.

Living sensibly with floods entails gaining and promoting a clear understanding of flood risks, quantifying and modifying the flood hazard, regulating exposure to the hazard, and reducing the vulnerability to danger and damage. This requires a balanced mix of structural and nonstructural measures.

This publication presents a risk management approach to flood management and a shift from flood control to integrated flood management in the PRC. It provides useful options to all those concerned with flood management in the PRC and in other countries.

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The first of these TA projects was the Flood Management Strategy Study,[1] which was processed by former ADB staff member KyeongAe Choe and was administered by ADB staff member Richard Bolt.

The second TA project was for Implementing the National Flood Management Strategy,[2] which was processed and administered by Yoshiaki Kobayashi.

The lead consultant in both TA projects was GHD in association with the PRC Institute of Water Resources and Hydropower Research (IWHR) in Beijing. The GHD team leader was John W. Porter, and the project director was Jinzhang Zou. IWHR team leaders were Xiaotao Cheng, Jinchi Huang, and Liyun Xiang. They were ably supported by other specialists in IWHR and GHD.

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[1] ADB. 2004. *Technical Assistance to the People's Republic of China for the Flood Management Strategy Study.* Manila.

[2] ADB. 2008. *Technical Assistance to the People's Republic of China for Implementing the National Flood Management Strategy.* Manila.


The Flood Management Strategy Study, a technical assistance (TA) project provided by the Asian Development Bank (ADB), was awarded for outstanding achievement under ADB's Second TA Award Program. This program is a subproject under another ADB TA project.[3] The program selected 7 from 87 advisory TA projects completed in the People's Republic of China from 2005 to 2009 for awards for outstanding achievement (1), policy support (1), institutional innovation (1), best dissemination (1), and honorable writing (3). At the ceremony on 4 March 2010, Xingjun Yu (right), director general, International Economic and Technical Cooperation and Exchange Center, Ministry of Water Resources, received the award from Jinkang Wu, deputy director general, International Department, Ministry of Finance.

Source: Ministry of Water Resources.

3 ADB. 2009. *Technical Assistance to the People's Republic of China for Facility for Policy Reform and Capacity Building III.* Manila.

# Executive Summary

Over the course of history, the use of rivers and lakes for sustenance, irrigation, navigation, and public and commercial enterprise developed a binding link between water and the people in the People's Republic of China (PRC). This dependence on water made inevitable the risk from floods. Extensive systems of flood control infrastructure were developed in the PRC. However, the limitations of structural measures under a philosophy of flood control became increasingly apparent toward the end of the 20th century.

In 2004, the Government of the PRC requested technical assistance from the Asian Development Bank (ADB) to help prepare a national flood management strategy (NFMS). As discussed in Chapter 3, a suitable framework was formulated to guide the NFMS. An action plan was also formulated to implement the shift from flood control to integrated flood management.

The framework proposed for the NFMS to serve the PRC in the 21st century relies on a risk management concept. Although there may be other definitions of flood risk, the definition accepted here is drawn from the insurance industry. Flood risk may be understood as the product of three contributing and necessary conditions:

$$\text{Flood Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$

Each of the conditions is treated or managed by distinct types of measures. Flood hazard is modified mainly by structural measures (e.g., dikes, dams, and diversions); although upper watershed management also plays an important role in mitigating sediment deposition and waterway instability by reducing soil erosion and fluvial sediment transport. Exposure to flood hazard can be best managed by land use controls in more developed parts of river basins. Vulnerability of people and assets to exposure can be modified by a range of nonstructural measures such as flood forecasting and warning and flood mapping.

The concept of flood risk and its management is the core of the strategic framework for flood management, but it is not the only aspect. The strategic framework also considers the institutional organization for management activity and the planning actions to mitigate flood risks. The framework also contains safeguards to mitigate the adverse social and environmental impacts and minimize the risks of unintended impacts.

Chapter 4 discusses the management of flood hazards. Over the past decades, massive investments have been made in structural flood control measures to modify flood hazards in the PRC, and highly developed systems of flood control works now exist throughout the country. Structural flood control measures in the PRC currently comprise numerous reservoirs, dikes, river regulation works, and detention areas. Large-scale construction of flood engineering works under a flood control policy has been central to the advancement of the modern PRC.

However, despite the investments made and success achieved in improving the security of life from flood danger, the cost of flood damages continued to escalate and, on average, thousands of lives are still being lost each year. The limitations of the flood control approach became evident even before 1998, but the major floods in that year brought the limitations into sharper focus.

Management of the exposure of people and assets to flood hazards is discussed in Chapter 5. People, property, assets, and infrastructure in a flood hazard area are exposed to danger, damage, or loss. Flood risks, and therefore the dangers and damages, increase with increasing exposure to flood hazards.

Land use measures can modify exposure to flood hazards. Resettlement is a management measure that has been used in the PRC to modify exposure to flood hazard. Land use management has not been fully utilized as a flood management measure in the PRC due to practical considerations and institutional constraints.

Chapter 6 focuses on the management of vulnerability to danger or damage. Vulnerability can be reduced if people take adequate precautions prior to flooding; i.e., if people receive flood warnings on time, know how to respond in order to limit danger and damage, and receive appropriate assistance during and after floods. Some of the precautions include measures that communities or individual families can organize themselves, although informed advice is helpful for their preparations. Other measures are better planned and managed by government authorities. Most effective is a top–down and bottom–up consultative approach with a two-way flow of advice to blend professional and local personal experience and ensure that community needs are identified and addressed.

Nonstructural measures to modify flood vulnerability include early flood warning, flood forecasting, flood mapping, community awareness and preparedness, emergency response, and post-flood recovery services including flood insurance.

Chapter 7 discusses the institutional framework needed for mitigating flood risks, including a sound institutional framework of legislation and policy and appropriate organizational structures, skills, training, and funding.

The Flood Control Law enacted in 1997 is the PRC's centerpiece legislation and is supported by regulations guiding the implementation of flood management policies. However, there remain areas of legislation and policy that can be improved, such as laws or regulations to manage the development on floodplains and in flood hazard areas, and rules and regulations to make flood insurance effective.

There are two parallel administration structures for flood management in the PRC. One is mainly concerned with the planning, construction, and routine management of flood control works, which are responsibilities of the Ministry of Water Resources at the national level, and administrative departments for water resources management at other levels of government. The other deals with the operational management and flood response initiatives during the flood season, which are the responsibilities of the flood control and drought relief headquarters at the national and other levels of government. For a flood management system to be fully integrated, it is essential for the Ministry of Water Resources to establish working partnerships with other administrative authorities.

Skills, training, and funding for flood management measures and the maintenance of existing structural works are also discussed in Chapter 7.

The planning structure is discussed in Chapter 8. Flood management planning should be spatially integrated in order to achieve social equity and manage flood risks and environmental impacts. It is generally recognized that the river basin is the natural physical scale at which flood management activities should be integrated. The core of flood management planning in the PRC has been, and should continue to be, at the river basin level. Flood management planning is then transposed from the river basin level to lower levels at which most flood management projects are implemented. A hierarchy of master plans is proposed in the chapter, including river basin master plans, subbasin master plans, urban drainage master plans, and rural drainage master plans. A structured planning methodology is also advocated for flood management planning and project appraisals, which entail a more systematic process of stakeholder consultation.

Chapter 9 describes the general requirements for safeguards to manage the exogenous impacts of flood management on society and the environment; with particular discussion of issues related to involuntary resettlement, ecology and the environment, and compensation for the use of flood detention areas (one of the key measures used in river basin flood management planning in the PRC). Reference is made to ADB's policy on environmental and social safeguards.

The publication concludes by reviewing some important flood management initiatives in the PRC in Chapter 10 and looking to the future of flood management in Chapter 11. Initiatives reviewed include the investments in flood defense works; the successful system for flood emergency response; and the more recent initiatives such as flood forecasting, flood mapping, flash flood monitoring and warning systems, and dynamic flood storage in flood mitigation reservoirs. Looking to the future, there are an enormous number of initiatives that would improve future flood management, including flood forecasting, flood risk mapping and hazard zoning, flash flood warning, structured planning methodology, and funding for maintenance.

# 1

# Introduction

Over thousands of years, Chinese civilization has been nurtured in valleys and plains adjoining the great rivers such as the Yellow River and the Yangtze River. The use of rivers and lakes for sustenance, irrigation, navigation, and public and commercial enterprise developed a binding link between the water and the people. Because of climatic variability, this dependence on water made inevitable the risk from floods and droughts. Flood control has therefore had a long history in pre-People's Republic of China (PRC).

After the rise of the modern PRC in 1949, attention was turned again to addressing floods and droughts. The energy and enthusiasm of the new PRC focused on controlling floods and harnessing the great rivers, as if nature could be subdued by the works of man. Rapid advances were made, and extensive systems of flood control infrastructure were quickly developed.

The limitations of structural measures under a philosophy of flood control became increasingly apparent toward the end of the 20th century. It is clear that investment in structural measures such as dikes, dams, and flood detention areas decreases the losses that would have been incurred. For example, the loss of life in floods along the Yangtze and other rivers in 2008 (3,650) was far less than in floods of similar extent in 1931 (145,000). However, population

Main river flooding

Source: Institute of Water Resources and Hydropower Research.

growth and rapid socioeconomic development dramatically increased the value of assets and the number of people at risk in floodplains. The costs of providing ever higher standards of protection generally increase exponentially so that complete security is unaffordable and unattainable. Typically, even flood protection measures of a limited standard attract development and, if poorly regulated, escalate the damages when the defenses are overwhelmed by over-standard floods. The boom in construction of flood control infrastructure also leaves the PRC with an enormous legacy of aging structures requiring huge recurrent expenditure for maintenance and rehabilitation. The need for a paradigm shift, from flood control centered on structural measures to flood management requiring a balance between nonstructural and structural measures, was already apparent in the PRC when the Flood Control Law was finalized in 1997. The imperative for the shift was reinforced by the experience of devastating floods in 1998. After the floods along the Yangtze and other rivers in that year and in accordance with an edict from the national government—the so-called "32-word policy" (Box 1), a program of action was initiated by the Ministry of Water Resources (MWR) including the return of polder lands to lake storage, resettlement of people from high-risk flood-prone land, and reforestation of upland areas—i.e., a suite of nonstructural flood management measures.

**Box 1 The "32-Word" Policy**

This policy statement, or more correctly a policy of 32 Chinese characters, was a quick response to the 1998 floods. It comprises eight directives which can be translated as follows:

- Protect the mountains to plant trees.
- Return arable land to forests.
- Demolish polders to release floods.
- Transform farmland into lakes.
- Contribute labor supply.
- Relocate people in new townships.
- Reinforce levees of main stem rivers.
- Dredge river channels and lakes.

Although these are little more than slogans, the underlying intention was to reforest upper basins, recover lands that had been reclaimed from lakes and floodplains, and restore flood storage lost to sediment deposition.

Source: H. Wan. 2003. Policies and Measures on Flood Mitigation in [the People's Republic of] China since 1998. Paper for the International Conference on Total Disaster Risk Management. Kobe, Hyogo, Japan. 2–4 December.

Despite the intentions of the Flood Control Law (1997) and the subsequent MWR policy for a shift from flood control to flood management, progress in implementing the provisions of the law and policy was slow. In 2004, the Government of the PRC requested technical assistance (TA) from the Asian Development Bank (ADB) to help prepare a national flood management strategy (NFMS).[1] After reviewing past experience and current practice in flood management domestically and internationally, a keystone of the NFMS was the formulation of a suitable framework to guide the strategy. The NFMS also required an action plan to implement the shift from flood control to integrated flood management.

Finalized by the end of 2005, the NFMS was well received at the national level, and greater use of the nonstructural measures has ensued. However, the need to raise awareness on the new approach and to advocate its appreciation not only at the national but also at the provincial and local levels of government in the PRC remains a challenge.

[1] ADB. 2004. *Technical Assistance to the People's Republic of China for the Flood Management Strategy Study.* Manila.

In 2008 and 2009, a follow-up TA project[2] was undertaken with ADB assistance to pilot the application of the NFMS in two case studies which focused on a flood detention area beside the Li River in Lixian County of Hunan Province and a flash flood area in Lichuan County of Jiangxi Province.

**Box 2 Wider Disaster Reduction Framework in the People's Republic of China**

Flood risk management is an important part of wider disaster reduction activities the People's Republic of China (PRC) is pursuing.

The PRC attaches great importance to legislation regarding disaster prevention and reduction and has enacted a number of laws and regulations in this regard, thus gradually institutionalizing disaster reduction efforts. Since the early 1980s, the Government of the PRC has promulgated more than 30 laws and regulations concerning disaster prevention and reduction.

The government has also persisted in incorporating disaster reduction in the sustainable development strategies at the national and local levels. In April 1998, the government released the Disaster Reduction Plan of the People's Republic of China (1998–2010), which was published, for the first time in the PRC, in the form of specialized plans. It put forward the guidelines, goals, tasks, and methods of disaster reduction work. In August 2007, the Government of the PRC issued the National Plan for Comprehensive Disaster Reduction during the Eleventh Five-Year Plan Period of the People's Republic of China,[a] requiring local governments to include disaster reduction in their social and economic development plans. In March 2009, the Government of the PRC issued [*People's Republic of* ] *China's Actions for Disaster Prevention and Reduction*,[b] recommending capacity development, public participation, and international cooperation for disaster prevention and reduction.

Sources:

[a] [People's Republic of ] China National Committee of Disaster Reduction. 2007. *National Plan for Comprehensive Disaster Reduction During the "Eleventh Five-Year Plan" Period of the People's Republic of China.* Beijing.

[b] Information Office of the State Council of the People's Republic of China. 2009. [*People's Republic of* ] *China's Actions for Disaster Prevention and Reduction.* Beijing.

[2] ADB. 2008. *Technical Assistance to the People's Republic of China for Implementing the National Flood Management Strategy.* Manila.

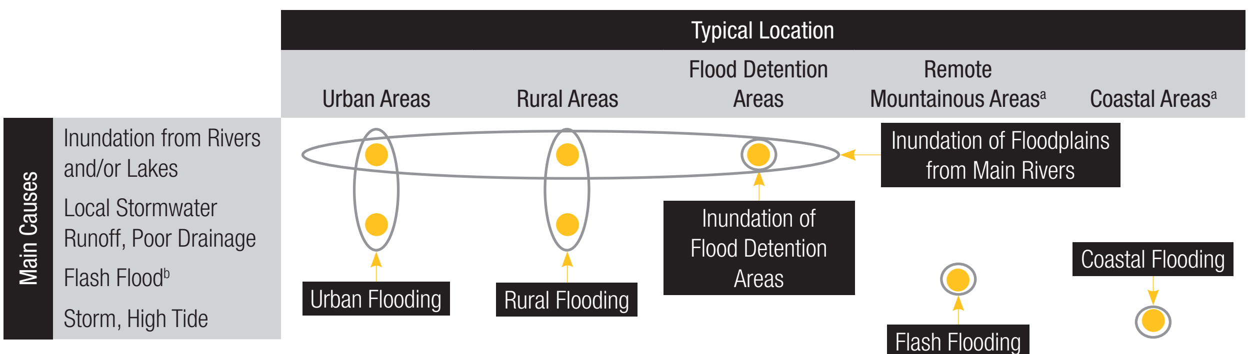
# 2

# Issues for Flood Management in the People's Republic of China

## A. Types of Flooding Problems

Types of flooding problems in the PRC are summarized in Figure 1.

**Figure 1** Types of Flooding Problems in the People's Republic of China




[a] These areas also can be classified as urban or rural areas.

[b] Flash floods can also occur from rivers and cause inundation.

Source: ADB.

### Inundation of Floodplains from Main Rivers

Advanced systems of flood control infrastructure exist for many large rivers in the PRC. They are generally supported by effective flood emergency response systems, which are increasingly supplemented by flood forecasting systems. However, the standard of protection varies and investment is required to extend essential infrastructure to all large rivers and many tributaries of the major river basins.

Flood storage reservoirs, dikes, and temporary detention areas are key elements of past flood control measures. Many flood control structures were constructed in the 1950s and 1960s, when standards of design, construction, and supervision were less rigorous than they are today. These structures are aging and may contain hidden defects. Many large and medium-sized reservoirs have been rehabilitated under sustained government programs since the 1990s; however, serious dike failures have occurred during past floods, and disasters have often been prevented only by keen vigilance during emergencies and large-scale mobilization of labor for flood defense.

**Table 1** National Impacts of Flood Disasters

| Average Annual Estimates (1990–2003) | |
|---|---|
| Economic damages | About $18.5 billion |
| Lives lost | About 2,000 |

Note: Average annual estimates based on Ministry of Water Resources data for 1990–2003, with damages adjusted to 2005 values according to changes in consumer price index and converted to US dollars assuming $1.00 = CNY6.75.

Source: ADB. 2005. *National Flood Management Strategy.* Consultant's report. Manila (TA 4327-PRC).

Funding the maintenance of existing infrastructure while extending protection to broader areas will be a challenge for future flood management in the PRC. Despite past initiatives, the greatest damage to private property and public assets has been incurred from this type of flooding (Table 1).

## Urban Flooding

Many cities and towns may be flooded by main rivers, so there is overlap with the type of flooding noted above; but flooding because of poor drainage of local stormwater runoff is often a greater problem. Extremely rapid urbanization associated with economic development and migration from rural areas has seen populations in some cities triple or even quadruple within a decade, making it difficult for city planners to provide adequate infrastructure. Newcomers are often unfamiliar with past flooding history. Because they are unaware of the flood risk or simply have no choice, they have settled on flood-prone land. Cities have expanded into surrounding farmland where standards of flood protection are lower. Drainage systems in many city centers have become antiquated, while the value of assets and property at risk has escalated. Zoning land and regulating land use are done poorly or not at all, often due to lack of awareness of flood risk and reluctance of local governments to inhibit development and forgo revenues.

Urban flooding

Source: Institute of Water Resources and Hydropower Research.

Flash flood

Source: Institute of Water Resources and Hydropower Research.

## Flash Flooding

Flash flooding, typically occurring in remote or mountainous areas, causes 70% of loss of life due to flood disasters. Landslides, mudflows, and debris flows caused by the sudden onset of intense storms account for many of these casualties. Managing this problem is difficult because

- warning times are shorter,
- populations are more dispersed, and
- access and communications are more difficult and expensive.

Under a national program over the past decade, areas at greatest risk from flash flooding have been identified and mapped, and warning systems combining technology and preparedness have been progressively implemented.

## Inundation of Flood Detention Areas

Areas designated for the temporary storage of floodwaters are a common feature of flood control in the PRC. There are around 100 major flood detention areas managed by the national government adjoining main rivers and tributaries, and numerous others managed by provincial and local governments. Most were lakes, wetlands, and low-lying areas with sparse populations when they were encircled by embankments to increase flood storage capacity. Due to increasing population, rapid socioeconomic development, and shortages of arable land, most were eventually settled and some now support large resident populations (Box 3).

**Box 3 Management of Flood Detention Areas**

Since 1988, a program for construction of safety facilities in flood detention areas has been undertaken to ensure adequate evacuation routes, provide safe refuge by means of elevated earth platforms, protect polders, etc. However, these facilities provide refuge for only about 20% of the population at risk.

After the big floods on the Yangtze River in 1998, resettlement programs were initiated to recover areas for flood storage use. In the Yangtze River Basin, 2.42 million people were resettled over 5 years. As a result of problems associated with resettlement under those programs, ongoing resettlement from flood detention areas is now conducted on a voluntary basis.

During the past decade, a policy of compensation for the use of detention areas has been introduced. Compensation is based on a proportion of property damage and crop loss. Although the policy has made it easier to temporarily store floodwaters in flood detention areas, the task of auditing assets and verifying damages is proving burdensome for local government administrations, delaying delivery of compensation and post-flood recovery. Moreover, development within detention areas cannot be stopped. This is the source of the problem.

Source: ADB. 2010. *Implementing the National Flood Management Strategy TA 7049-PRC.* Consultant's report. Manila (TA 7049-PRC).

## Rural Flooding

Poor drainage of local stormwater runoff is a serious problem in rural as well as in urban areas, causing crop losses and property damage. The problems are often aggravated by capture of local stormwater runoff behind dikes. Dikes intercept local stormwater runoff that otherwise would drain to rivers or lakes. This often results in waterlogging behind dikes for long periods of time. Pumping is often used to relieve the waterlogging, but this remedy may be unavailable when river floodways are near capacity during floods.

The occupation and use of flood detention areas creates a dilemma for flood management when floods occur, increasing damages and requiring well-organized flood warning and evacuation procedures to avoid casualties in these areas.

Aggravated waterlogging also occurs behind embankments in polder areas that are developed, often informally, in floodplains and flood detention areas. Polder embankments obstruct natural drainage paths, which may lead to higher waterlogging levels or longer durations of waterlogging behind the embankments.

At the same time, polders interfere with natural flood storage in floodplains and regulated flood storage in flood detention areas. An example is Dongting Lake, an important flood storage area in the Yangtze River Basin. Over the decades before 1998, numerous polder embankments had been constructed in the lake areas to enable local residents to make better use of the protected and enclosed lands. The benefits of excluding Yangtze floodwater far overweighed the disbenefits of waterlogging. However, the flood storage reduced by the polders was a key reason that downstream flood levels were higher in the floods in 1998 than in some earlier floods. After 1998, the government recognized this and, under the 32-word policy, directed that many polders be dismantled. In some places, embankments were breached to recover storage for Yangtze River floods, but the entire length of embankments was not removed. The remaining embankments still impede stormwater runoff and aggravate waterlogging. Resolution of these problems is usually left to local governments, so the main problems are administrative and funding constraints rather than technical difficulties.

## Coastal Flooding

Coastal flooding results from typhoons or other storms occurring in conjunction with high tides. On average, about four coastal floods occur annually in the PRC, mostly in July to September, and particularly in Fujian, Zhejiang, and Guangdong provinces.

Sea walls have been constructed in many coastal areas, but standards of construction vary and all are prone to damage. In 2004, Typhoon Yunna caused storm tides of 1–3 meters above normal high tide level along the Zhejiang coast, breaching sea walls in more than 1,200 locations; causing the evacuation of over 467,000 people; and damaging 200 docks, over 3,000 fishing boats, and 42,300 hectares of aquaculture development.

Losses caused by storm tides are expected to increase due to global warming and associated rising sea levels. As living standards improve, coastal regions will grow and higher-value assets will be exposed to coastal flood hazards.

## B. Constraints in Flood Management

### Erosion and Sediment Transport

Soil erosion and sediment transport are closely linked to flood hazard. Sediment deposition reduces the flood mitigation function of lakes and reservoirs. Riverbank erosion causes dikes to collapse during floods. Sediment deposits in river channels induce instability and reduce flood conveyance capacity. Every year, huge investment is necessary in river engineering works such as channel dredging to restore flood conveyance capacity. Human activities and land use in upper catchments are major contributors to sediment loads.

The relationship between soil loss and flood disaster was recognized by the Government of the PRC following the floods along the Yangtze and other rivers in 1998. The 32-word policy listed soil conservation and erosion management in upper catchments as a key measure to strengthen flood management. In the Yellow River (Huanghe) Basin where sediment loads are the highest in the world, major investment in soil conservation programs has been made, and large reservoirs have been constructed upstream with the primary purpose of capturing sediment to reduce deposition in the lower reaches.

Associated with the occurrence of severe storms and flash floods, landslides and mud and rock debris flows occur in mountainous regions, especially where steep slopes have been stripped of vegetation. These mass movements are particularly destructive when they impact on developed areas.

### The Nexus between Poverty and Flood Risk

In both urban and rural regions, areas at higher flood risk are often occupied by poorer sections of the population. In rural areas, recurring losses caused by flooding tend to perpetuate the poverty cycle. In urban areas experiencing rapid growth with inadequate planning, recent migrants often occupy land at highest risk of flooding that remains unused by others. Because of their lack of experience or knowledge of past flood history, they are particularly vulnerable.

In the PRC, flood detention areas are recognized as pockets of poverty. Years of labor and accumulation of capital and assets can be undone when the land has to be inundated, making it more difficult for residents to advance their economic position. Knowing the flood risk, residents may be more reluctant to invest in improvements or new ventures, so development is inhibited. Commercial enterprises relying on their custom also remain depressed, and may incur losses during floods. In all these ways, poverty is perpetuated.

Mountainous areas at greatest risk from flash floods and landslides are also comparatively disadvantaged, with poorer transport and communications facilities, and more difficult access to resources adequate to sustain livelihoods.

### Land Use Management

Floods are temporary events, occurring only when an unusual abundance of surface water exceeds the capacity of rivers, streams, and waterways, and causing water to overtop banks or dikes and inundate adjoining land that is normally dry. Therefore, flood management entails management of both water and land. Land use management and building regulations are important aspects of flood management that should receive a level of attention similar to that accorded to floodwater management.

Damages after the debris flow, Zhouqu County, Gansu Province, September 2010
Source: *Jakarta Post.*

In relation to flood management, land use management aims to ensure that development is compatible with the attributes of the land upon which development is to take place. Inappropriate development can include development incompatible with flood risk management, which leads to increased flood frequency, increased hardship for inhabitants, prolonged flood duration, and increased depths of inundation in nearby or downstream areas.

Inappropriate land use management has been a shortcoming of past flood management in the PRC due to the unprecedented pace of socioeconomic development and the increase in population densities in the modern PRC. To apply land use planning as a flood management measure in the PRC, better coordination between multiple administrative departments would be required especially at local government level where most land use planning is practiced.

Flood hazard mapping is a key tool for spatial planning that greatly facilitates land zoning according to flood risk. A program of flood hazard mapping is under way in the PRC. To realize its full potential, it should be linked to land use zoning and should be associated with development and building regulations.

Past lapses in land use planning have exposed private property and public infrastructure of considerable value to damage by flood and placed many lives in danger. The primary role of land use management is to avoid aggravating the situation through inappropriate future development in flood-risk areas.

While it is difficult to redress effects of past planning decisions, measures such as resettlement and resumption of land may be useful in some circumstances. In the PRC, ownership of land resides with the State, so revocation of leasehold is equivalent to land acquisition in Western countries.

## Data Acquisition and Information Management

Data and information play a key role in all aspects of flood management such as the planning, design, and operation of flood management systems; decision support for system operations; development and execution of emergency response plans; and asset management. More refined and accurate technical modeling systems demand more input information. These demands require improvements to data acquisition networks, advances in instrumentation and measurement technologies, and technologically advanced data communications and data processing facilities.

Because of the scale and complexity of flood management systems in the PRC, the resources required in terms of funding and of technical and administrative staff are considerable. With changing technology and generational obsolescence of equipment, another challenge is how to maintain functional and efficient information systems. These challenges require regular review of information systems and reliable funding sources for ongoing recurrent expenditure.

Knowledge flows from information, analysis, and research. Institutional memory loss threatens the effectiveness of flood management and our capacity to learn from the past. Important aspects of knowledge management include

- advance preparations so that resources can be mobilized during and after floods to capture important data (e.g., peak level data, flood extents, photography, and remote sensing data);
- formal requirements for post-flood reporting including the characteristics and impacts of floods;
- documentation and archival procedures that preserve information about past floods; and
- quality assurance procedures to assure that all tasks are properly managed to capture, record, document, and preserve relevant information (e.g., adherence to ISO 9000).

## Climate Change and Sustainability

The scientific community generally agrees that due to increasing emissions of carbon dioxide and other greenhouse gases, climate change will cause sea levels to rise and precipitation patterns to change over the course of the 21st century. Changing precipitation patterns will cause changes in hydrology, vegetation cover, and erosion. Although it is difficult to project these future developments, the evidence is already clear that change is occurring and cannot be ignored. In strategic planning, it is incumbent upon management to consider the implications of these changes so that plans become sustainable in the long term. Planning must be sufficiently resilient to deal with the uncertainty inherent in future climate scenarios. Resiliency implies implementing plans that can cope with the probable range of uncertainty in future predictions.

The Office of the National Coordination Committee on Climate Change[3] predicts that sea levels will rise globally between 31 centimeters and 65 centimeters by 2100. Differential rates of rise in temperature are anticipated around the world related to latitude and the disposition of oceans and land masses. The Intergovernmental Panel on Climate Change predicts that average temperatures will rise by between 1.5˚C and 4.5˚C by 2100.[4]

Changes in precipitation will vary even more, both spatially and temporally. In most parts of the world, greater extremes are anticipated, with more severe droughts; more intermittent, but more intense storms; and higher coastal

[3] Government of the People's Republic of China, Office of the National Coordination Committee on Climate Change. 2004. *The People's Republic of China Initial Communication on Climate Change.* Beijing.

[4] Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability.* Contribution of the Working Group to the 3rd Assessment Report. Cambridge.

storm surges. Seasonal differences between winter and summer rainfall are expected to change. Hydrological responses typically amplify any disturbance to precipitation, so more extended periods of low flow, and more severe episodes of flooding may be expected in general. The Office of the National Coordination Committee on Climate Change predicts that annual runoff will increase in southern PRC and decrease in the north of the country.

Quantitative predictions of changes in flood hydrology are very difficult, but there is a consensus that flooding is now a hydrologically nonstationary process, implying increasing probability for floods of any given magnitude. By corollary, for any design or planning probability of occurrence, the flood event magnitude will increase over the coming century. One of the more pressing technical challenges is to quantify such changes in flood hydrology and determine a likely range or confidence limits to the predictions.

Even in the absence of reliable quantitative predictions, flood management planners must be aware of the possible impacts of global warming and consider how well plans and strategies can be adapted to future uncertainties. Examples of how this is being treated elsewhere are available in the Foresight study on future flooding in the United Kingdom,[5] comparative analyses of different flood management strategies in the Netherlands,[6] and the Sustainable Yields study in Australia.[7]

The effects of global warming have the potential to alter the planning context within the life cycle of flood management schemes, modifying flood hazard and the exposure to flood risk. Plans developed today should be sufficiently robust and resilient to be sustainable and adaptable to the uncertainty within that planning horizon.

**Box 4 Integrated Water Resources Management**

Flood management is a part of integrated water resources management. The most direct linkages are with water supply and environmental management.

Water is a scarce resource in the People's Republic of China (PRC), and per capita water availability is well below the global average. Thus, flood management plans need to consider whether they affect existing water use. There is also a strong desire to make better use of floodwater as a resource. Most water storage facilities in the PRC are multipurpose, and their flood control function is achieved by maintaining flood pools (or air space) within reservoirs during the flood season each year. While this has played a major role in mitigating flood damages and reducing loss of life throughout the country, managers are now questioning whether operating water levels in storage can be modified to retain more water in storage at the end of the flood season. The challenge is how to do this without compromising flood-control objectives.

Modification of target operating water levels in storage affects the probability of downstream flooding. There may be a trade-off between the benefits of flood risk mitigation and water supply, but it is most important that net benefits to be gained are clearly demonstrated by rigorous appraisals of impacts before proceeding. This should never be done as a short-term response to water supply crises.

Other possibilities are

- dynamic operations using modern flood forecasting and weather forecasting systems to temporarily draw down water levels in advance of impending floods;
- allowing greater operational flexibility by varying target water levels at different stages of the flood season, based on more detailed hydrological analysis of seasonal inflow probabilities; and
- using floodwater for aquifer recharge, provided that land use can be adapted to land inundation requirements.

In the context of integration of flood management and environmental management objectives, appraisals of environmental impacts during planning and design of future flood management schemes should evaluate not only how to minimize adverse environmental impacts but also how to enhance environmental (and social) outcomes.

Source: ADB. 2005. *National Flood Management Strategy.* Consultant's report. Manila (TA 4327-PRC).

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[5] Government of the United Kingdom, Office of Science and Technology. 2004. *Foresight: Future Flooding.* London.

[6] Brouwer, R., R. van Ek, R. Boeters, and J. Bouma. 2001. *Living with Floods: An Integrated Assessment of Land Use Changes and Floodplain Restoration as Alternative Flood Protection Measures in the Netherlands.* Centre for Social and Economic Research on the Global Environment, Economic and Social Research Council Working Paper ECM no. 01–06. Norwich.

[7] Commonwealth Scientific and Industrial Research Organisation (CSIRO). 2008. *Water Availability in the Murray–Darling Basin.* A report to the Australian Government by the CSIRO Murray–Darling Basin Sustainable Yields Project. Canberra.

# 3

# Strategic Framework for Integrated Flood Management

## A. Introduction to Flood Risk Management

The framework proposed for a flood management strategy to serve the PRC in the 21st century relies on a risk management concept. Although there may be other definitions of flood risk (Box 5), the definition accepted here is drawn from the insurance industry. Flood risk may be understood as the product of three contributing and necessary conditions:[8]

$$\text{Flood Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$

### Hazard

A flood hazard exists wherever land is liable to flooding and there is a potential for harm, loss, or damage due to flood. Hazard increases with probability of inundation; but it is also dependent upon the physical attributes of the flooding, increasing with depth of inundation, velocity of flood flows, and duration of inundation. For different areas of land subject to the same probability of inundation, hazard is greater if the land is inundated to a greater depth or if flow velocities are higher. These attributes increase the potential for harm, loss, or damage. The duration of flooding is also relevant with respect to crop losses, and inundation of longer duration may aggravate structural damage to buildings and foundations.

### Exposure

There cannot be risk without hazard, but there may be hazard without risk. Flood risk is only present if there are assets that may be damaged; or if people live, work, or simply transit through the land where flood hazard exists. In other words, there is only risk because people or assets are exposed to the flood hazard. Flood risk increases with increasing exposure to flood hazard; i.e., flood risk increases with higher intensity of land use, increasing value of property or assets located on the land, and higher populations that live or work on that land or use the land for purposes such as transit or recreation.

[8] This formulation nicely captures the concept that if any one of the three elements of flood risk is absent (i.e., has a value of zero in the formula), then there is no risk.

**Box 5 International Risk Management Approaches**

There are many documents that deal with risk management approaches.

ISO 31000:2009[a] provides principles and generic guidelines on management of all types of risk, including terrorist threats and industrial accidents.

The New Zealand Standard for Managing Flood Risk (NZS 9401)[b] is a process standard that provides a risk-based approach for the comprehensive management of flood risk.

The European Union Directive on the Assessment and Management of Flood Risk[c] defines flood risk as the product of probability (hazard) and consequences (exposure and vulnerability) which is aligned with the framework this publication proposes and a good model for the People's Republic of China to emulate.

*Urban Flood Risk Management: A Tool for Integrated Flood Management*,[d] a guide issued by the World Meteorological Organization and Global Water Partnership in 2008, adopts the same model of flood risk (Flood Risk = Hazard × Exposure × Vulnerability) as this publication proposes.

Sources:

[a] International Organization for Standardization. 2009. *ISO 31000:2009.* Geneva.

[b] Government of New Zealand. 2008. *Managing Flood Risk – A Process Standard, NZS 9401:2008.* Wellington.

[c] European Union. 2007. *Directive on the Assessment and Management of Flood Risk.* Brussels.

[d] World Meteorological Organization and Global Water Partnership. 2008. *Urban Flood Management: A Tool for Integrated Flood Management.* Geneva.

## Vulnerability

While exposure to flood hazard creates the potential for personal danger or property damage during floods, the actual consequences of flooding also depend on how vulnerable people and assets are to danger and damage. Vulnerability relates to the classic distinction in flood damage assessment between potential damages and real (or actual) damages. Vulnerability is reduced if

(i) assets are made less susceptible to damage by water; and

(ii) people are more aware of the flood risk, are well prepared, have an appreciation of what they should do during a flood emergency, and have access to emergency services and post-flood support.

## Relevance to Flood Management Planning

This definition of flood risk is highly relevant to flood management planning, because as Table 2 indicates, each of the three contributing and necessary conditions for flood risk are treated or managed using distinct types of measures.

Table 2 Measures Modifying the Three Conditions for Flood Risk

| Modifying Hazard | Modifying Exposure | Modifying Vulnerability |
|---|---|---|
| Flood control dams | Zoning of land use | Flood forecasting and warning |
| Detention basins | Property acquisition | Emergency response plans |
| Levees or dikes | Planning development controls | Community awareness |
| Flood diversion channels | Building codes | Community preparedness |
| River channel improvements | Flood-proofing buildings | Post-flood recovery actions |
| Upper watershed management | Building on platforms | Flood insurance |

Source: ADB. 2011. *Flood Management in Selected River Basins.* Consultant's report. Manila (TA 7364-INO).

Flood danger

Source: Institute of Water Resources and Hydropower Research.

Structural measures are commonly used to modify flood hazard; for example, they modify flood frequency, depth of inundation, and flood extent. However, upper watershed management that reduces rates of soil erosion and sediment transport by rivers also modifies flood hazard by reducing sediment deposition and waterway instability downstream.

Land use controls in more developed parts of river basins mainly aim at reducing exposure to flood hazard by ensuring that only future development that is compatible with the flood risk proceeds or by converting the existing land use to another use which is more compatible with the flood risk. For instance, requiring building floor levels to be above flood levels modifies exposure to the flood hazard and reduces the vulnerability of the occupants. Resettlement and other forms of regulation of human activity are also directed at reducing exposure to flood hazard.

Vulnerability to exposure can be modified by a range of nonstructural measures. For example, flood forecasting—coupled with flood warning—is one effective means of reducing vulnerability, providing people with more time to react positively to minimize danger and property loss. Programs to raise public awareness of flood risk and improve community preparedness are another. Effective emergency response procedures and post-flood recovery services also reduce vulnerability.

## B. Building the Strategic Framework

The concept of flood risk and its management (pp. 12–13) is the core of the strategic framework for flood management, but it may not be sufficient. A strategic framework must consider the institutional foundation that provides the organization for management activity, and the planning process which determines how we plan our actions to mitigate flood risk. The framework must also contain safeguards to mitigate adverse social and environmental impacts and minimize the risk of unintended impacts. These allow for a more complete framework to be built.

## Institutional Foundation

The institutional foundation refers to legislation and policy, and the structure, organization, skills, and resources within institutions.

In the PRC, the Flood Control Law of 1997 provides the legislative base. This law adopts a flood management approach that adequately recognizes both nonstructural and structural measures in the management of floods. Policies implementing the intent of the Flood Control Law continue to evolve with the adoption of new technology such as flood risk mapping. Policy development is manifested in the periodic promulgation of new regulations related to aspects of flood management. Guidelines and manuals elaborate how to implement policy initiatives.

Because government institutions divide responsibilities so their mandates become manageable, one of the great challenges for integrated flood management is coordination. In flood management, integration of planning and actions can only be achieved through multiple institutions. Partnerships are essential; but effective partnership is very difficult everywhere, not just in the PRC, because institutions are unaccustomed to working collaboratively and managers are cautious about straying beyond their mandated roles.

Training programs are required to raise awareness and build capacity in relevant institutions at all tiers of government. Frequent opportunities should be provided for technical exchange and knowledge sharing to cultivate learning and skills development.

Sustained funding is essential to implement new flood management measures and maintain and operate existing assets. Multiple sources of funding are desirable, including private funding from those beneficiaries who can afford to contribute.

Institutional issues are discussed further in Chapter 7.

## The Planning Process

If the institutional foundation is regarded as the roots of the tree of flood management, then the key process of planning that takes place within institutions can be regarded as the trunk. Good planning supports the branches and the fruits, which are the measures implemented to manage flood risk and provide services that enhance security for people, public infrastructure, and private assets at risk.

River basin master planning has long been at the core of flood management planning in the PRC. River basin commissions for water resources management are established in all major river basins in the PRC and flood management planning is one of their tasks. Although there are aspects that could be improved, the existing model for river basin planning provides an excellent platform for future development.

The major river basins are very large; and flood management master planning should also be undertaken at intermediate scales (e.g., subbasins). Separate management plans should also manage stormwater drainage, flooding in large urban areas, and flooding in rural areas particularly where waterlogging is a problem. A hierarchy of flood management plans is desirable at a range of scales appropriate to the purpose.

The way planning is done is very important. A structured planning method is required to capture the strengths of integrated flood management through rigorous technical analysis, comprehensive assessment of planning options, appraisal of options based on the "triple bottom line" of sustainable development (economic viability, social equity, and environmental acceptability), benefit–cost analysis, and stakeholder participation. Stakeholders are those that have an interest in the planning outcomes, particularly those whose livelihoods or quality of life could be directly affected by the implementation of the flood management plan. While government institutions need to guide and direct the planning process, all stakeholders should be given an opportunity to participate throughout the process.

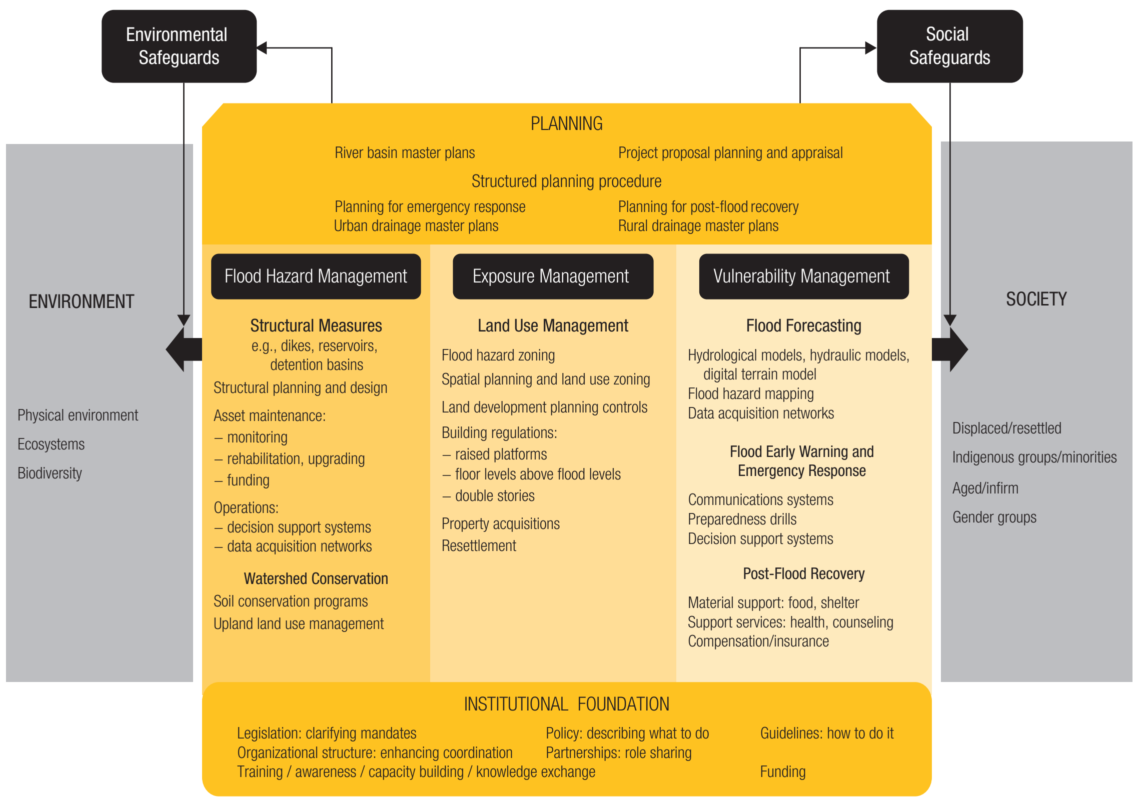
## Social and Environmental Safeguards

The flood management sector does not exist in isolation. It may have impacts on the environment and society that are by-products of flood management actions—what we may term "exogenous effects." Environmental impacts may include unintentional but foreseeable impacts on the physical environment or on the biosphere. Social impacts may include impacts on those displaced or resettled; indigenous groups; the disabled, aged, or infirm; or gender groups. A comprehensive management framework must contain safeguards to mitigate adverse social and environmental impacts, and minimize the risk of unintended impacts. As the safeguards are related to effects that are exogenous to the primary objectives of flood management, they may be appended to the core framework.

## Strategic Framework

The strategic framework for flood management is illustrated in Figure 2. It includes the core concept of flood risk and management, with institutional foundation, planning process, and social and environmental safeguards.

**Figure 2** Strategic Framework for Flood Management




Source: ADB. 2011. *Flood Management in Selected River Basins.* Consultant's report. Manila (TA 7364-INO).

4

# Management of Flood Hazard

## A. Flood Control Infrastructure

All structural flood control works modify flood hazard. For example,

- flood control reservoirs and flood detention basins reduce flood discharges downstream, directly modifying the physical characteristics of floods in terms of their spatial extent of inundation, depths of flooding, and flood flow velocities;
- flood dikes (levees) directly modify the spatial extent of flooding, also affecting flood depths and flow velocities;
- river channel enlargement and dredging directly modify flood depths; and
- flood diversion channels modify the spatial distribution of flooded areas to reduce hazard in areas where more people and assets are exposed.

Over the past decades, there have been massive investments in structural flood management measures in the PRC; thus highly developed systems of flood control works now exist throughout the nation. At the end of the 20th century, structural flood control measures in the PRC comprised numerous reservoirs, dikes, river regulation works, and detention areas. Dike systems totaling about 280,000 kilometers were constructed in middle and downstream reaches of rivers, protecting 34 million hectares of farmland and more than 400 million people. A total of 85,000 reservoirs were constructed to store and regulate floodwaters in upstream areas. Ninety-seven large flood detention basins of national importance were constructed in the seven major river basins to manage larger floods. There are major dams on all large rivers in the PRC. The reservoirs serve multiple purposes, but in general, each reservoir has a flood pool maintained to capture flood inflows and mitigate floods downstream during the flood season (May to September).

Along the eastern seaboard, sea walls provide coastal defenses against storm surges associated with typhoons. Bank stabilization works reduce the erosion of river banks and dikes.

The reasons for the heavy reliance on structural measures are high populations, limited arable lands to support those populations, and the imperatives for socioeconomic development to relieve poverty and improve living standards. There has been little alternative for people to live and work in areas subject to flood hazard, so structural works to modify the hazard are a logical approach to flood management. Large-scale construction of flood engineering works under a flood control policy has been central to the advancement of the modern PRC.

The optimism underlying the flood control philosophy is derived from the belief that people working together could harness the rivers and overcome the constraints of nature. Despite the investments made and success gained in improving security of life from flood danger, the cost of flood damages continued to escalate and on average, thousands of lives are still being lost each year.

Flood control dikes, Yellow River
Source: Institute of Water Resources and Hydropower Research.

Flood release from Three Gorges Dam, Yangtze River, 2010
Source: Chinadaily.com.cn

The limitations of the flood control approach became evident even before 1998, but the major floods that year brought them into sharper focus. Although loss of life was much less than in a flood of similar magnitude in 1931,[9] along the Yangtze River (Changjiang) many lives were lost, dikes incurred severe damage, and a worse catastrophe was only just averted by the valiant efforts of armies of flood fighters.

## Risks Associated with Operating Structures

Apart from the dilemma of how to safely operate complex systems of flood control infrastructure during large floods (Box 6), a different set of risks is generally introduced by implementing structural measures.

Dike construction, for example, encourages development in the protected area so that, although the probability of inundation may be reduced, the value of property and number of people at risk increase. The consequences of overtopping or breaching of dikes are then much greater than before dike construction. Unless the residual risk is clearly explained and the message is regularly repeated by authorities, residents of the protected area and users of protected land often fail to understand that the risk has merely changed and has not been eliminated. Authorities may themselves be complacent about the residual risk.

**Box 6 Operation of Structural Systems**

To support socioeconomic development, water resources infrastructure has proliferated to meet demands for hydropower, irrigation, and water supply. In many river basins, very complex systems of dams, regulators, diversions, and irrigation schemes now exist. Joint operations of these systems to meet multiple demands during normal supply periods is difficult; but the operations to minimize risk during floods are a major challenge, complicated by the capacity constraints of dike and river systems and floodwater diversions to detention storage, and with serious danger or damages possible from inappropriate operational decisions. Critical decisions have to be made within inflexible time constraints as flood situations evolve rapidly in space and time.

Operations of complex flood control structural systems are therefore an important area of research aimed at developing sophisticated decision support tools to assist managers and decision makers. Decision support tools must be user-friendly and accurate, and display information clearly; their sophistication must be adapted to these sometimes conflicting requirements. The decision support system must be linked to early warning systems that monitor meteorology and hydrology in real time and in two-dimensional space, and flood forecasting and emergency response systems.

Source: ADB. 2010. *Implementing the National Flood Management Strategy TA 7049-PRC.* Consultant's report. Manila (TA 7049-PRC).

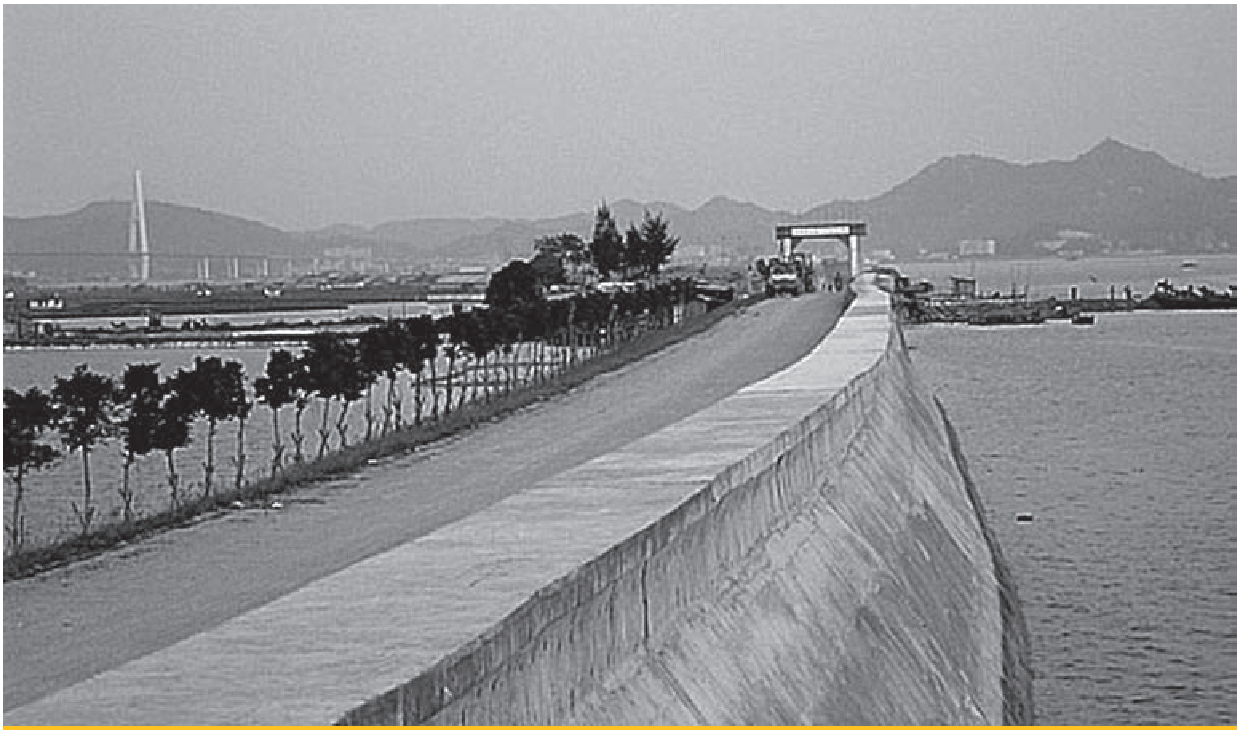
In designated flood detention areas, even when the intent to occasionally inundate the area has been clearly explained, an expectation grows that inundation will be unnecessary and awareness of the flood risk declines after a period of several years without need for floodwater diversion. Most flood detention areas in the PRC are dual-purpose. As some are occupied by substantial populations, this becomes a tricky flood management dilemma when large floods occur. Even when required to avert much greater losses, community discontent is a natural response when their area is selected to incur inevitable damage when inundated.

The PRC has 87,085 reservoirs.[10] About 90% were built during the period of the Great Leap Forward and the Cultural Revolution (1958–1976), using outdated, low technical standards and inadequate plans, surveys, designs, and construction. Of the total number of reservoirs, 43%, or 37,032 reservoirs, are in the most unsafe class III category.[11] The potential failure of class III reservoirs threatens lives and property downstream. During 1954–2007, 3,503 reservoirs, or an average of 65 reservoirs each year, collapsed and killed at least 27,876 people in the PRC.

9 About 3,650 lives were lost in the floods of 1998, but in 1931 the death toll was estimated to be 145,000.

10 Figure as of end of 2006, excluding reservoirs in Hong Kong, China; Macau, China; and Taipei,China.

11 The PRC has three safety classes of reservoirs. The number of class III reservoirs is as of the end of 2006 and changing as reservoirs are rehabilitated and new ones enter into this class. The class III reservoirs are below national standards in actual flood control capacity, do not work as designed, and pose a high safety risk.



Sea wall on the coast of the People's Republic of China
Source: YDTZ.com

Dike breach, Poyang Lake, Jiangxi Province
Source: theepochtimes.com

In addition, many endangered reservoirs do not store water up to their design level because of water leakage, instability of water-retaining dams, and inadequate spillway capacity for emergency discharge of rapidly rising floodwaters. Thus, these endangered reservoirs cannot control floods, supply irrigation water, generate hydropower, or provide household water year-round to users. Under the National Reservoir Strengthening Program which was set up by the Ministry of Water Resources (MWR) and completed at the end of 2010, more than 7,500 reservoirs have been rehabilitated. Reservoir rehabilitation will continue beyond the program. About 30,000 unsafe reservoirs still have to be rehabilitated. Class I and II reservoirs which were not part of the program are foreseen to deteriorate and will need urgent rehabilitation.

The risks introduced by structural measures can be treated but demand good management with assiduous attention to operational procedures, vigilant monitoring, and adequate data and information on which to base sound operating decisions.

## Maintenance of Flood Control Infrastructure

Systematic monitoring and maintenance programs are important in managing flood control infrastructure. Because of the extent of structural measures that have been implemented in the PRC, monitoring and maintenance are enormous tasks. There is a legacy of aging flood defense structures that require monitoring and maintenance:

- Dikes are often unreliable due to a range of factors such as geotechnical faults in embankments, unsound foundation conditions, erosion, and scour. Past monitoring and maintenance have been inadequate.
- The potential failure of a huge number of endangered reservoirs in the PRC threatens lives and property downstream. In addition, many endangered reservoirs do not store water up to the design level and cannot control floods.
- In some places, river engineering works have fallen into disrepair.
- Flood diversion channels are becoming blocked by sediment deposition resulting from low flow velocities during non-flood periods and requiring very expensive dredging and clearing.

The required resources and funding for systematic treatment, estimated to be at least CNY10 billion per annum, is a great challenge.

The Flood Control Law of 1997 prescribed a State fund for maintenance, construction, and administration of flood control structures and empowered provinces, autonomous regions, and municipalities to levy fees for this purpose. However, raising funds adequate for proper maintenance remains difficult.

Flood diversion channel

Source: Institute of Water Resources and Hydropower Research.

## B. Watershed Conservation

Since the 1998 flood disaster on the Yangtze River (Changjiang), the Three Gorges Dam has been constructed and now regulates flood flows in the middle and lower reaches of the river. However, the immediate effect of the 1998 disaster was to trigger a realization that structural measures alone could not guarantee security and that nonstructural measures are also important. The 32-word policy issued after the 1998 flood emphasized recovery of floodplain storage and soil conservation in upper basins. It led to a huge program to reclaim farmland, demolish polders, resettle people directly affected, reforest mountainous areas, and modify agricultural practices. It recognized that structural measures conjointly with elevated rates of soil erosion and sediment transport in rivers are not sustainable, and there is a need for land use management as an adjunct to flood management.

The deposition of sediment transported in streams is an important modifier of flood hazard, generally with adverse effects. Sediment deposition reduces the storage available in reservoirs and lakes for downstream flood mitigation and reduces the conveyance capacity of river channels. Near estuaries and at breaks of grade where flow velocities decrease, such as transitions from mountain valleys to plains, deposition of sediment reduces the longitudinal gradient of the river bed. This leads to waterway instability as rivers try to recover conveyance capacity by river bank erosion and, in flatter landscapes like deltas and floodplains, may lead to avulsions and the creation of new river courses.

Soil erosion and fluvial sediment transport are natural phenomena, and deposition on river banks and floodplains can enhance fertility. But changes to land use and vegetation cover by human development have upset the natural balance and artificially multiplied natural rates of erosion and sediment transport.

The important role of soil conservation in integrated flood management needs greater recognition, particularly during the development of master plans at the river basin scale. Management of land use in upper watersheds includes afforestation programs and programs to raise the awareness of the effects of inappropriate land use practices and to modify behavior in agricultural communities. Field programs and agricultural extension activities in rural areas should explain to land users how their land use practices are inappropriate for the conditions and how improved practices could enhance and sustain their incomes while conserving soil fertility and soil moisture and reducing runoff and erosion. Education should also target school children so they mature with better understanding of the interdependence of society and nature, and appreciate the need to achieve harmony and sustainability in our use of natural resources.

One of the constraints to effective land conservation in rural areas is that many of these rural land users belong to the poorest sectors of society and have few incentives to change their land use practices. As mentioned, extension programs should demonstrate how improved practices could enhance and sustain their incomes. Nevertheless, when subsistence is the main aim, farmers may not have the required resources to change their practices. Effective support in the form of direct material assistance is essential. Alternatively, some mode of compensation could be appropriate as those living downstream may be the main beneficiaries of the modified land use practices.

For example, programs such as payment for environmental services involve funding transfers from a beneficiary group (such as a highly developed municipality downstream) to a separate group that, through its land use practices, can improve or conserve water resources and/or the environment (e.g., poor upland farmers).

Payment for environmental services schemes have been implemented in the PRC and elsewhere. Although more often introduced to provide water conservation or water quality benefits, the principle has been extended to flood management.[12]

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[12] Echavarria, M. 2002. Water User Associations in the Cauca Valley, Colombia: A Voluntary Mechanism to Promote Upstream-Downstream Cooperation in the Protection of Watersheds. *Food and Agriculture Organization Land–Water Linkages in Rural Watersheds Case Study Series.* April. Rome. The report describes a case study in Colombia where a water user association of sugarcane growers hurt by flooding pays predominantly poor upstream communities to change their land management practices and protect the upper watershed.

# 5

# Management of Exposure of People and Assets to Flood Hazard

## A. Exposure

People who live and work in, or transit through a flood hazard area are exposed to danger. Private property, commercial assets, and public infrastructure located within flood hazard areas are exposed to damage or loss. Flood risk, and therefore the dangers and damages, increase with increasing exposure to flood hazard; i.e., flood risk increases with

- higher intensity of land use,
- rising value of property or assets located on land with flood hazard, and
- higher populations that live or work on the land or use it for other purposes such as transit or recreation.

In the PRC, the risk and consequences of flooding in the PRC are very high because the supply of land well suited to agriculture or development is limited, the population is exceedingly large, and the recent advances in socioeconomic development have led to rapidly rising value of the assets situated in flood hazard zones and increasing urbanization.

Exposure to flood hazard can be modified by land use management measures. Floods are very temporary phenomena. They occur only when water overflows from rivers and streams, overtops the natural banks, and encroaches on adjoining land. Land that is normally dry may be inundated during floods. Thus, flood management intrinsically concerns the management of both water and land use.

## B. Management Approach

### Objectives

Floodplains have always been desirable sites for human development. Apart from the ready availability of water, most arable lands are located on floodplains because they are fertile, and their soils are replenished by a succession of floods. Flatter slopes also favor ease of construction and access, and efficient supply and delivery of water and other services.

It is unrealistic to exclude development from floodplains. Similarly, it is unrealistic to expect the elimination of flood risk. In the interests of national and social progress, development on floodplains must be permitted. However, it must

Post-flood trauma, Zhouqu County, Gansu Province, August 2010
Source: news.163.com.cn (Zhiyong Gong).

be managed wisely to achieve the trade-off that maximizes the margin between development benefits and the cost of flood risk.[13]

Green, Parker, and Tunstall,[14] reporting for the World Commission on Dams, state that

> In the case of flooding, the appropriate economic objective is to maximize the efficiency of use of the catchment and not to minimize flood losses. Trends in national flood losses need not provide any guide to the success or failure of the national flood management strategy adopted: it can readily be shown that efficient flood management policy can be accompanied by a rise in both flood losses and the costs of flood management.

The implication is that the costs incurred by increased flood losses and costs of flood management may be acceptable if they maximize the positive margin of development benefits—i.e., if the benefits significantly exceed the costs. Even though this counters a popular expectation that increased expenditure in flood management should be accompanied by a decrease in flood losses, it is perfectly logical. It should be added that in determining the balance that is most

[13] See for example, Jarraud, M. 2005. State of the Art in Policy Development and Implementation—From Flood Management to Integrated Flood Management. Keynote speech presented at the Symposium on Floods, from Defence to Management. Nijmegen, Netherlands. 25–27 May 2005.

[14] Green, C. H., D. J. Parker, and S. M. Tunstall. 2000. Assessment of Flood Control and Management Options. *World Commission on Dams, Thematic Review Options Assessment* No. IV. 4 November. Cape Town.

People at risk, Fuzhou County, Jiangxi Province, June 2010
Source: *China Daily*.

appropriate for the PRC, the benefits and costs that need to be assessed are not only economic, but also social and environmental.

With respect to the management of exposure to flood hazard, land use planning and management aims to ensure that development is compatible with the attributes of the land upon which development is proposed, including the attributes of flood hazard.

## Methods

Resettlement is a management measure that has been used in the PRC to modify exposure to flood hazard (Box 7).

**Box 7 Modifying Exposure by Resettlement**

Resettlement is a form of land use management that has been applied in the People's Republic of China. Particularly after the flood disasters of 1998, large numbers of people were resettled in order to recover flood storage in floodplains and designated flood detention areas. Resettlement projects were supported by programs to rehouse relocated families and provide opportunities and services. However, regardless of how well these measures may have been implemented, enforced resettlement is a form of social engineering that inevitably causes some dissatisfaction, disrupting the established social fabric of community life and, in the case of rural communities, attachments to land. In some cases, people who had been resettled drifted back to where they originated, despite official displeasure. The policy has since been changed so that resettlement is now voluntary. Nevertheless, it remains a viable measure in the People's Republic of China for modifying exposure to flood hazard.

Source: ADB. 2005. *National Flood Management Strategy.* Consultant's report. Manila (TA 4327-PRC).

Urban development flooded

Source: Institute of Water Resources and Hydropower Research.

A more common approach in many countries is to adopt measures to regulate how land may be used. These are most effective when directed at future development and land use. Exposure to flood hazard can be contained at or near current levels by (i) regulating residential development to manage population increase in hazard areas, (ii) managing the types of enterprise permitted in hazard areas, and (iii) integrating planning of public infrastructure. Without such regulation, danger and damages from future floods will inevitably increase unless additional structural measures are implemented to modify the flood hazard.

A preliminary step is to delineate the extents of flood hazard areas and quantify or estimate the flood hazard (e.g., the frequency and depth of inundation). This requires hydrological and hydraulic analysis and flood hazard mapping.[15]

Ideally, a digital terrain model is available or can be acquired for hydraulic analysis and a geographic information system (GIS) is routinely applied in mapping. If data are inadequate for this type of technical analysis, preliminary flood hazard mapping may be based on past experience of flooding and flood extents, which can best be accomplished with community participation. The land can then be categorized according to its flood hazard, e.g., low, medium, or high hazard.

The basis of classification typically considers the frequency of flooding, depth of inundation, and velocity of flow. Other criteria may also be relevant, e.g., inundation of evacuation routes and duration of inundation. A combination of depth and velocity is commonly used to determine the danger to people trapped in floodwaters. Above a certain threshold, there is great danger of being swept away or danger to small children. The land is then zoned according to the hazard category.

[15] If the mapping also shows land use, buildings, and infrastructure exposed to the hazard, it may also be referred to as flood risk mapping.

Flash flood

Source: Institute of Water Resources and Hydropower Research.

Land use regulations can then be attributed to the different zones or categories of flood hazard. This is best done in association with statutory spatial planning, a typical local government responsibility. The flood hazard should be considered in conjunction with other spatial planning objectives. However, in general, the regulations should determine the:

- type of buildings that are appropriate;
- land use that is appropriate, which may exclude residential use or be limited to uses such as recreation and agriculture;
- siting of public services such as schools, hospitals, emergency services, and flood refuges;
- storage of hazardous chemicals and materials; and
- routing and/or siting of key infrastructure such as electricity substations, water supply, water treatment, and sewerage facilities.

The land use controls should be linked to building regulations, which are also directed to reducing vulnerability to exposure that may be permitted under land use management, but are inextricably linked to land use controls and zoning. Building regulations may specify minimum floor levels. For example, they may require dual-story housing or place conditions on electrical supply, drainage, and sewerage provision. Certain types of construction may be proscribed as unsuitable for structural integrity during inundation or may be required to have ancillary measures to allow the sealing of openings and flood-proofing during flood alerts. This is not an exhaustive account, but indicates the type of regulations that may be introduced. They should be connected to the system of approvals for building applications. The system should include provision for inspections to ensure compliance and appropriate penalties for noncompliance.

Flood impacts, Fuzhou County, Jiangxi Province, June 2010
Source: news24.com

Although methods of land use management are better suited to regulate future development, existing development exposed to flood hazard may also justify land use management intervention to redress past problems or planning omissions. For instance, this could entail voluntary or compulsory acquisition of properties. However, compulsory acquisition should be restricted to allotments where current land use or development exposes people to great danger or there is frequent inundation of the land (i.e., higher hazard land). After public acquisition, the land can be converted to alternative use more compatible with the flood hazard.

It may be possible to retain current land use and modify exposure to the flood hazard. For example, access to buildings may be modified, the lower levels of building levels may be converted to passive use such as car parks, and flood barriers and watertight seals may be added.

## Constraints

There are various reasons why land use management except for mass resettlement schemes has not been fully utilized as a flood management measure in the PRC. Some are practical considerations while others are common institutional constraints.

As noted above, in many locations in the PRC, there is limited land suitable for development because of the terrain and very high populations. Thus, there is a huge demand for development of the land even where there may be significant flood hazard. The pressure of that demand makes it difficult and impractical to avoid use of land liable to flooding.

Flash flood

Source: Institute of Water Resources and Hydropower Research.

Nevertheless, where use of flood risk land is inevitable, it would be possible to impose conditions on development and regulate building to make occupation of floodplain land safer and manage flood risk. However, this has been made very difficult by the extremely rapid pace of urbanization and socioeconomic development in the PRC. To start with, the resources to adequately plan, regulate, monitor, and enforce in the face of such dynamic expansion have been too limited.

In practice, local governments are in charge of most development. Governments of municipalities, counties, and towns supervise urban, industrial, and commercial development. There is competition to attract new development during periods of rapid economic expansion, and measures that may restrict or place conditions on development are generally unpopular with local governments.

At the national level, the division of responsibilities between different ministries, which is also largely replicated at other tiers of government, proves an obstacle to integrated flood management. While the Ministry of Water Resources (MWR) assumes responsibility for flood control and management, other key ministries are responsible in managing land use and regulating building construction.

Development management by the MWR in the past has been mainly restricted to nominally protected areas—principally the riparian land between rivers (or lakes) and the flood protection dikes flanking them. Administrative agencies have little incentive to stray beyond perceived boundaries of their mandates as prescribed in legislation.

The integration required could be achieved through partnership and unified action; but this has not happened because of the lack of effective mechanisms for joint planning and management. The inertia characteristic of government institutions means that the significant extra effort demanded by active joint management is avoided. The typical response is denial that an issue exists, which then obviates the need for any new initiative. Such institutional barriers are encountered everywhere.

6

# Management of Vulnerability to Danger or Damage

## A. Vulnerability

Exposure to flood hazard creates the potential for personal danger and property damage to occur during floods. The actual consequences of flooding also depend on how vulnerable assets, people, and their property are to danger or damage. Taking adequate precautions prior to flooding reduces vulnerability. This includes receiving flood warnings on time, knowing how to respond to limit danger and damage, and receiving appropriate assistance during and after floods.

Examples of advance precautions that may be taken to reduce vulnerability include

- using construction materials that are less susceptible to damage by water;
- building with floor levels raised above flood levels or with second stories or flat roofs that provide refuge (both modifying exposure, and reducing vulnerability);
- preparing animal shelters and dry storage for foodstuffs and perishable goods;
- providing evacuation routes and temporary refuge facilities;
- conducting advance planning and trials of emergency management procedures;
- developing reliable communications systems and flood warning data networks; and
- providing support services like flood forecasting and decision support systems.

Some of the precautions are measures that communities or individual families can organize themselves, although informed advice is helpful for their preparations. The first three examples listed are measures of this type. Other measures are better planned and managed by government authorities. Most effective is a top–down and bottom–up consultative approach with a two-way flow of advice to blend professional and local personal experience and ensure that community needs are identified and addressed.

Vulnerability and the social consequences of flooding also depend on prevailing economic conditions, nutrition, housing and education, the standard of governance, and existing public infrastructure and services. Poverty, low standards of housing and nutrition, and poor governance make communities more susceptible to the adverse impacts of flooding and make it more difficult for them to recover from natural disasters. Although these susceptibility issues are relevant to the management of flood risk, it is more appropriate they should be the subject of other programs for poverty alleviation, good governance, and structural improvements to education, housing, etc., that may be linked to flood risk management.

Salvage work after flood, Zhouqu County, Gansu Province, August 2010
Source: chinanews.com

## B. Management Measures for Reducing Vulnerability

The measures used to manage vulnerability in flood risk management are essentially nonstructural. They require meticulous planning and swift mobilization of planned actions during flood emergencies.

Although the time and effort required for thorough planning may be very demanding on available human resources, the costs of nonstructural measures are generally much lower than those of large- and medium-scale structural measures. Thus, nonstructural measures are now often regarded as more cost-effective.

It is also important to regularly review and test the procedures in the plans; particularly in view of shifting personnel, staff responsibilities, and organizational structures; but also to offset the complacency that grows during years without floods. This maintains preparedness for implementing plans, which may need to be activated at very short notice and at times which are inconvenient (e.g., at night-time or during holiday periods).

Even where structural measures provide some standard of management of flood hazard or where land use management measures may manage exposure to flood hazard, management of the residual risk is essential. This is one role of nonstructural measures that reduce the vulnerability factor of flood risk.

## Flood Warning

A simple prerequisite is to know about an impending flood so that appropriate action can be initiated. Flood warning therefore has a central role in flood management and the management of vulnerability in flood risk. All of the plans prepared in advance must be activated by a flood warning.

The purpose of flood warning is for the local authorities to initiate emergency response procedures and for the persons exposed to flood hazard to prepare for impending hazard to reduce damages and preserve their personal, family's, and neighbors' safety. If effective, these measures reduce the vulnerability of people, property, and infrastructure exposed to hazards.

The foundation of any good flood warning system is a data acquisition network that can monitor conditions of precipitation and river levels in the field and transmit these data in real time or near real time to a center or centers where data is managed and analyzed.

The recent expansion of networks that use global systems for mobile communications such as wireless telephone systems has rapidly assumed prominence in data transmission technology. However, more traditional telemetry systems based on dedicated telephone lines, satellite services, or radio are still operational in many places and remain viable alternatives.

Computers at control centers generally manage and analyze data transmitted and are capable of raising auto-alerts based on pre-programmed criteria, typically thresholds of river levels and/or accumulated rainfall. Communication technology is also important in disseminating warnings to managers responsible and community flood wardens. Global systems for mobile communications again play a key role; but because mobile telephones may be switched off or inoperable, establishing backup communications using an alternative medium (redundancy) is recommended, with protocols to ensure that messages are received and acted upon.

For flash floods, warning times are short. However, even short warning times can be valuable. In the PRC, a program has been initiated to implement and operate pilot flash flood monitoring and warning systems in susceptible mountainous areas. Warning times could be extended if short-term weather forecasting can be used to prepare quantitative precipitation forecasts. In theory, a reasonably accurate quantitative precipitation forecast can be prepared at a regional level using weather radar for spatial estimation of precipitation depths and satellite imagery for synoptic analysis. Current developments in Europe and the United States are based on combining regional forecasting with more local forecasts that also use monitored precipitation and river hydrological data.

## Flood Forecasting

Flood forecasting depends on flood warning systems, hydrological and hydraulic modeling, geographic information system (GIS) software, computer processing equipment, etc. Technological advances continue to be made in these fields, and it is an ongoing challenge to update to most recent technology and stay ahead of equipment and software obsolescence.

Hydrological models of river basin runoff response to rainfall are used to estimate the magnitude of flood discharges. These models should be linked to data acquisition systems monitoring field data in real time or near real time. Ideally, the models should have feedback algorithms that can update forecasts based on latest available data (Box 8).

A limitation of hydrological forecasting models is that they forecast discharges at specific locations, typically key monitoring stations, that may be widely separated. Using the forecast discharges, hydraulic models are used to generalize the forecasts to estimate flood levels and extents of inundation along the rivers and through floodplains. Hydraulic modeling is most powerful when used in conjunction with GIS spatial data on land use, infrastructure, and building development to show estimated flood levels and depths of inundation. This allows the impacts of flooding to be visualized.

**Box 8 Flood Forecasting with Infrastructure Operations**

Flood forecasting can be complicated by the need to consider operations of flood control infrastructure within river basins, such as gated dams used for flood mitigation or controlled diversions to flood detention areas. Both are common in the People's Republic of China. The problem is alleviated if thorough analysis using standard design floods is conducted in advance of the passage of floods through dams and diversions of floodwaters to flood detention areas. Such analysis should be undertaken at the design stage and then the standard operating procedures can be hard-wired into the forecast methods. However, problems arise because the downstream conditions assumed during design may have changed over time or because the design analysis was not thorough. In any case, during real floods, there may be significant departures from the standard floods used in design and planning. Therefore, it may be desirable to include algorithms in forecasting models that permit the user to test alternative modes of infrastructure operation and provide the flexibility to adapt to evolving flood conditions in real time. In this case, the forecasting tool would also be used as a decision support tool. This can substantially increase the iteration time of forecasts, and becomes most practical in larger river basins with longer warning times.

Source: ADB. 2010. *Implementing the National Flood Management Strategy TA 7049-PRC.* Consultant's report. Manila (TA 7049-PRC).

A constraint in flood forecasting may be the availability of adequate historical data to calibrate and validate the forecasting models. This applies to smaller river basins subject to flash flooding.

Two-dimensional hydraulic modeling of floodplains requires a digital terrain model. If not already available, topographic data has to be acquired and a digital model prepared, which could involve delays.

## Flood Mapping

Hydraulic modeling of floods provides the basis for flood mapping. Modeling results on flood levels and flow velocities overlaid on a digital terrain model provides flood hazard maps with depths of inundation, typically for a range of design floods with different probabilities of exceedance. If GIS layers show land use, buildings, and infrastructure (indicators of assets and people exposed to the hazards), maps produced may be termed flood risk maps.

Flood mapping is a keystone of the new European Union directive on flood management,[16] and different types of mapping undertaken in Europe are considered.[17]

Flood maps may be used in land use management (pp. 23–29), development planning, emergency response planning, and during flood emergency response. Flood risk maps are also a valuable aid in community consultation and community-based flood risk management.

Land protected by dikes constructed to a design flood standard should always be included in flood risk mapping. This is important to avoid reinforcing incorrect ideas that the flood risk may have been eliminated by dike construction. Actual extents of inundation during any future flood event in which dikes are overtopped or breached will depend upon the mode of failure, which may be impossible to predict. The entire area protected remains subject to flood risk. The probability associated with that risk cannot be nominated precisely, but assuming that the structural integrity of the dikes is sound, it should be less than the exceedance probability of the dike design flood standard.

## Community Awareness and Preparedness

Raising public awareness of flood risk is important for those exposed to flood hazard. This is important in situations with a lower frequency of serious flooding (where awareness fades over time), new urban developments (where

[16] European Union. 2007. *Directive on the Assessment and Management of Flood Risk.* Brussels. For information on the different types of mapping undertaken in Europe, see European Exchange Circle on Flood Mapping. 2007. *Handbook on Good Practices for Flood Mapping in Europe.* Brussels.

[17] European Exchange Circle on Flood Mapping. 2007. *Handbook on Good Practices for Flood Mapping in Europe.* Brussels.


Past flood level markers and emergency response poster, Henan Province, 2009

Source: *Liang Zhiyong*, Institute of Water Resources and Hydropower Research.

residents lack past flood experience), and in mountainous areas susceptible to flash flooding (where response must be swift). Preparedness can only follow from awareness.

Providing more opportunities for participation in the planning process may be important in this regard. Information on planning issues can also be made available in websites and via social networking on the internet, including links to releases of flood mapping and planning studies.

Traditional media such as radio, television, and newspapers can communicate effectively and regularly remind the public of the risk of flooding, as well as disseminate flood warnings. Distribution of information leaflets to residents with advice on simple and practical measures to protect their families and property can be an effective means of raising awareness.

Material should also be prepared for inclusion in school curricula. Children are particularly vulnerable as they typically lack experience of floods. Raising the issue in classrooms may prompt family discussions and disclosures from parents about their past exposure to floods that may not have been discussed otherwise. Assistance from teachers should be sought so that the material can be presented in the most meaningful and interesting way to students.

Community-based flood risk management (CBFRM) is a technique promoted in other countries. The concept underlying CBFRM is that communities at risk can and should organize in advance, participate in planning, and prepare themselves for the flood hazard to which they will be exposed. Most communities require external support and modest funding to be able to do this. While the funding required by communities may be modest, the support and advice required may be substantial, and government-sponsored community workers may need to spend considerable time in the field to impart basic knowledge and skills and encourage participation. Identification of people or groups who will commit and champion the cause within their communities is essential to sustain these programs. An initial part of each community program entails educational training that raises awareness of the flood risk so that people will be motivated to undertake the necessary planning and preparations. Those identified as potential champions should be provided with additional training so that they can train others. Communities should be assisted to acquire simple materials and equipment to undertake preparations and perform their own


Dike breach

Source: china.org.cn

monitoring. For best outcomes, CBFRM should be linked to government services such as early warning systems, emergency response action plans, and post-flood recovery assistance. These services become more effective if the communities to benefit are informed in advance of government initiatives and participate in their planning and implementation. Awareness of flood risk needs to be maintained by regular information and media campaigns. Annual drills also serve to maintain preparedness.

## Emergency Response

The PRC has well-developed and well-organized flood emergency response systems. Together with structural flood control measures, they form the robust backbone of flood management practice in the PRC. There are flood control and drought relief headquarters (FCDHs). The State FCDH at a national level is responsible for flood emergency nationwide. FCDHs are replicated in seven river basin commissions (RBCs),[18] provincial water resources departments, and local governments' water resources bureaus.

During each flood season, the meteorology, hydrology, and oceanology departments are responsible for providing and updating weather, hydrology, and storm tide forecasts to the FCDHs. Other departments are responsible for maintaining supply of materials, telecommunications, transport, and power required for flood management activities and flood fighting.

The FCDHs assume a command role during flood emergency operations, and other agencies are obliged to assist. The operation of flood control infrastructure (reservoirs and other regulating and diversion structures) comes under their command, although the operations typically continue to be implemented by the usual operators based on FCDH orders. FCDHs are responsible for coordinating emergency response activities, including strengthening or repair of flood defense works (e.g., dikes), flood fighting, evacuations, and rescues. Emergency response often requires actions by various administrative departments of government, but leadership and command authority of high-level officials of the FCDHs, which were conferred by the State Council, enable effective coordination of all actions necessary to manage public safety and security. Administrative heads of governments who lead the FCDHs also possess the authority to mobilize community assistance, the People's Liberation Army, and the People's Armed Police to assist in flood fighting.

[18] The Changjiang Water Resources Commission for the Yangtze River Basin, the Hai River Water Resources Commission for the Hai River Basin, the Huai River Water Resources Commission for the Huai River Basin, the Pearl River Water Resources Commission for the Pearl River Basin, the Songliao River Water Resources Commission for the Songhua and Liao river basins, the Taihu Basin Authority for the Tai(hu) Lake Basin, and the Yellow River Conservancy Commission for the Yellow River Basin.

Preparedness exercises are important for maintaining readiness and should be carried out every year prior to flood seasons. Critical performance reviews should be undertaken every year after each flood season. These help identify weaknesses that may potentially impair implementation of the emergency response plans (e.g., due to changes in personnel, disrepair of equipment, or erosion of structural works) in time for corrective action. Equipment must be maintained in operational condition, or replaced or updated. Materials must be stockpiled in preparation for possible use if floods develop.

## Post-Flood Recovery

Recovery activities after flood disasters are closely associated with emergency management. In the short term, they focus on the material needs of flood victims, including temporary supply of food and shelter. They then focus on providing support services such as assistance in cleanup activities, teams of health professionals to prevent spread of epidemics and waterborne diseases, and counseling to overcome personal distress and financial problems. Public infrastructure may require repairs and rehabilitation where public services such as water supply and sewerage need to be restored. Governments may elect to provide financial assistance for incurred losses, housing repairs, businesses that may encounter hardships due to disruption of normal commerce, loss of stock and supplies, etc. Governments may also offer incentives to families and enterprises to make them less vulnerable to damage and disruption in future floods. In the PRC, the Ministry of Civil Affairs and the Ministry of Health play key roles in post-flood recovery, but many others are involved in the restoration of services and infrastructure repairs under their separate areas of responsibility. These operations are performed, coordinated, and undertaken reasonably well, partly because post-flood recovery falls under the same kind of coordinated command as emergency management. As part of its role to mitigate the direct impacts of flood events, the FCDH has the authority to direct coordinated response to aid post-flood recovery and maintain public health and security. Nongovernment agencies may provide complementary assistance during the flood relief and recovery phase.


Flood rescue

Source: Institute of Water Resources and Hydropower Research.

Flood relief operations

Source: Creative Commons.

## Flood Insurance

Financial aid (or compensation) that central and local governments of the PRC currently deliver falls far short of actual financial losses incurred during floods. Although they vary from year to year, flood losses currently amount to around 1% of gross domestic product, and are an unwanted burden on limited government revenue. Their unpredictable timing is inconsistent with formal budgetary planning, and when large floods occur, government assistance required for post-flood recovery is a drain on financial resources and often entails redirection of funds from other national priorities.

Flood insurance (or, more generally, disaster insurance) has the potential to greatly ease the financial burden on government and enable better planning of the allocation of limited resources. Flood insurance has been applied with varying success in many other countries. The National Flood Insurance Program is an important part of the national flood management strategy in the United States. Good models are available in other countries such as Spain's Consorcio de Compensacion de Sequros and New Zealand's Earthquake Commission.

There have been trials of government-sponsored insurance schemes in the PRC during the 1990s, which were generally unsuccessful. While there were many reasons for their collapse, insurance can rarely (if ever) be successful if directed purely at high-risk areas (e.g., flood detention basins). In insurance jargon, this represents adverse selection and provides little opportunity for cross-subsidization that can make insurance more affordable and viable. More universal flood insurance (or disaster insurance) is required for this flood management measure to effectively manage the financial vulnerability of those in flood risk areas.

**Box 9 Indemnity versus Parametric Insurance**

A characteristic feature of normal fire insurance is that it is indemnity based—i.e., the sum insured is based on the loss sustained by the policyholder. Initially, the sum insured was the actual assessed value of the property during the period of the insurance, which became known as the indemnity value.

There is an alternative form that is widely used in weather insurance, and has the potential to be more widely used in catastrophe insurance. This is commonly described as parametric insurance, or in one particular form as index-based insurance. The most common form of parametric insurance is rain event cancellation insurance where an organizer of an outdoor event takes out insurance for a specified amount which can be claimed if recorded rainfall in the vicinity of the event location exceeds a specified amount within a specified time period up to the event, and maybe including part of the event. In this system, claims are not related to the loss sustained by the policyholder, but are fixed by the amount of cover specified by the policyholder.

The main advantage of indemnity insurance is that the policyholder is compensated for the actual assessed loss sustained. The main disadvantages of indemnity insurance are that (i) it is dependent on an assessment of the damage post-event which can take time and can be a source of dispute, (ii) the assessment of the risk for premium setting and catastrophe reinsurance purposes is dependent on an estimate of the vulnerability of the property to the pre-event, (iii) and premiums are effectively fixed by the indemnity or replacement value of the property.

The main advantages of parametric insurance are that (i) in general, assessment of claims is dependent only on a measured parameter relating to the physical magnitude of the event, so claims can be processed rapidly with only a small risk of dispute; (ii) the assessment of risk is restricted to the specified event parameter, about which more is generally known than about vulnerability; and (iii) policyholders can limit the sum insured to the amount of premium they can afford. The main disadvantage is that in a particular event the actual loss sustained may be significantly different from the claim, if any, that can be made. This is known as "basis risk." For parametric risk to be acceptable, the basis risk must be manageable.

Source: Walker, G., T. Lin, and Y. Kobayashi. 2009. Is Flood Insurance Feasible?: Experience from the People's Republic of China. *ADB Sustainable Development Working Paper Series* No. 5. Manila: Asian Development Bank.

Except for inundation of flood detention areas (p. 5), damage from all the types of inland flooding has the potential of being covered by flood insurance, whether indemnity based or parametric (Box 9), subject to the following considerations:[19]

(i) Flood insurance is most feasible if supported by detailed mapping of the flood risk and reliable data on building floor level elevations relative to flood risk levels.

(ii) Normal indemnity flood insurance is likely to be more feasible for property in lower risk areas. For property in higher risk areas, normal indemnity flood insurance might need to be accompanied by significant co-insurance by the property owner and government subsidies of the premiums in order to be feasible.

(iii) Parametric insurance is more suited for flood than most other hazards because of the much lower associated basis risk, and is always affordable because the property holder can tailor the sum insured to the amount of premium which is affordable. However the government may still consider the necessity of providing additional premium contributions for household property in higher risk areas (e.g., areas below the 50-year flood level) to ensure a reasonable level of cover.

Parametric flood insurance appears to have a number of advantages for the insurance of properties in the higher risk categories as it allows the property owner to select an amount of insurance cover independent of the type of property to be covered based on financial costs and benefits, it is simpler to administer, and it is less prone to moral hazard and disputation over claims.

While there is great potential for insurance to play an important role in the PRC, the following are required before a sound insurance scheme can be devised:

(i) Further development of the finance sector under a market economy is required so that private individuals gain more confidence about securing loans from banking and lending institutions and in the security of insurance firms to whom they entrust premiums.

[19] Walker, G., T. Lin, and Y. Kobayashi. 2009. Is Flood Insurance Feasible?: Experience from the People's Republic of China. *ADB Sustainable Development Working Paper Series* No. 5. Manila: Asian Development Bank.

Rail bridge collapse

Source: www.news.cn

(ii) Levels of private wealth (particularly the value of private assets) will have to increase before there is a large and willing customer base.

(iii) In terms of affordability, a government fund scheme without reinsurance would appear to provide the most feasible approach to flood insurance, but would require a considerable commitment by the government to a liability to large losses.

(iv) From normal revenue in addition to subsidizing premiums.

(v) If a scheme based on indemnity flood insurance is to be implemented, a detailed study of flood damage losses at the building floor level for different types of occupancy and construction type and different depths of floor inundation will be required to estimate premiums reliably.

To optimize the design of any proposed scheme of flood insurance, ensure a low rate of reinsurance, and manage the sustainability of the scheme, it will be necessary to undertake a detailed study of the potential event losses to the scheme and their frequency of exceedance. This requires significant hydrological research.

Crop damage

Source: Institute of Water Resources and Hydropower Research.

7

# Institutional Foundation

The foundation for management of flood risk is a sound institutional framework of legislation and policy, organizational structure, skills and training, and funding. In all of these respects, the foundation is firm in the PRC. The Flood Control Law of 1997 is the centerpiece legislation supported by regulations guiding the implementation of flood management policies. The Ministry of Water Resources (MWR) at the national level, and administrative departments for water resources management at other levels of government, have clear mandates to lead flood management planning, and have a large, skilled workforce and good managerial capacity to implement the policies.

Nevertheless, the transition from flood control to integrated flood management presents formidable challenges. It demands a raised awareness and changed consciousness about the role of nonstructural flood management measures and the social and eco-environmental dimensions of flood management. It also demands a new way of implementing and integrating flood management within existing organizational structures that will require greater partnership and coordination.


Flash flood, Chongqing Municipality, August 2009

Source: Chengdu Business.

## A. Legislation and Policy

In the PRC, laws are passed by the People's Congresses and implemented by the State Council. The Water Law of 1988 included a section—Chapter V—on flood control and flood fighting, but the need for a change in approach from flood control to flood management provided the impetus for promulgating a separate Flood Control Law in 1997. When the Water Law was revised in 2002, the original Chapter V was excised.

Some interesting features of the Flood Control Law are listed in Box 10.

Laws are supplemented and supported by numerous regulations, generally drafted by relevant administrative departments or ministries—in this case, the MWR. Laws set out broad policy while regulations describe how to give effect to that policy, but this is only a generalization. The Flood Control Law, for example, contains substantial detail on how certain aspects of flood management should be implemented. Inevitably, there has been a need to supplement the provisions of the law with additional administrative regulations over time. More technical aspects of how to implement the policy may also be the subject of technical guidelines or manuals.

There are now several important regulations supplementing the law directing how specific aspects of flood management are to be implemented, some of which precede the Flood Control Law of 1997. To date, supplementary regulations are restricted to functions that are the responsibility of the MWR. These include regulations relating to safety and compensation provisions for flood detention areas, river management, flood fighting, dam safety, flood protection standards, and flood impact assessments.

Lack of laws or regulations to manage development on floodplains and in flood hazard areas is one reason why flood detention basins, floodways, lakeshores, wetlands, and areas at high risk of flash flooding have been occupied, allowing inappropriate land use and increasing exposure to flood hazard.

The Flood Control Law also encourages sharing of flood risk through insurance measures but without being specific about how this might be achieved. Because huge losses may be incurred in flood disasters, either the premiums

**Box 10 Flood Control Law Provisions**

Key management measures identified in the Flood Control Law include

(i) formulation of flood control (management) plans for rivers, lakes, and cities, and for storm surge in coastal areas;

(ii) formulation of control (management) plans for elimination of waterlogging (poor rural land drainage);

(iii) formulation of estuary regulation plans for the Yangtze, Yellow, Pearl, Liao, Huai, and Hai rivers;

(iv) delineation of planned reserves zoned for flood control use (e.g., flood detention areas);

(v) engineering structures in river courses and lakes, with proposed construction works being subjected to the review and approval of the water resources administrative department of the relevant tier of government;

(vi) zoning flood control areas as "flood-prone," "flood detention," and "protected" zones, with provision for administration of the use of land within zones;

(vii) establishment of support systems by the State Council and relevant governments of provinces, autonomous regions, and municipalities to provide compensation and aid to flood detention areas;

(viii) provision of flood impact assessment reports and formulation of precautionary measures where a construction project not intended for flood control is to be carried out within a "flood-prone" or "flood detention" area;

(ix) formulation of flood fighting and emergency response planning through Flood Control and Drought Relief Headquarters of county and higher level governments, or directly by the State Flood Control and Drought Relief Headquarters in the cases of the Yangtze, Yellow, Huai, and Hai river basins, which are subject to approval by the State Council; and

(x) establishment by the State of a fund for maintenance and construction of flood control and water conservancy works, and provisions for levies by provinces, autonomous regions, and municipalities for construction, maintenance, and administration of river engineering projects.

Source: Government of the People's Republic of China. 1997. *Flood Control Law.*

will be impossibly high or the insurance company will be bound to suffer losses if only those at greatest risk take out premiums. In these circumstances, the market mechanisms will almost certainly fail.

This has been the experience of past government-sponsored trials of flood insurance in the PRC. Cross-subsidization with other policyholders at lower risk is necessary to make insurance economically viable. The government needs to take a more active role to formulate viable rules and regulations if flood insurance is to be effective.

## B. Organizational Structure

There are two parallel administration structures for flood management in the PRC. One is mainly concerned with planning, construction, and routine management of flood control works, while the other is in charge of operational management and flood fighting initiatives during the flood season.

### Flood Operations

During flood emergencies, flood control and drought relief headquarters (FCDHs) at the national and other levels of government administration take command of flood operations, flood emergency response, and post-flood recovery. To confer adequate authority for coordination and swift response, the head of the State FCDH is the Vice Premier, a member of the highest executive body in the nation—the State Council. Leaders of relevant ministries are official members of the State FCDH, and may operate from the State FCDH office at times during the flood season (Figure 3). In a similar manner, the head of a provincial FCDH would be the governor of the province, with leaders of relevant provincial administrative departments as official members of the provincial FCDH.

Figure 3 Institutional Organization for Flood Operations and Flood Fighting

| | |
|---|---|
| **State FCDH** | |
| Head: | Vice Premier |
| Members: | Leaders of relevant ministries |
| Office: | Located at the Ministry of Water Resources |
| **River Basin FCDH** | |
| Members: | Leaders of provinces within the river basin, head of the river basin commission |
| Office: | Located at the river basin commission |
| **Provincial FCDH** | |
| Head: | Governor |
| Members: | Leaders of related provincial administrative departments |
| Office: | Located at Department of Water Resources |
| FCDH at Other Levels (city, county, etc.) | |

FCDH = flood control and drought relief headquarters.

Source: ADB. 2010. *Implementing the National Flood Management Strategy TA 7049-PRC.* Consultant's report. Manila (TA 7049-PRC).

The FCDH organization has been very effective in planning and managing flood emergency response.

### General Administration and Planning

At the national level, the ongoing tasks of administration and planning of flood management are the responsibilities of the MWR. These responsibilities are mirrored at the regional tier of government by a department of water resources in provinces and autonomous regions, or a water resources bureau in special municipalities. In the PRC, there are 23 provinces, 5 autonomous regions, and 4 special municipalities (Beijing, Chongqing, Shanghai, and Tianjin). Most provinces and autonomous regions can be compared to major European nations in terms of area and population. Similar arrangements apply at lower tiers of government.

In eight major river and lake basins in the PRC, seven river basin commissions (RBCs) are responsible in formulating plans for water resources management and flood control (flood management). RBCs manifest a conscious decision by government to manage water resources at the river basin scale. They are instruments of the central government's MWR, however, staffed exclusively with water professionals and administrators with the designated role of coordinating, planning, and managing large river basins spanning several provinces. In the Yellow River Basin, the first basin where a RBC was instituted, the coordination works acceptably well. In other river basins, limitations of the organizational framework in conjunction with the political and economic power of provinces can be barriers to successful coordination.[20]

Everywhere in the world, government institutions divide administrative responsibilities to become more manageable. Many of the goals of the society are not so readily divisible, so overlap or gaps often arise. Flood management is one such goal, in which effective integration can only be achieved by multiple institutions. While it is appropriate for the MWR to be the lead institution in future flood management, it needs to work in partnership with other agencies to achieve the objectives of integrated flood management.

The MWR has been quite effective in planning and implementing flood control structural works, and more recently in developing flood forecasting and other nonstructural capabilities. To fully integrate flood management, it is essential to establish working partnerships with other administrative authorities and to coordinate ongoing flood management planning although the effective mechanisms to achieve this are lacking. The main missing link in flood management in the PRC is land use management. This has come about because the MWR has been responsible for flood control or flood management, and land management and spatial land use planning clearly fall outside its mandate.

## C. Skills and Training

A highly competitive education system in the PRC guarantees a good supply of trained professionals. However, changing technology and the shift from flood control centered on structural measures to a more integrated flood management employing both nonstructural and structural measures require additional training for practicing professionals and revision of water resources engineering curricula in tertiary education institutions.

There is broad, if not universal, awareness of the need to shift from flood control to integrated flood management in the related professional engineering sector in the PRC. The level of understanding of what integrated flood management entails and what benefits it can deliver varies, and there is widespread uncertainty and lack of knowledge about how to put it into practice. Training of professional staff and capacity building within institutions is necessary if this desire is to be translated into effective management and good practice.

Because of the large scale of the flood management community in the PRC, and its dispersion in provinces and local governments throughout this large nation, the tasks of training, capacity building, and awareness raising are daunting. If integrated flood management is to be practiced effectively, regular training should be sustained over a prolonged period.

The flood management community (or flood control community) in the PRC has been strongly dominated by engineers and concentrated within the MWR (and its surrogate institutions at other tiers of government). It needs to become more broadly based if the shift to integrated flood management is to be realized. More professional planners (e.g., social, infrastructure, and urban planners); economists; and environmental scientists need to embrace the

[20] World Bank. 2009. *Addressing China's Water Scarcity: Recommendations for Selected Water Resource Management Issues.* Washington, DC.

discipline. Other government administrative departments must also be involved. To achieve this, broadening of the practice, training, capacity building, and awareness raising are again essential.

Targeted training sessions are necessary at all tiers of government. Careful explanation of integrated flood management and flood risk management is required. The beneficial outcomes of implementing integrated flood risk management must be made clear and emphasized in terms of the three planks of sustainable development—economic, social, and environmental benefits. It will also be most important to demonstrate how integrated flood risk management can be implemented to achieve those benefits. This is done best using case studies.

It would also be extremely valuable to target government leaders and decision makers, who may be non-professionals. Among other things, integrated flood management means integrated actions to manage floods, often requiring partnership between different administrative departments of governments. Active management is desired to achieve the coordination that has been lacking in past flood management practice. This is essential if the shift to integrated flood management is to be realized. Active management presupposes informed management. Different approaches may be necessary to raise the awareness of leaders in government with respect to flood management and the need for coordination and institutional partnerships to achieve integrated management.

Future research needs to be directed toward overcoming the constraints to integrated flood management, adapting flood management to the specific circumstances of the PRC and its diverse provinces, and identifying the future needs of flood management in the country (e.g., climate change, shifting social attitudes and expectations, and demographics). Tertiary education of water resources professionals also needs to be adapted to reflect the broader social and environmental dimensions of the work they will be required to do during their professional careers and to explain risk management theory and practice.

Policy shifts and advances in technology should be supported by the preparation or revision of technical guidelines explaining how the policy can be implemented and how to apply new techniques. New or revised guidelines should be accompanied by thorough training programs. Some guidelines and training should be directed to specific subjects to expand knowledge of recent innovations that have yet to be widely integrated in flood management (e.g., hydraulic modeling, flood hazard mapping, and spatial planning).

## D. Funding

Despite huge past investment in flood control structural measures in the PRC, much can be done to improve security from flood risk of people, assets, and infrastructure exposed to flood hazard. Many lives are lost each year, and there has been no decline in the trend of flood damages. Ongoing investment is required in both nonstructural and structural flood management measures and reliable sources of future funding are essential.

The impressive investment in structural flood defenses in the modern PRC has played a vital role in containing damages and nurturing national economic and social development, as well as contributing to the reduction in loss of life. The scale of monitoring and maintaining a legacy of aging flood defense structures is monumental. Past political and engineering emphasis on implementing works by harnessing the rivers, controlling floods, and taming nature, led to construction that was sometimes of inadequate technical design in terms of acceptance of risk and longevity of service. In the mid-20th century, many works were accomplished by people power with limited technical inputs. These shortcomings have been corrected in the contemporary PRC, but the ongoing safe operation of many older structures depends heavily on adequate funding for monitoring, maintenance, and rehabilitation (p. 21).

Funding these activities is a great challenge. Since recurrent expenditure for monitoring and maintenance of most structures is a responsibility of local governments, their application is very uneven across the nation. There is inequity in the sources of funding, as administrative areas with poorer resources are at a disadvantage. This perpetuates inequalities that already exist, e.g., between more agrarian and more urban areas, between areas with backward or advanced industry and commerce, and between coastal and inland economic zones.

In the absence of viable flood insurance schemes, governments in the PRC also carry the extra burden of providing partial compensation for flood losses.

Flood control and flood management have been and will continue to be funded largely from government revenue for the good of society. However, as the PRC progresses toward a market economy, greater efforts are being made to seek or require contributions from beneficiaries. This needs to be implemented incrementally. Nongovernment contributions must be affordable, but in many regions affordability is steadily increasing with economic prosperity.

Cross-subsidization opportunities exist for example when wealthier urban communities derive benefits from flood management measures upstream. Equitable mechanisms for payments and dispensing of contributions may be difficult to formulate, but are certainly possible if based on adequate consultation between beneficiaries, authorities, and the communities where measures are to be implemented.

# 8

# Planning Structure

The process of flood management planning determines how we plan and implement our actions to mitigate flood risk.

## A. Master Plans

Flood management planning should be spatially integrated in order to achieve social equity and to manage flood risk and environmental impacts. It is generally recognized that the river basin is the natural physical scale at which flood management activities should be integrated. Planning and implementing local-scale flood mitigation in isolation leads to conflict and aggravation of flooding problems elsewhere. Planning in isolation to protect assets and lives on one side of a river may modify flood hazard and increase flood risk on the opposite bank. Planning in isolation on one upstream reach of a river may modify flood hazard and increase flood risk downstream. In the case of reservoirs and dikes, flood hazard and flood risk may increase upstream too, because of a backwater effect. Potential adverse impacts on water delivery and viability of wetlands and other aquatic ecosystems may be incurred downstream by planning in isolation on one upstream reach of a river. Downstream flood hazard and flood risk may also be aggravated by land use practices upstream, such as deforestation or agricultural practices that modify runoff and erosion. Continuing upper catchment development, land clearing, and sediment deposition in river channels, coupled with rapid development of cities and land adjacent to the middle and lower reaches of rivers, has eroded protection levels of the people, industry, and commerce adjacent to the rivers, requiring regular revision and updating of flood protection works. For example, MWR data show peak flood levels in the middle and lower reaches of the Yangtze River in 1998 were comparable or higher than peak flood levels in 1954, even though the peak flood discharge was lower.[21]

The core of flood management planning in the PRC has been, and should continue to be, at river basin scale. This recognition led to the creation of RBCs, commencing with the Yellow River Basin, then extending to other main river basins. Today, virtually the entire mainland of the PRC is subject to river basin master planning by RBCs. River basin flood control plans are the large-scale master plans for flood management activities, although many await reformulation to reflect the strategic shift from heavy reliance on structural flood control to more integrated flood management.

Large-scale river basins in the PRC make the integration of flood management planning very challenging. The Yangtze and Yellow river basins are among the world's largest, extending over areas larger than most countries and sustaining hundreds of millions of people. Within each basin, the complexities of geography, climate and hydrology, land use, patterns of urban and rural settlement, and systems of infrastructure for flood management and water resources exploitation present additional challenges of scale to effective planning. Despite these challenges of scale, integration of flood management at river basin scale remains of paramount importance.

[21] At Shashi, Hubei Province, the peak discharge in 1998 was 60,000 cubic meters per second compared with 71,200 cubic meters per second in 1954; but the flood peak of 45.2 meters was 0.55 meters higher than in 1954. See also Chen, Y. C., and H. J. Lu. 2003. An Analysis of Variation of Maximum Flood Stage of Lower Yangtze River. *Journal of Hydraulic Research.* 41(3). pp. 235–238. Madrid.

Currently, river basin master plans are strong on planning for the main stem of the rivers, and sometimes for selected major tributaries, but are not fully integrated at the river basin scale. Current weaknesses arise from the limitations of the RBCs which are, in effect, field offices of the MWR. Past river basin master plans have focused on flood detention areas, flood-prone areas on river reaches without dikes and, where dikes exist, only the floodway areas between dikes. These are the areas over which the MWR currently has some jurisdiction. However, this does not include all flood risk areas and current plans avoid flood management issues that would require coordinated action in partnership with other government institutions.

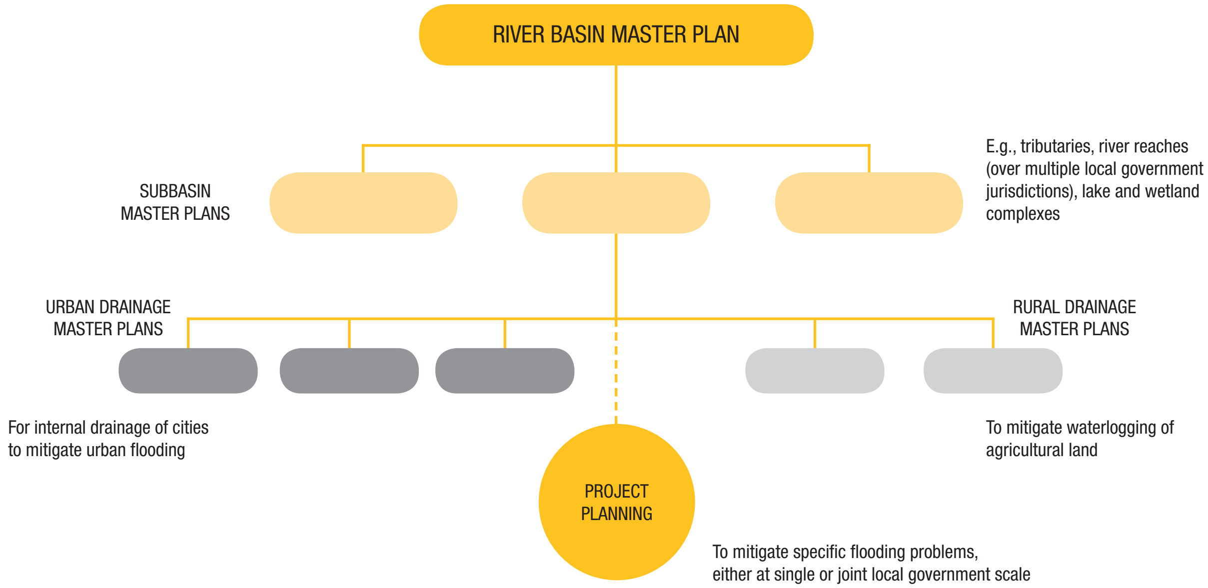
At a more comprehensive planning level, river basin master plans for flood management should cover the entire river basin, not just main river systems. A more holistic approach is required if catchment management aspects such as soil conservation and rural and upper watershed land use practices are to assume their proper role in integrated flood management.

It is difficult to transpose management planning from a river basin scale to smaller scales at which most flood management projects are implemented. For this reason, supplementary master plans for flood management are recommended at intermediate scales in future planning. Intermediate-scale master plans should be prepared for subbasins within the larger river basins and should not be delineated by administrative boundaries. If this requires coordination between provinces, it can only be in the national interest and plan preparation would be an appropriate role for the RBC in consultation with provincial agencies. These flood management plans for subbasins would cover all the main tributary systems within the larger river basin. They must be compatible with provisions of the master plan for the entire river basin, with end-of-system flood discharges consistent with assumptions of the river basin master plan.

To address urban and rural flooding (pp. 5–7), separate master plans are recommended for drainage of local stormwater runoff in large urban areas and rural areas prone to waterlogging (due to poor land drainage). In urban areas, master planning for stormwater drainage and flood mitigation must be coordinated with other urban planning of infrastructure and urban development.

These recommendations lead to a proposed hierarchy of master plans, as illustrated in Figure 4. Any proposed project should also be compatible with the relevant master plans, so single-project planning has been incorporated into the diagram too.

**Figure 4** General Framework of Master Planning




Sources: ADB. 2010. *Implementing the National Flood Management Strategy TA 7049-PRC.* Consultant's report. Manila (TA 7049-PRC); ADB. 2005. *National Flood Management Strategy.* Consultant's report. Manila (TA 4327-PRC).

Dike protection, Hubei Province, August 2007

Source: www.cjw.gov.cn

## B. Structured Planning Methodology

During the process of flood management planning, both for individual project appraisal and the broader-scale integrated flood management master planning, conforming to a structured approach to planning and appraisal is recommended. The recommended methodology captures the strengths of integrated flood management through rigorous technical analysis, comprehensive assessment of planning options, appraisals based on the triple bottom line of sustainable development (economic viability, social equity, and environmental acceptability), benefit–cost analysis, and stakeholder participation. Apart from avoiding costly planning mistakes, adherence to a structured planning methodology provides a consistent basis for comparison of proposed flood management projects competing for government approval and limited available funding.

A structured methodology involves a fundamental sequence of steps in flood management planning and project appraisal, as described below and illustrated in Figure 5.

### Definition of Management Objectives

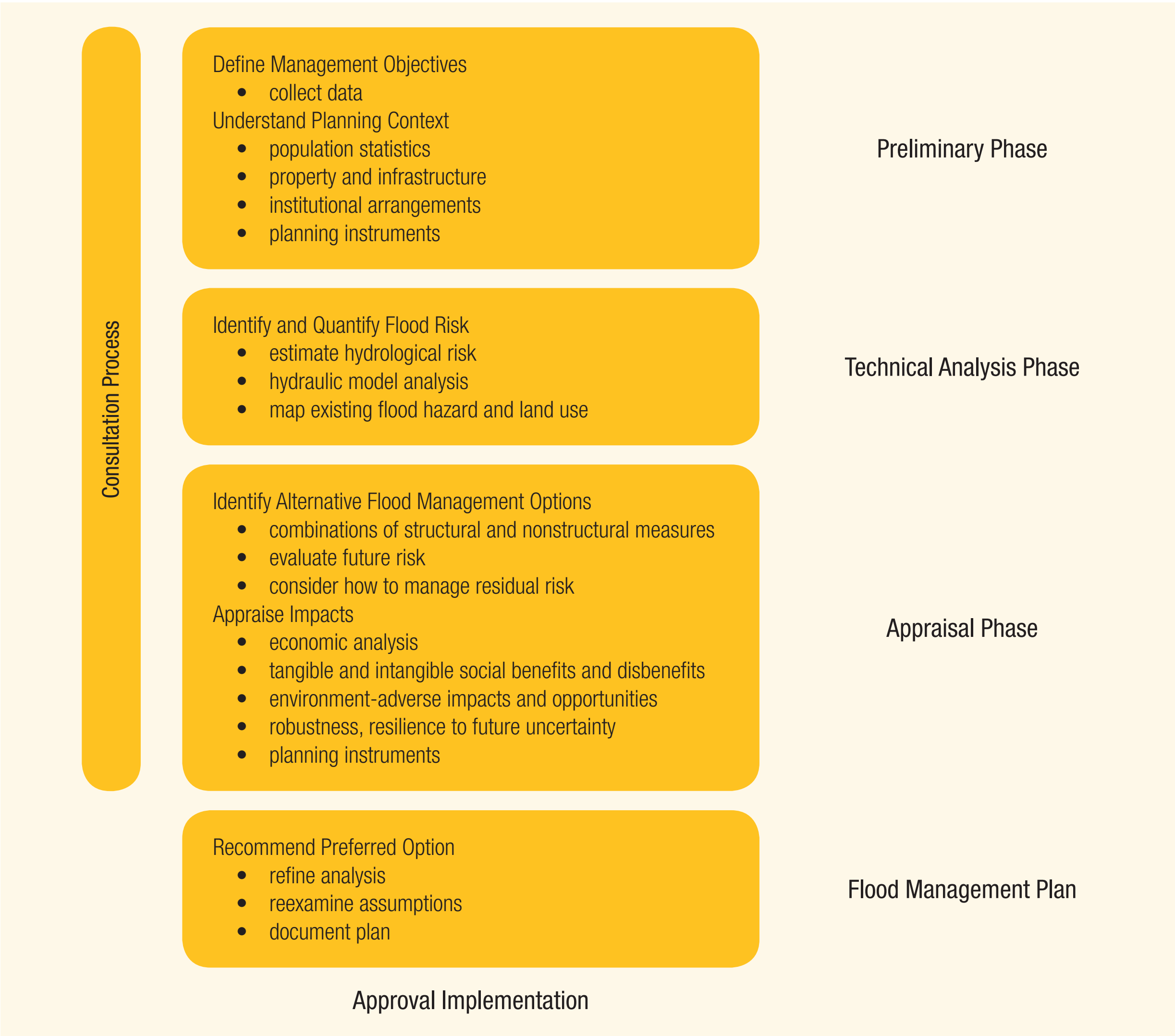
This is best achieved with a clear statement identifying the problem to be managed. The statement should be simple but specific. It is inadequate to just use a general description of the objective, such as "to reduce flood risk." The people and public and private assets that are exposed to flood risk should be noted and explained why it is considered necessary to reduce or manage the risk. Some examples of why it may be considered necessary to manage the risk include (i) the number of lives that could be lost is unacceptable, (ii) development plans for the area or region require management of the altered flood risk, (iii) property damages to private or public assets may be regarded as unacceptable, and (iv) disruption to commercial or industrial enterprise is undesirable. Defining the management objectives clearly and maintaining a clear vision of the objectives throughout the structured planning and appraisal process are important in ensuring the best outcomes.

### Understanding the Planning Context

The context of the planning process is characterized in terms of

- land use and activities carried out in the area affected;
- population and its distribution (rural and urban, children and elderly, poor and wealthy);

**Figure 5** Flood Management Planning and Appraisal Methodology




Source: ADB. 2005. *National Flood Management Strategy.* Consultant's report. Manila (TA 4327-PRC).

- public infrastructure and assets;
- routes for access and evacuation;
- locations of essential services such as telecommunications and utilities (i.e., water supply, sewerage, gas, and electricity); and
- particular aspects that distinguish the community affected and its exposure and vulnerability to flood risk.

The planning context also includes the institutional organization of government administration and the planning instruments applicable in the area or region, such as land use plans, environmental management plans, soil and water conservation plans, broader-scale flood management master plans, and river basin management plans. Understanding the planning context typically requires data gathering and analysis at this preliminary stage of a structured approach.

## Identification and Quantification of Flood Risk

This step entails technical analysis of the nature and spatial extent of flood hazard, the exposure of people and assets to the flood hazard, and characterization of their vulnerability. Flood hazard analysis requires hydrological and hydraulic modeling studies, and typically includes geographic information system (GIS) application and mapping of the flood hazard. The exposure of property and infrastructure would also be shown in mapping; including buildings, land use, main access and evacuation routes, and flood control works. Vulnerability may be characterized by identifying

- sectors of the population (such as children, the elderly, and infirm) who are less capable of fending for themselves;
- availability of flood warning;
- warning times available for emergency response preparations;
- community awareness of the flood risk and preparedness to take appropriate actions to protect themselves and limit damage;
- effectiveness of existing flood emergency procedures (flood fighting in the PRC);
- access to higher ground; and
- resilience to recover from the adverse impacts of flooding.

## Identification of Alternative Flood Management Options

After identifying the existing flood risk, alternative ways of reducing or managing the flood risk should be considered. Types of measures that may be used for flood risk management that modify hazard, exposure, or vulnerability were discussed in Chapters 4 to 6. Generally, a combination or portfolio of flood management measures will be most effective in managing flood risk. One combination or portfolio of measures (nonstructural and structural) may be termed a flood management option. The merits of several flood management options should be considered and compared with respect to their implications, impacts, and benefits.

The identification of existing risk would have been determined mainly in the technical analysis phase. In the appraisal phase, each flood management option should also be considered in terms of future and residual risk. Future risk considers the extra risk that would be associated with future development or climate change and the reduction in risk that can be achieved by the flood management options. Planning must also consider how to manage the residual risk recognizing that the flood risk can never be eliminated without unacceptable economic, social, or environmental impacts.

Comparing flood management options and considering future and residual risk generally entail additional hydraulic model application and GIS analysis, and may (at least in the case of future climate change) require additional hydrological analysis.

## Appraisal of Impacts

The appraisal of each flood management option should include assessment of the economic, social, and environmental implications, impacts, and benefits. It is insufficient to justify an option on economic grounds alone, although it is generally essential that minimum economic benefits can be demonstrated and the benefits should at least outweigh the costs. Every attempt should be made to quantify all benefits, but inevitably there can be benefits that are either difficult to quantify or are intangible. Recognizing this, there will be occasions where an adverse economic analysis can be overruled for social, political, or environmental reasons.

Some social benefits are linked to economic benefits, although they may be difficult to quantify. Examples are increases in property values or anticipated increase in production and living standards for the locality or region. Other social benefits are intangible, and can only be described. Examples are reducing public health risk, removing sources of anxiety and trauma, and increasing positive attitudes to private property development and business enterprise. It may not be possible to avoid adverse environmental impacts, but the planning process should consider how measures could be implemented to minimize adverse impacts. A comparison of the adverse impacts of different flood management options is one of the key aspects of options appraisal. For example, there may be opportunities to enhance environmental quality through restoration of wetland habitats or improving degraded water quality. Any opportunities for positive environmental impacts should be ranked highly during the appraisal process.

The robustness and resilience of alternative flood management options also needs consideration and comparison during the appraisal of impacts—i.e., how well the options would perform in view of uncertainties in analysis, particularly with respect to future social, development, and hydrological conditions; and how adaptable the options may be to coping with future scenarios different to those assumed.

## Recommendation of Preferred Option

The flood management option that emerges from the appraisal phase as the preferred option is then refined and presented as a flood management plan. Refinement typically entails reviewing details of the measures included in the preferred option and reviewing assumptions adopted during the comparative appraisal.

The least-cost alternative should be identified for implementing structural measures, considering both capital expenditure and recurring expenditure for maintenance and post-flood repairs. Examination and review of the social and environmental benefits and costs should be undertaken in greater depth than at the appraisal phase so that the associated uncertainty can be reduced. In some cases, additional research may be appropriate to improve confidence in some assumptions adopted in the analysis, particularly assumptions about environmental or social outcomes. Review may include how robust and resilient the preferred option may be to uncertainties about future conditions. After the additional analysis of the preferred flood management option has been completed, the flood management plan should be documented in a format suited to review by approval agencies.

## Participation by Stakeholders

While governments at appropriate levels need to guide and direct the structured approach to planning and appraisal, in the interests of equity all stakeholders should be given an opportunity to participate throughout the process. Stakeholders are those who have an interest in the future outcomes, particularly those whose livelihoods or quality of life could be directly affected by implementation of the flood management plan. They may include

- residents in areas of appreciable flood risk;
- landlords, managers of businesses, and industrial enterprises located in areas of appreciable flood risk;
- commercial enterprises that do business in the area, even though they may be located outside the immediate area at risk;
- owners of public infrastructure located in the affected area;
- the relevant RBC;
- government agencies with management responsibilities (this would normally include those with responsibilities for land use planning and development and water supply and sewerage, and may by discretion extend to other responsibilities such as public health, agriculture, environment, transport, soil and water conservation, power and telecommunications, and tourism, depending on their interests); and
- other individuals or groups with special interests in the area affected (e.g., advocates for environmental conservation of lakes or wetlands).


Preparedness: flood emergency stockpile, Henan Province, 2009

Source: *Liang Zhiyong*, Institute of Water Resources and Hydropower Research.

In many countries, stakeholder participation is facilitated by convening a flood management committee, whose role is to oversee the entire process, at the inception of the planning and appraisal process. At the end of the planning process, the committee may present the flood management plan to approval agencies at higher government levels. In the PRC, the appropriate chairmanship of the flood management committee would be local government, provincial government, or the RBC, depending on the scale of the proposed planning area. Offers for participation on the committee should be made to representatives of the stakeholder groups. It is the committee that should request appropriate organizations to undertake the necessary technical studies and report to the committee.

9

# Environmental and Social Safeguards

## A. General Objectives

As mentioned in Chapter 3, the flood management sector may have impacts on the environment and society, and a comprehensive management framework must contain safeguards to mitigate adverse social or environmental impacts and minimize the risk of unintended impacts.

Most governments and all international development assistance agencies, including ADB, have safeguard provisions that address exogenous environmental and social impacts. These have been formulated from past experience. ADB, for example, has the Safeguard Policy Statement covering environment, resettlement, and indigenous peoples (p. 54).

Riparian recreational parkland

Source: Institute of Water Resources and Hydropower Research.

These formal safeguard mechanisms should be regarded as minimum requirements. Moreover, they cannot be expected to be universal and cover all the possible ramifications of undertaking development works and interventions. Planners and designers should look beyond the confines of the formal safeguard provisions to consider, assess, and manage the potential impacts of flood management measures before they are implemented.

In doing so, there should be an awareness that whatever the labels used for these provisions, the intention is to preview a comprehensive range of likely or foreseeable environmental and social impacts so that the environmental and social outcomes of our flood management proposals can be managed optimally.

Safeguards required include

- protection of the physical environment;
- protection of biodiversity and endangered and threatened species;
- identification of the locations of hazardous materials;
- involuntary resettlement social safeguards;
- indigenous peoples' social safeguards;
- assessments of the social implications for gender (e.g., women's issues);
- assessments of social implications for disabled, infirm, or disadvantaged persons; and
- identification of the locations of strategic community services (i.e., emergency agencies and key community infrastructure, such as schools and hospitals), should not be inundated during floods.

## Resettlement

Providing for families resettled involuntarily to allow flood management measures to proceed must be rigorous to ensure they are adequately assisted with equivalent or improved housing, services, and income opportunities. An objective of benign resettlement is that those resettled will enjoy living conditions better than those pertaining before resettlement. Governments therefore have an obligation not only to ensure good standards of housing when people are relocated, but also to provide good employment prospects and a sustained high standard of social support services to assist people during transition and their establishment in new communities.

Effort is required to ensure better housing is combined with retraining, incentives, and development assistance to provide strong opportunities for employment, and with social development support to promote effective bonding of new communities. The needs of individuals and communities are varied and numerous, and if those needs are not well provided for, resettlement can fail or breed resentment and disaffection. Effective consultation and participation in planning and decision making is essential to identify those needs and satisfy future needs.

## Environment and Ecology

It is widely recognized that the conservation of biodiversity is fundamental to long-term sustainable development. Loss of natural habitats is acknowledged as a major threat to biodiversity, undermining the viability of ecosystems and human communities dependent upon these resources. One of the major objectives of environmental safeguards is to protect, maintain, or rehabilitate valued habitats and those that sustain endangered or threatened species, or support communities or indigenous groups partly or highly subsistent upon natural resources. In the context of flood management, aquatic, estuarine, wetland, riparian, floodplain, and terrestrial habitats may potentially be impacted.

Some of the more obvious impacts on habitats that may derive from structural flood management measures include obstruction to passage of fish and other aquatic species by dams and flow-regulating structures, separation of rivers from floodplains by construction of dikes, and disruption of benthic communities and aquatic ecosystems by channel dredging works.

Apart from changes to the frequency, inundation levels, and seasonality of water delivery to habitat units, environmental assessments should also consider impacts on the physical environment and fluvial geomorphology from potential changes in erosion, sediment transport and deposition, and water pollution or water quality.

## Compensation for Use of Flood Detention Areas

Social safeguard issues arise from one of the distinct features of flood management in the PRC. There are hundreds of designated areas for detention of floodwaters in the country, which are designed to be deliberately inundated in large floods to avoid discharges that would exceed design capacities of dikes and other flood defenses downstream (p. 6). These flood detention areas are parts of floodplains contained behind the dikes, to which floodwaters may be diverted through gated structures or by deliberate breaching of the embankments. Social issues arise because the land is normally used for agriculture or animal husbandry, and in some cases these areas may still be inhabited by large populations.

After the flood disasters of 1998, a resettlement program was initiated to relocate occupants of some of the flood detention areas. At first, the program included involuntary resettlement, although this was later discontinued. For other areas, a range of safety measures were implemented (e.g., raised earth platforms for temporary refuge, and construction of evacuation routes, shelters, and polders) together with the upgrading of flood warning measures, forecasting procedures, and emergency response plans.

The government introduced a policy of compensating for disadvantage caused by floodwaters diverted to flood detention areas (Box 3). Although excellent in principle, there have been many practical difficulties in implementing the policy. On the government side, administration of the regulations for compensation has generally been delegated to local governments. These additional duties have proved onerous, diverting resources from other responsibilities, and troublesome because of public dissatisfaction and dispute. On the community side, disputes arise over the adequacy of levels of compensation, rights to compensation, and differentials in compensation for different types of land use.

To contain the costs of compensation, governments have imposed some restrictions on the types of land use that are permitted. While this is consistent with the principles of land use management espoused in Chapter 5, users of land in flood detention areas have expressed discontent with controls placed upon agricultural activity and crop selection. These restrictions vary from one flood detention area to another.

Reliance on government compensation has other adverse ramifications. Persons eligible for compensation often come to regard compensation as a natural right and develop a psychology of dependency on government assistance with the attitude that "it is up to the government to take care of everything to make sure I am secure." In practice, the government can never provide an absolute guarantee. There are limits on what it can do and it is most important that persons at risk are aware of that, have adequate appreciation of the risk involved in their use of the land, and make good preparations for themselves to minimize the impact of future inundations. Any psychology of dependency saps initiative and enterprise that is important for realization of the full productive potential of the land.

Production statistics bear out the fact that flood detention areas are depressed pockets of the social economy. This is not surprising, as there are real and necessary constraints upon the use of land in flood detention areas. Because of those constraints, residents sometimes argue that they should receive special treatment and priority in receiving benefits. In response, it can be argued that it is not the government that has imposed constraints on the use of the land. These lands were already at considerable risk from flood prior to recent structural improvements and the introduction of compensation measures.


Post-flood cleanup Zhouqu County, Gansu Province, August 2010

Source: chinanews.com

## B. ADB's Policy on Environmental and Social Safeguards

Social and environmental safeguards for ADB projects are laid out in the ADB policy paper *Safeguard Policy Statement*.[22] This includes safeguard requirements related to environment, involuntary resettlement, and indigenous peoples.

All three safeguard policies involve a structured process of impact assessment, planning, and mitigation to address the adverse effects of projects throughout the project cycle. The safeguard policies require that (i) impacts are identified and assessed early in the project cycle; (ii) plans to avoid, minimize, mitigate, or compensate for the potential adverse impacts are developed and implemented; and (iii) affected people are informed and consulted during project preparation and implementation.

The procedural requirements are set out in the Operations Manual, Section F1/OP (March 2010).[23] In general, these entail an initial screening and scoping process. Unless the screening and scoping indicates that related risks and impacts are negligible, an impact assessment process is required, followed by a management plan to avoid, mitigate, minimize, and/or compensate for risks and adverse impacts. Processes are also defined for public disclosure and stakeholder participation.

ADB's water policy Water for All[24] recommends integrated water resource management to improve the planning, conservation, development, and management of water, forest, land, and aquatic resources in a river basin context, in order to maximize economic benefits and social welfare in an equitable manner without compromising the sustainability of vital environmental systems and meet the increasing challenges of water scarcity, pollution, and degradation of watersheds and ecosystems. The policy also requires that ADB's environmental and social impact assessment procedures are rigorously applied to all large water resource projects, particularly those involving dams and storage, and any adverse environmental effects are properly mitigated, the number of affected people in the project area must be minimized, and those adversely affected must be adequately compensated.

22 ADB. 2009. *Safeguard Policy Statement.* Manila.

23 ADB. 2010. Safeguard Review Procedures. *Operations Manual: Operational Procedures (OP).* OM F1/OP. Manila.

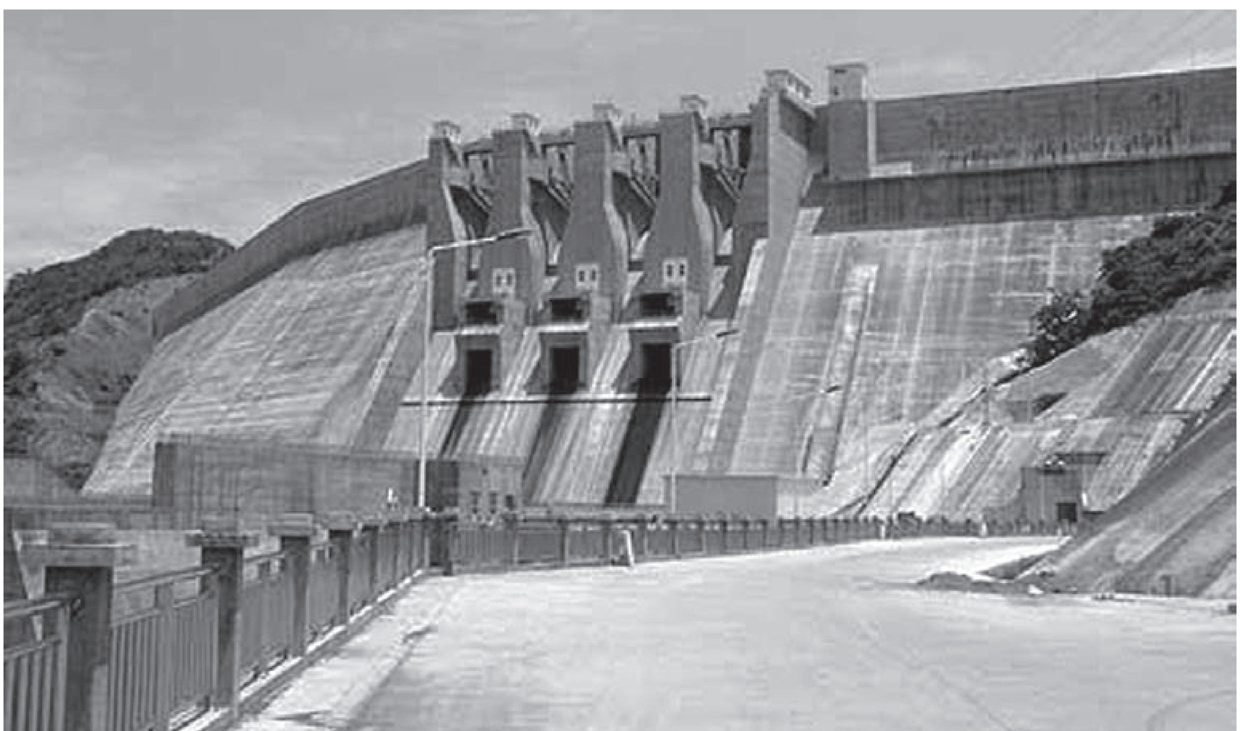
24 ADB. 2003. *Water for All: The Water Policy of the Asian Development Bank.* Manila.

10

# Flood Management Initiatives in the People's Republic of China

## A. Structural Flood Defense Works

Learning to live with the risk of floods has a history as long as human civilization. After the birth of the PRC in 1949, a new spirit of optimism and self-reliance created a burst of construction activity to "harness the rivers" and "contain the floods." Acknowledging flood control as a cornerstone of socioeconomic development, thousands of dams were constructed to regulate river flows and hundreds of thousands of kilometers of dikes were constructed to flank the rivers downstream. Although reservoirs created by dams in the rivers were multipurpose, they were generally gated to allow large flood releases and are operated to maintain a flood mitigation pool during the flood season.



Flood control reservoir, Baise County, Guangxi Zhuang Autonomous Region

Source: *Sina Culture.*

The broad philosophy of flood control in river basins has been to use dikes and channel excavation (dredging) to provide consistent hydrological standards of flood protection for development downstream, and to "control" floods within these design discharges by the upstream operation of reservoirs, flood detention areas, and flood diversion channels.

Supported by massive investments in structural flood control works, this system has made an important contribution to current rapid socioeconomic progress.

Floods are one example of nature's extreme disasters, and they may be violent and beyond human control. There are diminishing returns as one raises flood protection standards at ever increasing cost. This is now being recognized in the shift in philosophy from flood control to flood management. During the formative decades of the PRC, the enthusiasm to construct flood protection structures meant that engineering quality was sometimes substandard. However, numerous faulty structures have been progressively rehabilitated. The vast array of structural flood defense works implemented in six tumultuous decades is now the core of flood management in the PRC and, with adequate monitoring and maintenance, will serve its people well into the future.

## B. Emergency Response and Post-Flood Recovery

As mentioned in Chapter 6, the PRC has well-developed and well-organized emergency response systems which, together with structural flood control measures, form the strong backbone of current flood management practice in the PRC. The FCDHs are responsible for emergency response. During flood emergency operations, the FCDHs take command of emergency response including the operation of flood control infrastructure. They have leadership and command authority to coordinate emergency response activities which often require actions of various administrative departments of government including civil affairs and defense agencies. Ministers and senior executives of several national ministries responsible for flood emergency response are official members of the FCDHs.

After the occurrence of flooding, governments are responsible for organizing the relevant departments and units to ensure relief work in the disaster area for supply of necessities, health care, and immunity; relief materials; public security; resumption of classes, resumption of production; and rebuilding of homes; as well as repair of various engineering structures damaged by flooding within their jurisdiction. The Ministry of Civil Affairs plays a lead role in post-disaster relief and recovery efforts, with assistance from the Ministry of Finance and other relevant administrative departments.

A key to the effective planning and successful operations is the authority conferred upon the FCDHs by having a vice-premier as head of the State FCDH and governors as heads of provincial FCDHs. Another factor of key importance is that those appointed to positions of responsibility are held accountable for any failure to perform their duties.

## C. Selected Recent Initiatives

### Flood Forecasting

Flood forecasting is a nonstructural flood management measure that is widely used in the PRC. It has been progressively adopted as a responsibility of the Ministry of Water Resources (MWR) and its RBCs since the 1980s. Flood forecasting relies on hydrological models to forecast the magnitude and timing of flood peaks, and is sometimes linked to weather service forecasts. Flood forecasting is undertaken on the main stem rivers by relevant RBCs (e.g., the Yellow, Yangtze, and Pearl rivers). Flood forecasting for major tributaries is generally undertaken by bureaus within the provincial administrative departments for water resources management.

Flood rescue team in action

Source: Institute of Water Resources and Hydropower Research.

Because of the enormous scale of the country, much work remains to be done to extend flood forecasting to all river systems where they are needed. This need is well recognized and given prominence in current flood management planning in the PRC.

Flood forecasting depends on modern technology, e.g., data acquisition instrumentation, data transmission technology, hydrological and hydraulic modeling, GIS software, and computer processing equipment. Technological advances are continuing in these fields, and updating to most recent technology is an ongoing challenge. In particular, data acquisition and data transmission and communications networks require improvement to enhance existing flood forecasting systems.

Flood forecasting can also be greatly enhanced when linked to hydraulic models of flood behavior. To date, this linkage has not been common in the PRC.

## Flood Hazard Mapping

Flood hazard mapping is achieved by the application of hydrological and hydraulic modeling, coupled with digital terrain data and GIS. It provides valuable support to many nonstructural aspects of flood management, including land use management, flood forecasting and warning, emergency response planning and flood fighting, and potential flood insurance schemes.

After a period of research and development, the issuing of a recent regulation on methods for flood mapping has led to a burst of activity to map selected high-risk areas in main river valleys. Flood hazard mapping has now been


Flood emergency response

Source: Institute of Water Resources and Hydropower Research.

commenced for all the large rivers and major urban centers in the PRC. To date, these nonstructural initiatives have been tailored to the institutional needs of flood operations and emergency response during floods—i.e., government needs—rather than community needs. Flood mapping of valleys downstream of some large reservoirs has also been undertaken in association with dam-break analyses.

## Flash Flood Monitoring and Warning Systems

Flash floods are the type of flood responsible for the greatest loss of life in the PRC. In response, the national government has included action to combat flash floods in its 5-year plans. High-hazard locations have been identified and located throughout the nation; and a prototype design plan for systems for flash flood monitoring and warning was developed in a collaborative effort between the MWR, the Meteorological Bureau, the Ministry of Land and Resources, the Ministry of Housing and Urban–Rural Development, and the Ministry for Environmental Protection. The flash flood monitoring and warning systems (FFMWSs) have been progressively implemented over recent years as pilot trials, commencing in 2005 with 12 counties selected from 12 provinces as initial pilot trials. Another 100 have been funded since then by the national program.

FFMWS includes a network of gauging stations that monitor precipitation and/or river levels and discharges. These include automatic stations that transmit data in real time and manual stations that report in near real time. The FFMWS includes a database and data management software. The data collection platforms allow users to make inquiries of the database, and present data in web-based GIS format and visual alert information. In case supervisors are not present at the time an alert is triggered, alerts are sent automatically by short message services (text messages), supported by audible warnings. That triggers activation of emergency response plans which include dissemination of warnings to village committees, emergency teams, and all persons affected, and evacuation of residents if necessary.

Flash flood monitoring and warning system, Suichuan County, Jiangxi Province
Source: John Porter.

## Dynamic Flood Storage Operations

Research has been undertaken to improve the operation of multipurpose reservoirs. A number of findings have been made with regard to design flood estimation, seasonal variations in floods, and methods for dynamic variations in operating rule curves based on rainfall and short-term flood forecasting to estimate reservoir inflows.

Pilot studies[25] are being conducted and monitored, and the participation of reservoir management bureaus has been conditional upon the completion of dam safety checks, a review of dam flood hydrology, and a review of water resource assessments. Several pilot projects have achieved significant hydropower energy benefits through the adoption of a dynamic rule curve rather than a static storage target level during the flood season—i.e., varying flood storage pool rather than maintaining a fixed volume pool. Research is ongoing to investigate operational impacts on downstream flood mitigation and the impact on availability of water resources for productive use.

[25] In the PRC, pilot studies are more like first-generation trials of project implementations for a policy that has already been carefully studied and approved.

# 11

# Looking to the Future

Much has already been achieved in flood management in the PRC; but with more resources, greater awareness of flood risk management, and evolving technological innovation, progressive improvements can and should be made. The strategic framework based on risk management presented in this publication is proposed to aid that evolution and assist the shift from flood control to more integrated flood management. Studies undertaken for the MWR with ADB assistance have identified the following suggested initiatives that would improve future flood management.

## Living with Flood Risk

A key lesson of flood risk management is learning to live with flood risk. People and governments need to recognize that the risks of danger and damages from floods can not be eliminated entirely, and they must instead learn to accept some degree of risk in return for the benefits to be derived from using land subject to flood risk.

In urban areas, the benefits are clear where alternative land is unavailable for development. In rural areas, land subject to flood inundation generally benefits in terms of soil fertility and can provide sources of food and materials dependent on seasonal fluxes. Agrarian practices can be conducted in harmony with the flood cycle. Floods are periods of renewal for nature and are a natural land-forming process; they sustain many aquatic and riparian ecosystems and benefit biodiversity and the richness of the environment in which we live.

Living sensibly with floods entails gaining and promoting a clear understanding of the flood risk and then managing the residual risk after structural works have been undertaken; i.e., it entails quantifying and modifying the flood hazard, regulating exposure to the hazard, and reducing the vulnerability to danger and damage. This requires a balanced mix of structural and nonstructural measures.

## Land Use Management

Exposure to flood hazard can be modified by land use management. Development on flood plains must be managed wisely to achieve the trade-off that maximizes the margin between development benefits and the cost of flood risk. Resettlement is a management measure that has been used in the PRC to modify exposure to flood hazard. A more common approach in many countries is to adopt measures to regulate how land may be used, by delineating the extents of flood hazard areas, quantifying or estimating the flood hazard, categorizing the land according to its flood hazard, and attributing land use regulations linked to building regulations to the different zones or categories of flood hazard.

The main missing link in flood management in the PRC is land use management. This has come about because the MWR has been responsible for flood control or flood management, and land management and spatial land use planning fall outside its mandate. To fully integrate flood management, particularly land use management, it is essential to establish working partnerships with other administrative authorities and to coordinate ongoing flood management planning. However, the effective mechanisms to achieve this are lacking.

## Flood Forecasting

Flood forecasting procedures for vulnerability management have been introduced since the 1980s, and are an important flood management measure because of population densities, rapidly expanding development, and the serious consequences of flooding in the PRC. The accuracy and lead warning times of many existing forecasting systems could be improved with better data monitoring networks and updated methodology.

Recent advances in hydraulic modeling should be integrated into forecasting procedures, most of which currently rely on hydrological methods only. Technological advances in spatial topographic data acquisition allow application of two-dimensional hydraulic models in broad floodplain areas and forecasting procedures can be linked to flood mapping to provide much greater detail about extents of inundation and flood impacts.

## Flood Risk Mapping and Hazard Zoning

A program to commence systematic flood mapping for vulnerability management has been approved under the national 5-year plans for the water sector. Research should be ongoing to improve the resolution and accuracy of hydraulic modeling on which mapping is based.

Broader application of flood risk mapping is required. Flood risk mapping provides valuable support to many nonstructural aspects of flood management, including land use management, flood forecasting and warning, community awareness and preparedness, and potential flood insurance schemes; as well as for emergency response planning and flood fighting which has been the focus to date.

Mapping data of flood frequency, inundation depths, and flow velocities can be used to undertake flood hazard zoning, which should be one of the criteria for spatial land use planning, and can then be linked to building applications, development conditions, and building regulations.

Flood risk mapping (and emergency response planning) should be extended to "protected" areas, behind dikes for example. Too often, these areas are given low priority by local authorities, which prefer instead to rely on flood fighting organization; but the consequences of overtopping in above-standard floods or structural failure can be grave given the levels of development permitted there.

While there is reluctance to give wide access to mapping products (due to concerns about accuracy of results and alarming the public), sharing the maps with communities would be most effective in raising awareness of flood risk and contributing to genuine stakeholder consultation.

## Decision Support Systems

Decision support systems assist flood hazard and vulnerability management. Many river basins in the PRC have complex systems of flood management structures. During floods, the operation of these structures needs to be carefully coordinated to optimize outcomes. During flood emergencies, operational decisions are urgent and critical to avoid disaster. Thus, adequate support must be given to decision makers.

With modern computerized modeling, it is quite feasible to produce accurate decision support tools. Operations of structures can be modeled with precision. Natural processes like the generation of runoff from rainfall and the passage of flood waves down valleys and through floodplains are more difficult, but the limitations have less to do with technology and the models than with the spatially distributed processes and inadequacy of data available for their definition and quantification. Future progress will depend on improved data acquisition and field monitoring, accumulation of event data in flood databases, and refinement and recalibration of models applied.

## Structured Planning Methodology

Standardized planning procedures using a well-structured methodology should be adopted for the development of flood management plans and for appraisal of project proposals. A model for the structured planning methodology was presented in Chapter 8. Adherence to such a standardized planning method will ensure better economic viability, social equity, and environmental sustainability in flood management planning in the PRC, and will facilitate greater stakeholder participation. A standardized method also helps governments compare the merits of different project proposals and prioritize proposals submitted for limited available funding.

While governments at appropriate levels need to guide and direct the structured approach to planning and appraisal, in the interests of equity, all stakeholders who have an interest in the future outcomes—particularly whose livelihoods or quality of life could be directly affected by implementation of the flood management plan—should be given an opportunity to participate throughout the process. Stakeholder participation is a fundamental element of good governance, and people have a basic right to participate in decisions that may affect them.

## Flash Flood Warning

Many flash flood monitoring and warning systems for vulnerability management have already been implemented in the PRC closely adhering to standardized guidelines. This is a salutary initiative that will help save many lives.

Flash floods are recognized as the biggest killers among natural disasters in many parts of the world and rapid advances have been made elsewhere applying new technology. New innovations elsewhere should be carefully reviewed and adapted to the conditions and needs of the PRC. Short lead times and the extreme spatial and temporal variability of severe convective thunderstorms make it very difficult to accurately forecast flash floods. Findings in Europe and the United States are that the linkage of regional climate forecasting and local monitoring systems provides a quantum improvement in flash flood warning quality. In Europe, the Associated Programme on Flood Management[26] has produced guidance on flash flood warning based on the implementation of flash flood warning systems in Eastern Europe. These systems link local flash flood monitoring networks with regional weather forecasting employing numerical climate models capable of quantitative precipitation forecasts and estimation of thunderstorm likelihood. New systems in the United States also link observations and forecasting at more local levels with support and modeling provided at the larger regional or national level using weather radar and synoptic analysis of satellite imagery.

An FFMWS is generally implemented by the government at a county scale with little community consultation. A more productive partnership between the government and beneficiary stakeholders would be a great improvement to (i) raise awareness of flood risk and government initiatives to manage flood risk, (ii) increase preparedness to take appropriate evasive actions during the short warning lead times available, and (iii) enhance positive cooperation during activation of emergency response plans.

## Funding for Maintenance

Adequate budget allocations must be made by governments for the implementation of new flood management measures. Given the huge armory of flood defense works already in place, and the extent of aging or unsound works, it is equally important to ensure a sustained contribution from government revenue to maintain and monitor existing structures. This has been a shortcoming of past flood management.

[26] World Meteorological Organization and Global Water Partnership. 2007. *Guidance on Flash Flood Management: Recent Experience from Central and Eastern Europe*. Geneva.

After construction, operation and maintenance are often left as responsibilities of local governments, particularly at county and village levels. Other perceived priorities are too often given precedence from limited local government revenue. An alternative model for sharing of funding burdens between different levels of government should be found, with binding obligations upon local governments to perform appropriate maintenance.

There is a danger of replicating this shortcoming after the implementation of FFMWSs under current pilot programs, as no firm provision has been made for the ongoing maintenance and operation of these systems.

## Other Funding Issues

There will always be constraints on government funding and limitations on how much can be allocated to new flood management initiatives and essential maintenance. It is therefore important to seek contributions from beneficiaries. The administration of flood management may be a public good, but when specific flood management measures will serve to reduce losses to identifiable target areas, it is reasonable to require beneficiaries to contribute to the capital costs and maintenance, provided that levies are affordable and mechanisms that determine levy amounts are equitable. Growing prosperity in the PRC means that such levies will become increasingly affordable. In many places, governments already demand payments from larger beneficiary enterprises. The challenge for the future will be to devise more equitable mechanisms for sharing of the cost burdens that can facilitate a broadening of the income base.

When flood damages are incurred, the burden on government to reinstate public infrastructure and support communities that have sustained losses is particularly onerous because the timing and amounts of these expenditures are unpredictable and defy rational budgetary planning to some degree. After major flood disasters, important government projects or programs planned well in advance may have to be deferred while post-flood recovery funding assumes priority.

Flood insurance has a role to play in easing this erratic burden on government funding. Past flood insurance trials in the PRC have failed because they have not been commercially sound. The government may need to regulate market conditions and devise a model suited to the circumstances in the PRC, but greater recognition of these insurance market realities is required at official and community levels before insurance schemes to relieve the government burden become feasible.

**Flood Risk Management in the People's Republic of China**
Learning to Live with Flood Risk

This publication presents a shift in the People's Republic of China from flood control depending on structural measures to integrated flood management using both structural and non-structural measures. The core of the new concept of integrated flood management is flood risk management. Flood risk management is based on an analysis of flood hazard, exposure to flood hazard, and vulnerability of people and property to danger. It is recommended that people learn to live with flood risks, gaining and promoting a clear understanding of flood risks, quantifying and modifying the flood hazard, regulating exposure to the hazard, and reducing their vulnerability to danger.

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