STRENGTHENING FLOOD RISK MANAGEMENT POLICY AND PRACTICE IN THE PEOPLE'S REPUBLIC OF CHINA

LESSONS LEARNED FROM THE 2016 YANGTZE RIVER FLOODS

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Strengthening Flood Risk Management Policy and Practice in the People's Republic of China: Lessons Learned from the 2016 Yangtze River Floods

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ABBREVIATIONS

ADB	–	Asian Development Bank
FERM	–	flood and environmental risk management
FFWS	–	flash flood warning system
GDP	–	gross domestic product
NFMS	–	National Flood Risk Management Strategy
PRC	–	People's Republic of China
YREB	–	Yangtze River Economic Belt

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EXECUTIVE SUMMARY

In the People's Republic of China (PRC), the annual economic losses due to flood disasters have been increasing throughout history—despite the steady decline of mortality from flood events due to increased investments in flood risk management. This continuous escalation of economic damages is largely due to the expansion of economic exposure from the surge of development activities on the floodplains. It is also attributable to the hazards particularly associated with the impacts of land-use changes, reduced flood retention and conveyance capacity of the water bodies, and effects of climate change.

In 1949, the PRC embarked on a program of key structural flood-control works, including construction of river and coastal levees, building and rehabilitation of reservoirs and polders, establishment of floodplain storage zones, provision of drainage in urban areas, and dredging of major rivers. Following the severe Yangtze River basin flood in 1998, the Government of the PRC realized that structural measures alone were not sufficient to manage the impact of floods. Thus, to augment structural measures, greater emphasis was placed on the implementation of nonstructural solutions—e.g., catchment management, land-use planning, building regulations, resettlement, flood forecasting and warning system, emergency response plans, and postflood recovery actions. In 1998, the PRC began investing heavily in flood risk management measures targeting the populated areas along the major rivers. Recorded as the second most costly flood disaster in the PRC, the 2016 Yangtze River flood demonstrated that the cumulative losses from flooding in small catchments can be very substantial; hence, the need to provide flood risk management for the entire river basin.

An important lesson learned from the recent 2016 and 2017 flood events is that the majority of flood damages does not come from the main stem river but from small- to moderate-sized river sub-basins. Rapid urbanization of small cities and towns in these sub-basins has triggered flash flood and landslide disasters which, in the past, were not regarded as among the government's priorities. The risks of these types of disasters are particularly difficult to manage as the impacts, though severe, are relatively localized, requiring a localized approach. In the absence of appropriate policy and strategic measures, this problem will likely persist for a long time as the government continues to adopt a small-town development strategy to fuel the economic growth and accommodate the growing population. The private sector, which is also at the frontline of flood disasters, can play a significant role in reducing these economic damages and in mitigating flood risk. However, their potential role needs to be harnessed and adopted in the strategic framework of flood risk management.

Another lesson learned from the 2016 and 2017 flood events is that there is a fundamental nexus—and an inextricable link—between flood risk management, environmental management, and ecosystem sustainability. If the risk management planning fails to acknowledge the importance of this nexus, it will leave an undesirable footprint in the communities and the ecosystems. The impact of increased runoff from urban areas and from localized flood prevention measures, for example, will create a footprint that adversely affects all towns and cities downstream and impairs the ecology of the river systems. Therefore, it is also essential to develop a flood risk management footprint and accountability system that will address rural–urban integration, upstream–downstream linkages, and integrated water resources management at the basin scale. This system will help monitor and evaluate the increase or decrease of flood risk in any locality due to physical changes in any part of the basin. It will also facilitate the process of mainstreaming flood risk management into development planning.

The Asian Development Bank (ADB) is currently supporting the *Xinyu Kongmu River Watershed Flood Control and Environmental Improvement Project* in Jiangxi Province, PRC. The project takes an "environment first" approach in the development planning and aims to (i) provide flood protection for villages and towns located adjacent to the Kongmu River, (ii) ensure effective management of risk from flooding and waterlogging in the development of the new urban district, (iii) ensure that said development does not aggravate flooding or water quality downstream, and (iv) enhance environmental and living conditions. The project created a new benchmark for future ADB investments and assistance to support an integrated flood and environmental risk management approach, as outlined in the Yangtze River Economic Belt (YREB) master plan and proposed in the ADB–PRC YREB investment framework.

I. INTRODUCTION

In 2016, floods in the People's Republic of China (PRC) caused damages of $38 billion (CNY256 billion).[1] This represents the second most expensive disasters triggered by natural hazards in the country's history and, globally, the fifth costliest recorded outside of the United States. Over 800 lives were lost. Since 1950, the PRC has implemented a formidable program of structural works and nonstructural initiatives to combat floods and reduce their impacts on society and the economy. Given that past effort, the enormity of the losses suffered during the floods in 2016 merit a review of past policy and practice to consider what lessons may be learned and how future flood risk management in the PRC may be improved.

Flash floods in Qichun County. Houses were submerged, and a car and other debris were swept away as flash floods hit Qichun County, Hubei Province of the People's Republic of China on 19 June 2016 (photo by the China Institute of Water Resources and Hydropower Research).

[1] Aon Benfield. 2016. *Natural Catastrophe Report for China in Summer 2016.* October. http://thoughtleadership.aonbenfield.com/documents/201610-china-summer-floods.pdf.

More specifically, lessons learned are relevant for the continuing engagement of the Asian Development Bank (ADB) with the Government of the PRC to develop and support a strategic framework for coordinated green development and integrated river basin ecosystem management in the Yangtze River Economic Belt (YREB). ADB's strategic framework for the YREB will prioritize interventions that will target the key ecosystem and water resources management issues, and therefore strengthen environmental protection and rehabilitation of the YREB.[2] Such approach will ensure ADB's investment will play a catalytic role in the broader program of the YREB. Lessons learned from recent flood events in the Yangtze River basin will also serve as an anchor for future engagement of ADB–PRC partnership in water sector development and inclusion in the PRC.

II. FLOODS IN THE PEOPLE'S REPUBLIC OF CHINA

The PRC is particularly susceptible to floods due to the formation each year of the *mei-yu* front, a volatile boundary between warm tropical air masses that develop in the south around April or May each year, and colder continental air masses further north. The front extends from the Tibetan plateau eastwards as far as Japan. Instability induced by the front can produce heavy rainfall in the following months over the Yangtze River basin. Tropical cyclones that develop in the adjacent sea and make landfall may also wreak havoc in the eastern provinces. As a consequence, floods recur every year, especially in the southern parts of the country (Box 1). Losses are especially severe in years immediately following El Niño events in the Pacific Ocean. Massive floods in 1998 and 2016 followed strong El Niño conditions. In 2016, rainfall sustained over flood season months (i.e., June–August) in the Yangtze River basin exceeded average rainfall by more than 20% (Box 2).

Heavy flooding in Fujian Province. Flash floods and debris flows triggered by super typhoon Nepartak hit the Fujian Province in the eastern coastal region of the People's Republic of China on 9 July 2016 (photo by the China Institute of Water Resources and Hydropower Research).

[2] ADB. 2017. *Technical Assistance to the People's Republic of China for Preparing Yangtze River Economic Belt Projects.* Manila.

Box 1: Recent Flood Disasters in the People's Republic of China

In mid-June 2016, heavy rainfall across the southern region of the People's Republic of China began generating severe flooding. Rainfall was particularly heavy in the middle and lower Yangtze River basin, with rainfalls of 1,250 millimeters to 1,350 millimeters accumulated by mid-July. A number of rainfall stations recorded the highest rainfall in history for durations ranging from 3 hours to 7 days, including a 7-day rainfall of 582 millimeters in the major city of Wuhan. Floodplain storage filled, levees came under stress, and many urban areas in the river basin were inundated, including parts of Wuhan, Nanjing, and Nanchang. Some levees failed, mainly on smaller tributaries. The greatest losses were incurred in Hubei Province. Anhui was another province that was very badly affected. Homes and agricultural areas adjoining the Poyang Lake in Jiangxi Province were flooded.

In early July, tropical cyclone Nepartak crossed the coast, drenching the provinces of Fujian, Jiangxi, and Zhejiang, wreaking further damage and taking more lives. Later the same month, severe storms occurred further north, creating havoc in Hebei, Henan, and Shanxi provinces, and in Beijing. Hebei was worst affected. The provincial capital, Shijiazhuang, was awash. Many lives were lost when a flash flood in nearby Xingtai City overtopped levees of the Qili River while residents were sleeping.

In many cities and towns, infrastructure and public utilities (such as power, water, transport, schools, shopping malls, dams, etc.) were damaged and services were disrupted. Besides massive flooding along the Yangtze River and its tributaries, the heavy rainfall triggered numerous landslides, flash floods in mountainous areas, and severe waterlogging in many cities.

Major flood disasters occurred again in 2017, although not as severe or as widespread as in 2016. In July 2017, 63 people were killed in floods and landslides in Hunan Province, with the Xiang River (a major tributary of the Yangtze River) reaching record levels. Parts of the provincial capital, Changsha, were inundated. There were more than a hundred dead or missing in landslides caused by torrential rain in the mountainous north of Sichuan Province in June and August.

Sources: *Al Jazeera Media Network*. 2017. Dozens killed in China floods as rivers overflow. 5 July. http://www.aljazeera.com/news/2017/07/china-floods-170704093817347.html; Aon Benfield. 2016. *Natural Catastrophe Report for China in Summer 2016*. October. http://thoughtleadership.aonbenfield.com/Documents/201610-china-summer-floods.pdf; *Hindustan Times.* 2017. 30 killed in two landslides in China, 12 missing. 30 August. http://www.hindustantimes.com/world-news/30-killed-in-two-landslides-in-china-12-missing/story-GjhoYAuhbXRWM5vzZg3U1L.html; Reliefweb. 2017. China: Floods and Landslides. June. https://reliefweb.int/disaster/fl-2017-000075-chn; and Xinhuanet. 2016. China strives to battle severe floods, challenges remain. *Xinhua Insight*. 26 July. http://news.xinhuanet.com/english/2016-07/26/c_135542090.htm.

In 2016, floods in the PRC affected 20 provinces, damaged 7.2 million hectares of crops, destroyed 410,000 homes, killed over 900 people, and resulted in estimated economic losses of $38 billion (footnote 1). The majority of these losses ($24.5 billion) occurred in the Yangtze River basin. In 1998, floods were likewise very widespread, and estimated losses (adjusted to 2016 values according to change in consumer price index) amounted to $53 billion (CNY357 billion) (footnote 1). Those were the largest economic flood losses in the PRC's history. The Yangtze River basin was hardest hit then, with peak flood levels generally a little higher than in 2016. It is further worth noting that the Yangtze River floods in 2016 had battered many private entities, particularly the industrial and business activities, leading to losses that run into several billion dollars' worth of economic values.[3]

[3] H. Liu. 2016. Flood Insurance in China: Lessons & Opportunities. China Water Risk. http://chinawaterrisk.org/resources/analysis-reviews/flood-insurance-in-china-lessons-opportunities/; and W. Kron. 2017. Like a Hole in the Sky. Munich RE. https://www.munichre.com/topics-online/en/2017/topics-geo/China-floodings.

Box 2: The Yangtze River Basin

In terms of mean annual flow, the Yangtze River is the fifth largest in the world (after the Amazon, Ganges-Brahmaputra, Congo, and Orinoco). The Yangtze River basin drains an area of 1.8 million square kilometers, equivalent to one-fifth of the land area of the People's Republic of China (PRC), home to approximately one-third of its population, and producing about 40% of its wealth (gross domestic product). The river and its main tributaries are responsible for the river basin being the economic powerhouse of the nation, for centuries serving to transport goods between cities and villages, many of which have grown into important centers of manufacturing and commerce.

The Yangtze River is the world's busiest waterway. Products are transported to port cities (e.g., Chongqing and Wuhan) from inland PRC, and then distributed via highways and railways to the rest of the country. International shipments of goods also take place in the major ports of Ningbo and Shanghai in the Yangtze River delta, two of the largest ports in the world. The economic and social importance of the river basin produced the concept of the Yangtze River Economic Belt (YREB) as a focus for future development and driver of national prosperity. The YREB includes nine provinces (Anhui, Guizhou, Hubei, Hunan, Jiangsu, Jiangxi, Sichuan, Yunnan, and Zhejiang) plus the special municipalities of Chongqing and Shanghai, with a population approaching 600 million. The Asian Development Bank's engagement with the YREB supports coordinated green development and more integrated management of the environment, water quality, ecosystem function, and climate resilience.

Within the Yangtze River basin, there are now thousands of kilometers of river dikes flanking the Yangtze River and its main tributaries. Hundreds of dams contribute to flood mitigation, culminating with the construction of the mighty Three Gorges Dam on the main river channel near the downstream end of what is regarded as the upper river basin. In the floodplains of the middle and lower basin, numerous flood detention areas have been designated that can be used to divert floodwaters for temporary storage during passage of major flood peaks.

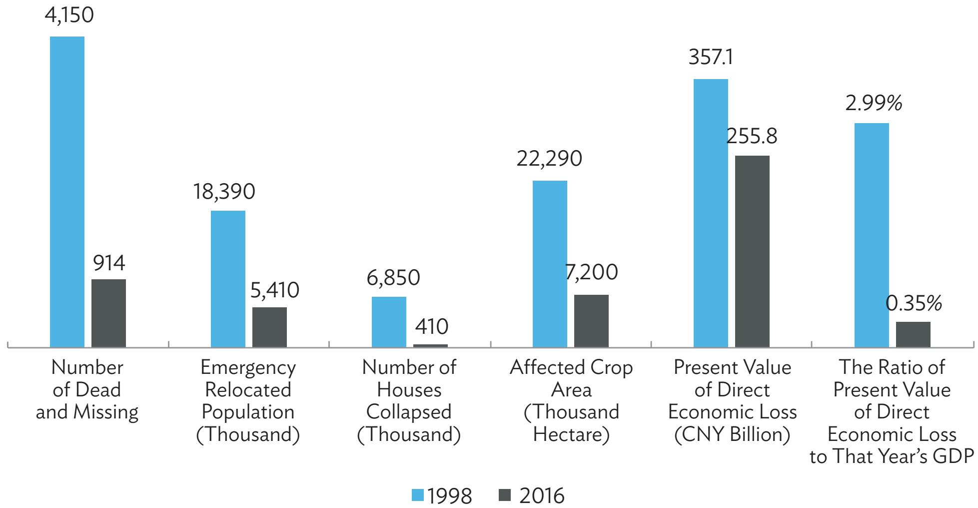
Source: Government of the People's Republic of China, Ministry of Environmental Protection, Foreign Economic Cooperation Office and China Water Risk. 2016. *Water-Nomics of the Yangtze River Economic Belt: Strategies and Recommendations for Green Development along the River*. http://chinawaterrisk.org/research-reports/water-nomics-of-the-yangtze-river-economic-belt-strategies-recommendations-for-green-development-along-the-river/.

Although floods in 1998 and 2016 were both severe, losses sustained in 2016 were relatively less than in 1998 (Figure 1). This may be because, since 1998, the PRC has intensified its efforts and investments in flood risk management. Improved flood forecasting and response system helped reduce flood losses.

However, many more lives were lost in floods in 1931 and 1954. In 1954, around 37,000 deaths occurred, even though flood levels were similar to those in 1998. Economic losses were much lower in 1954 because the value of assets exposed to flood hazard was then much lower. Flood risk management measures implemented since the foundation of the PRC in 1949 have achieved a dramatic reduction in lives lost to flooding. On the other hand, substantial development has been permitted in flood-risk areas, so there is a distinct trend of flood damages increasing since 1949. Main drivers of this trend have been urbanization arising from massive internal rural-to-city migration, and other land use changes.

Despite that trend, a measure of economic success of the PRC's recent flood risk management efforts is the direct value of losses incurred by floods relative to national gross domestic product (GDP), which indicates the economic impact of flood losses on the national economy. As shown in Figure 1, the adjusted 2016 value of losses was substantially greater in 1998 than in 2016. Losses in 1998 were equivalent to 3.0% of GDP that year; while, as a consequence of rapid economic growth, losses in 2016 were equivalent to just 0.35% of GDP (footnote 1).

Figure 1: Flood Losses in the People's Republic of China, 1998 and 2016



CNY = Chinese yuan, GDP = gross domestic product.

Source: Aon Benfield. 2016. *Natural Catastrophe Report for China in Summer 2016*. October. http://thoughtleadership.aonbenfield.com/documents/201610-china-summer-floods.pdf.

III. FLOOD RISK MANAGEMENT IN THE PEOPLE'S REPUBLIC OF CHINA

Policy Evolution

The PRC has long endured the devastating impacts from flood disasters as it is frequently hit by mega flood events. This makes flood risk management crucial in the country's socioeconomic development. A lot of effort has been expended to fight and control flood; however, great challenges still lay ahead. Starting from the concept of flood control, there has been a slow yet gradual shift in paradigm to flood management and, most recently, to flood risk management.

Flood control measures. The PRC has long embarked on flood control measures, but primarily in relation to the operation of its irrigation systems. From 1840 to 1900, flood control policy and technical guidelines were formulated alongside the development of levees as main flood control infrastructure. After 1949, the government embarked on an ambitious program of flood control. The flood control policy employed structural works to 'harness the rivers' and mobilized social resources to fight flood disasters. Key structural measures implemented by the Ministry of Water Resources to modify flood hazard included raising levees and constructing new dams, dikes, and flood detention areas in major rivers. Flood Control and Drought Relief Headquarters were set up to prepare for flood disasters by coordinating government activities to defend and operate flood control infrastructure during floods, and to respond to flood emergencies (flood fighting). These measures were very effective in reducing numbers of flood-related deaths.

Limitations of the success of the flood control policy and past practice became evident after major floods in 1996 and 1998 exposed the inadequacy of relying solely on structural solutions to control flood.

Flood management policy. The impacts of massive economic losses prompted a revision of policy, initially exemplified by the *Flood Control Law* of 1997 and a 32-word policy declaration released after the floods of 1998 (Box 3). These may be seen as the start of the paradigm shift in policy from flood control (the idea that these disasters triggered by natural hazards can be controlled) to flood management (emphasizing the use of both structural solutions and nonstructural measures, acknowledging that total control is impractical). This change in policy was applied in the construction of the Three Gorges Dam in the Yangtze River basin.

Box 3: Flood Control Law and 32-Word Policy

The *Flood Control Law* of 1997 continues to underpin flood risk management in the People's Republic of China today. It supports a more holistic planning approach, better integrating nonstructural and structural measures within flood management plans at a number of scales, including at river basin scale, and improved management of flood detention areas. It makes tentative moves toward regulation of development, but is restricted to flood-risk zones such as the limited zone between flood levees. Many regulations have since been enacted that aim to guide implementation of the provisions of the *Flood Control Law*.

The policy statement issued after the 1998 floods contains 32 Chinese characters that propose eight directives to address problems identified from the floods. Most directives were aimed at addressing a number of land use management issues adversely impacting flood-prone areas, e.g., reforestation of headwater areas, recovery of floodplain storage, and resettlement of residents in high-risk areas such as flood detention areas. Other directives were aimed at strengthening levees and improving conveyance capacity of rivers affected by sediment deposition.

Source: Y. Kobayashi and J. W. Porter. 2012. *Flood Risk Management in the People's Republic of China: Learning to Live with Flood Risk.* Manila: Asian Development Bank. https://www.adb.org/publications/flood-risk-management-peoples-republic-china-learning-live-flood-risk.

The important role of land use change and development was recognized. For example, because of rapid economic development and urbanization in the PRC, the value of public and private assets and infrastructure at risk in flood hazard areas had also escalated dramatically. Land clearing and deforestation in upper basins had increased runoff, and soil erosion had raised sediment loads transported by the rivers. Land reclamation for agriculture had removed much of the natural capacity for temporary storage of water on floodplains in the middle and lower parts of river basins.

Current paradigm shift: flood risk management. In 2004, the PRC requested ADB to assist in the preparation of a National Flood Risk Management Strategy (NFMS).[4] Although the NFMS was finalized by end of 2005, it was never officially adopted as a policy of the PRC. Nonetheless, it has influenced subsequent policy development, and it provides a useful framework in consideration of flood risk management needs.[5] The strategy was based on a risk management concept borrowed from the insurance industry. The NFMS identified three components of flood risk, as indicated below:

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

[5] Y. Kobayashi and J. W. Porter. 2012: *Flood Risk Management in the People's Republic of China: Learning to Live with Flood Risk*. Manila: Asian Development Bank. https://www.adb.org/publications/flood-risk-management-peoples-republic-china-learning-live-flood-risk.

Flood Risk = Hazard x Exposure x Vulnerability

where:

Hazard = a source of potential damage or harm to people or property. Hazard increases with increasing flood depth, increasing flow velocity, or increasing frequency of occurrence.

Exposure = the presence of people or property on the floodplain that could be harmed or damaged by flood hazard.

Vulnerability = the degree to which people or property exposed to flooding can be damaged or harmed.

Different types of measures are applicable to modify flood hazard, exposure, or vulnerability. Flood hazard may be reduced by structural measures such as dams, dikes, diversion channels, etc.; and by watershed conservation in upland areas that reduce runoff and sediment wash-off. Land use controls and building regulations, including resettlement, can help manage, if not reduce, exposure to flood hazard. Vulnerability can be reduced by employing a variety of nonstructural measures that include flood forecasting and early warning, campaigns to raise community awareness and preparedness, emergency response planning, postflood recovery programs, etc.

Ecological civilization. As a result of the various flood risk management efforts of the government, loss of lives due to floods has dropped significantly; yet, economic damages continue to rise, reaching a historical high in 2016. The increased occurrence of urban floods, along with their implications in the water quality and ecology, has prompted the PRC government to once again shift its focus on flood risk management and make it an integral part of environment and ecosystem conservation by promoting an ecological civilization—one that balances economic growth with environmental well-being and climate change considerations.[6] In its Master Plan for the Reform of Ecological Civilization Institutions released in 2015, the State Council called for the establishment of an ecological civilization by 2020. This vision of an ecological civilization is also supported by the 13th Five-Year Plan for Economic and Social Development of the PRC (2016–2020).[7]

Relevant Practices

Since the turn of the century, several new initiatives have been made in the PRC to complement the preexisting strengths of structural measures and emergency response. Reforestation projects have been undertaken to reduce runoff and soil erosion in upland watersheds. New technology has been applied to improve flood monitoring and flood forecasting, and to produce flood risk maps. Projects have been implemented to recover floodplain storage and to improve regulation and management of flood detention areas. Many other initiatives to improve flood risk management have been introduced or proposed—some of which are described in Chapter 5 (p. 13)—thereby, demonstrating a broadening of the approach to flood risk management policy and practice in the PRC.

[6] "Ecological civilization" refers to achieving harmony between growth, people, and nature. It includes activities to mitigate ecological damage, relieve pressures on natural resources, and improve the balance between the environment and the economy. (ADB. 2016. *Country Partnership Strategy: People's Republic of China, 2016–2020*. Manila.)

[7] Central Committee of the Communist Party of China. 2015. 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016–2020). Beijing. http://en.ndrc.gov.cn/newsrelease/201612/P020161207645765233498.pdf.

Projects have also been implemented to reverse environmental degradation, including upland reforestation projects. Efforts have been made to recover floodplain storage. Although such efforts are inevitably compromised by the degree of development permitted in the past on reclaimed lands and in flood detention areas, some success has been achieved by removal of polders in major floodplain storages such as Dongting Lake and Poyang Lake, resettlement, and other management measures. Much has been done to improve the security of dams, many of which were constructed during the early decades of the PRC when standards of design and construction were comparatively poor.

Devastation from flash floods in Minqing County. Collapsed roads and damaged buildings due to flash floods greeted residents of Minqing County, Fujian Province of the People's Republic of China in early July 2016 in the wake of super typhoon Nepartak (photo by the China Institute of Water Resources and Hydropower Research).

IV. ANALYSIS OF OUTSTANDING PROBLEMS AND ISSUES

In step with the rapid economic growth and urbanization that has taken place in the PRC since the 1980s, a large number of people and assets have accumulated in flood-risk areas, including on floodplains and in cities in mountain valleys. As a result, the PRC is facing more damaging floods along with serious environmental consequences. Projected climate change impacts will likely exacerbate this trend by increasing the frequency and severity of flooding and environmental problems.

The scale of losses during the 2016 floods demonstrates that efforts in the PRC to manage flood risk must be sustained and reinvigorated, and funding needs to be prioritized to achieve effective social and economic outcomes with respect to safety and security. Appropriate policy is required to guide future implementation of practical flood risk management measures that will achieve those effective outcomes. Consideration of what transpired during the 2016 and 2017 flood seasons in the PRC should serve to identify practice and policy directions that will best reward future efforts and expenditure. A number of relevant issues are considered below.

Most problems in smaller river systems (sub-basins). An important lesson learned from the 2016 flood events, particularly along the Yangtze River basin, is that the majority of flood damages does not come from the main stem river but from small- to moderate-sized river sub-basins. Rapid urbanization of small city and towns in these sub-basins has triggered flash floods and landslides—disaster events not regarded as among the government's priorities in the past.

Throughout the middle and lower Yangtze River basin, flood emergencies (or "dangerous situations") arose at more than 3,300 locations during the 2016 floods. Of those, over 3,200 were reported on small tributaries that are generally provided with lower standards of flood protection or where standards have not kept pace with the rapid rate of development. On the main stem river, there were just 50 flood emergencies, which were mainly caused by hidden structural flaws in the river dikes causing piping or dispersion of material, a legacy of inadequate historical design and construction standards. Vigilance in monitoring dike conditions during major floods on main rivers typically enables remedial measures to be implemented before disastrous breaches occur. On innumerable smaller tributaries, however, flood emergencies develop more rapidly after intense bursts of rainfall, and remedial measures are more difficult to implement quickly and are of lesser priority than on major tributaries. Because of lower design standards and capacity constraints, flood protection infrastructure such as dikes are more easily overwhelmed. It appears that much of the damages and most loss of life were attributable to emergency situations on small, higher order river basins (such as third- or fourth-level tributaries).

Maintenance of older infrastructure. Because of the scale of past works, maintenance of flood protection infrastructure is an enormous challenge in the PRC. There are more than 35,000 kilometers of river dikes and levees in the Yangtze River basin, which alone illustrates the scale of the problem. Inevitably, with constraints on funds available for maintenance, more rigorous monitoring and remediation are directed to main river levees where consequences of failure are greatest. This investment gap is another factor in why losses were disproportionately high in smaller tributary systems during the 2016 floods.

Along with rapid landscape change and land price appreciation in urban areas, human encroachment into rivers and flood plains becomes apparent. Lack of proper regulations and codes of practice—particularly for utility services that perform maintenance or expansion works of existing river infrastructure—has caused problems in the restoration of these rivers and dikes. A clear example of this was a local heating company, which, during the installation of its pipeline, dumped heaps of construction muck into the river and cut out a portion of the existing dike in the Qili River. The company did not complete the pipe installation work before the flooding season, which resulted in huge overbank flows and dike failure leading to the deaths of 25 people in Daxian village in Xingtai City, Hebei Province.

Urban flooding. A considerable proportion of the economic loss and social disruption occurred because of flooding in urban districts. More than half of the PRC's land area is arid or mountainous, unsuited to agriculture or settlement. In many regions, land available for urbanization is limited, leading to development on flatter, low-lying flood-prone land that is relatively inexpensive and easier to acquire and service. The rate of urbanization in the PRC is exceptionally high because of rapid economic growth and industrialization, with massive internal migration from rural areas to cities. Urbanization aggravates flooding problems. It increases the percentage of impervious area and increases volume of runoff. Urban stormwater drainage typically increases velocity of flows, thus leading to higher peak discharges. Natural surface depressions and wetlands that intercept runoff are often lost during the process of urban land development.[8] It is not just a local issue. Increased runoff and degraded water quality from urban areas adversely affects all towns and cities downstream and impairs the ecology of the river systems.

Urban stormwater drainage. Many new urban areas are poorly planned and provided with inadequate stormwater drainage for the increased runoff. Adequate stormwater drainage requires large upfront investments by developers. As it provides no subsequent income stream, this discourages adequate investment in stormwater services. Where dikes protect towns and cities from river flooding, urban flooding includes waterlogging that is caused by local runoff trapped behind the dikes. Pumps may be necessary to discharge runoff accumulated behind dikes, but pumps are not always provided or are of inadequate discharge capacity, and are often poorly maintained.

Lack of integration of flood risk management in land use planning. A linkage in planning for land use management and planning for flood risk management is essential to manage the exposure of public and private development to flood risk. Consideration of flood risk in land use planning has been largely ineffective in the PRC. In general, the PRC has allowed inappropriate use of land that is at risk from flood hazard, particularly in urban development; and, it has failed to adequately regulate land use activity in zones designated as flood detention areas. Supervision by higher tiers of government has been lacking in this respect, allowing local governments to disregard the nexus between land use planning and flood risk management. Land development is a handy source of revenue for local governments, and local governments are rewarded for meeting national and provincial development targets. In the past, these incentives have too often overridden the need for sensible development of flood-risk land.

Aggravated by a separation of institutional responsibilities for land use management and flood risk management, new flooding problems are being created by the challenges of rapid urbanization and land use change, greatly increasing the number of people and value of assets exposed to flood hazard on the floodplains. Because multiple administrative departments (e.g., water resources, land resources, environmental protection bureaus, etc.) are involved in the management of flood risk, better coordination is therefore essential in applying land use planning as a flood risk management measure.

Policy implementation failures at local government level. In some cases, recent losses were derived from failures to implement national policy provisions for flood risk management at local government level. An integrated approach to flood risk management requires an effective partnership and better coordination between multi-sectoral agencies and multi-tiers of government, particularly at the local level where most policies are implemented. In the PRC, however, this remains a challenge as local government leaders lack adequate experience in doing collaborative work and are wary about going beyond their mandated responsibilities.

Local officials have many priorities that demand their ongoing attention, and assiduous implementation of flood risk management measures may be neglected. When vigilance flags, as can easily happen after many years without flood emergencies in their jurisdiction, it leads to what may be termed "alert fatigue." A good example of this appears to be the disaster at Xingtai in Hebei Province in July 2016. Warning of an impending emergency was issued too late to enable evacuation by residents or effective mobilization

[8] For example, Wuhan, the capital of Hubei Province at the confluence of Yangtze and Han rivers, was once known as the "city of 100 lakes." However, lakes and wetlands were filled to make way for construction projects, so more than two-thirds of its lakes have disappeared since 1949—down from 127 to 40. Storage capacities of the 40 remaining lakes have been reduced by heavy sedimentation due to erosion and construction activities.

of government resources. Furthermore, the channel of the Qili River at Xingtai, dry for several years, was obstructed by construction activities at the time of the flood, and building development had been permitted in unprotected, high flood-risk zones beside the river banks.

Lack of community participation. A related problem is a lack of community engagement in planning and management, in general, and in flood risk management, in particular. In past history, over many centuries and even millennia, emperors were judged by their citizens on the prevalence of disasters like floods and droughts on their watch. Something of this cultural tradition persists today, reflected in expectations by citizens that their protection and security from disasters triggered by natural hazards will be looked after by the government, and in the highly commendable and systematic national approach by the government to mitigate impacts of floods on society and the economy. However, international good practice in flood risk management requires more of a partnership between government agencies and communities at risk, so that members of the community are aware and well informed about the flood risk where they live or work, and are better prepared to undertake measures and actions coordinated with government management plans. During flood emergencies, this could increase safety of their families and improve security of their property and assets. Raising public awareness of flood risk is particularly important in newly developed urban settlements (where residents lack past flood experience), in areas susceptible to flash flooding (where response must be quick), and in regions with low incidence of serious flooding (where awareness fades over time).

Flash floods in mountainous areas. During both 2016 and 2017, flash floods including debris flows and landslides caused considerable damage and lamentable loss of life. Landslides may also be triggered by earthquakes, but those in 2016 and 2017 were triggered by torrential rains. The risks of these types of

A trail of destruction left by landslide in Hunan Province. Numerous flash flood, debris flow, and landslide events resulted in huge economic damages in Hunan and adjacent provinces of the People's Republic of China in July 2016 (photo by the China Institute of Water Resources and Hydropower Research).

disasters are particularly difficult to manage, as the impacts—though severe—are relatively localized, and the locations where they occur cannot be accurately predicted. Good management entails identification of sites at greatest risk, raising community awareness of the risk, and implementing early warning systems—although, unfortunately, the warning that can be provided for such events is seriously limited, and especially so for landslides.

Future climate change. Predictions by climate modeling of the effects of future climate change may not be accurate or reliable, but there are several recent studies that concur in concluding that average rainfall is likely to increase in southern PRC, including the Yangtze River basin. There is also agreement in conclusions that rainfall intensities of short-term storms will increase. That means the hazards from river floods, flash floods, and landslides are all likely to increase. The probabilities of disasters occurring will increase, the frequency of events recurring like those in 2016 and 2017 will increase, and even more severe disasters are quite likely during the course of this century. Apparently, it is too late to reverse the climate trend that has already begun; however, the socioeconomic impacts of future disasters can still be tempered by effective flood risk management policy and practice, and especially by greater emphasis on nonstructural measures that deal with residual risk (i.e., the risk remaining after implementation of structural measures).

Impaired water (flood)-environment-ecosystem nexus. More generally, there has been increasing linkage between water management and environmental management in recognition of the nexus between management of water, environmental degradation, and sustainability of ecosystems. With respect to flood risk management, this linkage is particularly important in urban areas, where the management of stormwater runoff to combat urban flooding is linked to effective municipal waste management and to downstream water quality.

There is a fundamental nexus between flood risk management, environmental management, and sustainability of ecosystems. The three are inextricably linked. Insufficient consideration of this important nexus in management planning leaves a footprint on communities and ecosystems downstream. It can, and often does, degrade downstream water quality and can adversely impact ecosystems in many ways by altering flows in rivers and the transport of sediment and pollutants. In recent planning for the Yangtze River Economic Belt, there has been strong emphasis on green development, but the role that flood risk management has to play in achieving green development has been neglected. This has been especially apparent in development of new urban districts, where land use of rural areas adjoining older urban districts has been changed (urbanized) to cater to the relentless population drift to cities. In older urban districts too, more is needed in flood risk management than the construction of more drains or bigger drains. Wherever possible, to minimize the downstream footprint of urban development, improvements in stormwater management should introduce more source retention of rainfall; more detention of runoff in tanks, ponds, and wetlands; expansion of green space and porous pavements; capture of trash; stormwater treatment, etc. Fortunately, the sponge city concept, discussed on p. 13, is gaining momentum in the PRC.

Institutional challenges. There remain some aspects that are relatively neglected. Just as the nexus approach requires good institutional coordination among relevant sectoral line agencies (particularly, water and environment sectors), so does an integrated river basin management approach need close multi-stakeholder coordination. Although flood risk mapping provides an excellent tool, the integration of flood risk zoning into land use management and building regulation is still very limited. The constraints are largely institutional in character, and could be corrected given political will, leadership, and perseverance. Raising community awareness of flood risk and improving levels of community preparedness is highly desirable but will be difficult to achieve. It requires engagement of affected communities in flood risk management planning and open sharing of information that may be resisted by communities and governments alike. Traditionally, people in the PRC are accustomed to leave such responsibilities to the government and may not wish to be involved. Meanwhile, governments—and particularly local governments—may be unwilling to reveal (or even acknowledge) the actual risk to which people and businesses in their jurisdiction are exposed.

V. EXAMPLES OF MAJOR FLOOD RISK MANAGEMENT INITIATIVES IN THE PEOPLE'S REPUBLIC OF CHINA

In the last decade or so, authorities in the PRC have introduced major initiatives to improve flood risk management. Among them are the flash flood warning systems (FFWSs), the sponge city concept, and the new river chief system.

Flash flood warning systems. By the turn of the century, most casualties from water-related disasters in the PRC were no longer from main river flooding, but were occurring in mountainous regions due to flash floods as well as landslides, mudslides, and debris flows arising from heavy downpours. Statistics show that in the first decade of the 21st century, at least three-quarters of deaths caused by water-related disasters were occurring from those types of disasters in mountainous regions. After a preparatory phase, the Government of the PRC approved in 2006 the implementation of pilot projects in 103 counties to test FFWSs. The measures employed in FFWSs were principally nonstructural measures. All rely on key components including data acquisition networks to monitor rainfall and water levels, command centers, and a well-organized protocol for disseminating warnings and assisting evacuations to places of safe refuge. Alerts are based on simple criteria such as rainfall exceeding a predetermined trigger level.[9] After the pilot projects, by 2015, FFWSs had been implemented in over 2,000 counties across the country. This is a remarkable achievement over a short period of time. To be an effective end-to-end and people-centered early warning system, the service should be expanded to the grassroots communities in small- and moderate-sized ungauged river sub-basins with advanced but localized flood forecasting system supported by meteorological, hydrological, and river observations.[10] The FFWS program should also engage local communities at the household level and raise community awareness and preparedness.

Sponge city. In recent years, the government has promoted the application of a sponge city concept, an ecosystem-based approach, for new urban development and urban redevelopment to mitigate the impacts of urbanization.[11] Sponge city development adopts a range of measures to enhance infiltration of rainfall into soils and intercept stormwater runoff for use as a resource. These include (i) mandating minimum landscaped areas; (ii) construction of rain gardens; (iii) use of pervious pavements; (iv) interception of rainfall from roofs and pavements for nonpotable use; (v) disconnection of roof down-pipes from street drains (requiring runoff to run through gardens prior to entering roadside drains in order to delay runoff and enhance infiltration); (vi) use of grass swales in place of piped drains; (vii) use of detention basins to store runoff during peak flows for subsequent slow release; and (viii) use of vegetated swales and wetlands to filter pollutants from runoff, thereby improving water quality, as well

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9 D. Sun, D. Zhang, and X. Cheng. 2012. Framework for National Non-Structural Measures for Flash Flood Prevention in China. *Water.* 4 (1). pp. 272–282.

10 United Nations International Strategy for Disaster Reduction. 2006. *Developing Early Warning Systems: A Checklist.* Third International Conference on Early Warning. Bonn, Germany. 27–29 March. http://www.unisdr.org/we/inform/publications/608.

11 X. Li et al. 2016. Case Studies of the Sponge City Program in China. Conference paper for the 2016 World Environmental and Water Resources Congress. West Palm Beach, Florida. 22–26 May. https://www.researchgate.net/publication/303362681.

as other measures. A *Technology Guide for Sponge City Construction* was produced in 2014. In 2015 and 2016, central government agencies jointly sponsored a program to implement the sponge city concept through pilot projects in 30 cities in the PRC.

River chief system. A new river chief system is currently being implemented nationwide. This system will coordinate administrative management to overcome past issues arising from division of responsibilities for management of water resources and the environment, and produce better environmental outcomes in rivers and lakes. First trialled successfully to ameliorate serious water pollution in Taihu Lake, the river chief system delegates senior officials to ensure effective coordination. River chiefs are held accountable for improved condition of water bodies under their jurisdiction. Typically, the jurisdiction of a river chief extends over several jurisdictions spatially (i.e., over many local or even several provincial governments) and coordinates actions of multiple departments at each tier of government. This initiative recognizes the importance of the water-environment-ecosystem nexus, and directly addresses one of the greatest challenges of effective water management, the integration of administrative efforts by multiple government agencies. The river chief system has potential to assist in conjunction with a new 'ecological red-line' policy which will delineate protected zones within which future development will be either restricted or carefully regulated to avoid past mistakes of "irrational development."

VI. ADB'S INTEGRATED FLOOD AND ENVIRONMENTAL RISK MANAGEMENT APPROACH IN THE PEOPLE'S REPUBLIC OF CHINA

ADB's Flood Risk Management Support in the People's Republic of China

Since 2000, ADB has invested $2.7 billion in the PRC in 20 water sector projects. Flood risk management-related projects ($1.4 billion) primarily focus on green infrastructure and ecosystem-based approach, and they are mainly for demonstration purposes. These pilot projects vary, depending on the local needs, and cover a range of endeavors—e.g., ecological restoration and reforestation; environmental protection, including solid waste management; land use development and management, including land-cover improvement; river and lake sediment control; river trainings and waterlogging mitigation, including stormwater drainage systems; slope stabilization through bio-engineering methods; soil and water conservation; and wetland protection and rehabilitation, including artificial wetland development.

In terms of technical assistance, ADB has provided opportunities for partnership with government agencies in the PRC to advance modern flood risk management policy and practice. The development of a strategic framework in the National Flood Risk Management Strategy project noted in Chapter 3 (p. 6) is just one example. Currently, ADB is collaborating with the PRC to identify appropriate investments to support the strategic framework for green development of the Yangtze River Economic Belt (YREB) that will (i) contribute to the overall environmental targets of the YREB; (ii) contain basin-level intervention components; (iii) enhance climate resilience of cities and communities; (iv) cover highly innovative features, including high technology applications; (v) get relevant local level administration to buy in, and can be replicated elsewhere in the YREB; and (vi) address environmental or water resource management challenges facing transprovincial level administration.

ADB's Integrated Flood and Environmental Risk Management Approach: Project Innovative Features

In the wake of the recent flood events in the PRC and the development of the YREB master plan, ADB has been promoting an integrated flood and environmental risk management (FERM) approach in its efforts to demonstrate best practices across the PRC and establish new performance standards and good practices for investment in flood risk management. These efforts are well aligned with the above-mentioned flood risk management initiatives currently being promoted by the government (i.e., flash flood warning systems, sponge city, and river chief system). Lessons from these ADB-initiated FERM projects can serve as a model case study for cities and small rivers in the PRC, and sets a benchmark for the proposed investment framework for the development of the YREB.

The ADB-funded FERM projects will introduce innovative planning, design, and implementation methods following these guidelines:

(i) Formulate a comprehensive FERM plan in watersheds as prerequisite for other development plans. This will help align existing river basin master plans with recent government policies, such as the river chief system and the YREB master plan.
(ii) Demonstrate a nexus approach for the inextricably intertwined water (flood)-environment (waste)-ecosystem management through the integration of structural and nonstructural measures. This approach will help promote the integrated flood, solid waste, wastewater, and ecological management in the basin level and avert fragmented interventions.
(iii) Develop a FERM footprint and accountability system that will address rural–urban integration, upstream–downstream linkages, and integrated water resources management. This system will help monitor and ensure the reduction of flood and environmental risk at the project site and in the downstream areas.
(iv) Mainstream FERM in sectoral project planning and design to mitigate flood damage and, at the same time, reduce the locality's flood and environmental risk.
(v) Adopt FERM-sensitive land use planning measures to minimize flood exposure (relocation) and adverse social impacts. One such measure is the introduction of discontinuous dike with provisions for flood protection in critical locations and flood retention in other areas to reduce flood in the downstream reaches. These projects will improve the coordination among different line agencies at different levels to improve project design and implementation.
(vi) Pilot nonstructural measures—such as the localized flash flood early warning system—using information and communication technology as well as community-based approaches. This is important since national flood forecasting and early warning system primarily covers the major river basin areas but not the localized areas in small tributaries.
(vii) Strengthen institutional capacity in FERM by piloting a real-time river observation system that will support the application of the river chief system. Such application can be replicated in the YREB and other regions.

The Kongmu River Technical Assistance Project

The Xinyu Kongmu River Watershed Flood Control and Environmental Improvement Project in Jiangxi Province (Box 4) is concerned with developing integrated and climate-resilient FERM strategies, following the guidelines for ADB-funded FERM projects, for a new urban district located just upstream of Xinyu City.[12] It will help the city government of Xinyu manage and mitigate flood and environmental risks, leading to improved living conditions. This will be achieved through the implementation of an integrated approach that provides a well-balanced mix of structural and nonstructural interventions, including capacity building.

[12] ADB. 2016. *Report and Recommendation of the President to the Board of Directors: Proposed Loan for the People's Republic of China for the Jiangxi Xinyu Kongmu River Watershed Flood Control and Environmental Improvement Project*. Manila.

Box 4: The Xinyu Kongmu River Watershed Flood Control and Environmental Improvement Project, Jiangxi Province

This Asian Development Bank (ADB)-supported project aims to provide flood protection for villages located adjacent to the Kongmu River, ensure effective management of risk from flooding and waterlogging in the development of the new urban district, ensure that said development does not aggravate flooding or water quality downstream, and enhance environmental and living conditions. The project will conduct trials and implement a number of innovative measures that will demonstrate a nexus approach for flood–waste–ecosystem management. Specifically, the project will improve water quality, largely mitigate flooding in the project area by capturing almost 75% of the peak surface runoff from the urbanized area, and reduce annual average flood damage in downstream Xinyu City.

A city planning and design approach was adopted to absorb rainfall and surface runoff aimed at reducing stormwater (urban floods) and polluted runoffs and utilizing this water in eco-friendly ways. The design techniques include permeable surfaces, gardens, rainwater harvesting, green spaces, and connected lakes. The improvement of the solid waste management system—which can reduce the export of solid waste into waterways, thereby yielding both water quality and flooding benefits—and the construction of water storage canals and wetlands can retain water for flood control purposes and, at the same time, treat stormwater runoff and improve water quality.

The project applies the sponge city approach in the development of the new urban district. The stormwater drainage network will be constructed to retain existing small lakes for flood detention and water quality improvement, and include green space for recreation and enhancement of infiltration. This will allow functional integration of stormwater and urban flood risk management with environmental water quality control and innovative urban land use planning to provide exceptional standards of urban amenity for residents and businesses in the new district.

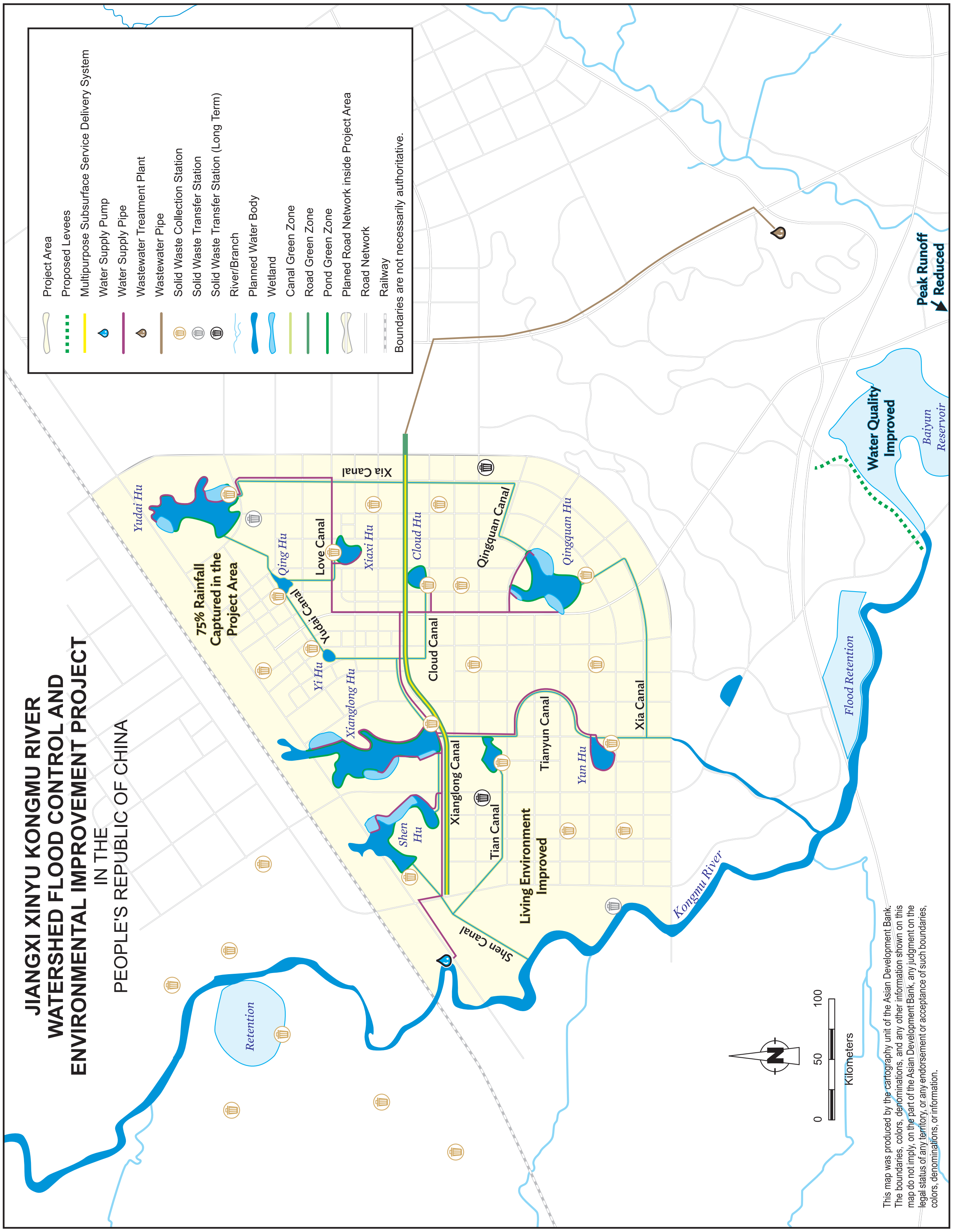
Moreover, the project will develop the capacity of government agencies and the general community to manage flooding and environmental risks. Capacity will be increased through targeted training and education programs (including raising public awareness) and implementation of pilot projects to test the application of the sponge city concept and flood proofing of buildings. Flood proofing of buildings is commonly applied in developed countries, but is not generally applied in the People's Republic of China (PRC). This project will help to develop flood proofing solutions appropriate for the PRC.

The project will also develop an improved flood forecasting and early warning system for villages along the Kongmu River. The Kongmu River basin is small, with only less than an hour between storm rainfall and flooding; therefore, a flash flood warning system is required where alerts can be triggered by either rainfall or river water levels.

Source: ADB. 2016. *Report and Recommendation of the President to the Board of Directors: Proposed Loan for the People's Republic of China for the Jiangxi Xinyu Kongmu River Watershed Flood Control and Environmental Improvement Project.* Manila.

Figure 2 illustrates the project output components of the Jiangxi Xinyu Kongmu River Watershed Flood Control Project covering the following: integrated rural and urban flood management infrastructure (output 1), solid waste and wastewater management infrastructure (output 2), and flood and environmental risk management capacity (output 3). Implementation period of the project is from 2017 to 2023, with total project cost reaching $299 million ($150 million of which is financed by ADB).

Figure 2: Proposed Outputs of the Jiangxi Xinyu Kongmu River Watershed Flood Control Project, People's Republic of China



Source: Asian Development Bank.

VII. CONCLUSIONS AND RECOMMENDATIONS

This review of recent flood experience in the PRC in the context of national flood risk management policy and practice leads to a number of conclusions and recommendations that are highly relevant as to how ADB can best support the PRC government by targeted assistance, and guide it towards fruitful new directions to face the challenges of the future. It will also provide a conducive opportunity for new dialogue, regional cooperation, and ADB–PRC collaboration for responding to flood risk management and climate variability.

Integration of land use planning and flood risk management. A key to improving future flood risk management in the PRC and addressing major challenges arising from rapid economic development and climate change is to adopt the environment first approach and integrate (current and future) flood risk into land use planning. This would also leverage opportunities by steering growth in a resilient manner. Land should be zoned according to level of flood risk or flood hazard (e.g., high, moderate, and low hazard zones); and regulations imposed and enforced that permit only uses of land compatible with the relevant zones. Improved land use planning should ensure that new development limits exposure of people or property to flood risk. Resettlement and redevelopment should remove people and property from hazardous areas. Unfortunately, there is an institutional division of responsibilities for land use planning and for water resources management (which includes flood risk management) that must be overcome. Local governments, in particular, rarely have the necessary skills and resources. Proper regulations and codes of practice are required to operate and maintain the existing flood infrastructure while expanding the urban services. Support should therefore be provided (e.g., technical support, guidelines, financial assistance, pilot projects, targeted training) to assist local government better integrate flood risk management into land use management.

Urban flood risk management. Flooding or waterlogging of urban areas in small towns and cities in small river basins was a major issue during recent floods. More attention will need to be directed to improving urban stormwater systems in the future. Implementation of the sponge city approach enables a more sustainable means of providing improved stormwater drainage while at the same time improving water quality management, delivering ecological and public benefits to urban areas, and managing the nexus between flood risk management and downstream environmental and ecosystem footprints. Urban development and urban redevelopment projects should support the government drive to implement sponge city measures. Solid waste disposal and wastewater management are also important factors that need to be integrated into urban stormwater management, because inadequate services encourage use of stormwater drains for disposal of solid waste and increase pollutant loads in urban runoff.

Nexus approach of water, environment, and ecosystem management. Water management (particularly, flood risk management), environmental protection, and sustainability of ecosystems are inextricably intertwined development goals. Hence, there is a need for applying a nexus approach for water–environment–ecosystem management through the integration of structural and nonstructural measures. The nexus approach would facilitate the unification and harmonization of goals across sectors, making development goals more cost-effective and efficient and reducing the risk that actions will undermine one another. Investment projects should adopt an integrated flood-resilient development planning to maximize flood control and strengthen environmental and ecological outcomes. If planned and designed properly, a single measure can simultaneously address all flooding, environmental, and ecological needs. The ADB-supported Xinyu Kongmu River Watershed project in Jiangxi (Box 4), for example, recognizes the nexus between water–environment–ecosystem management, as well as the footprints that new development could implant on communities and ecosystems downstream.

Development of sub-basin scale flood risk management plans. The PRC has comprehensive basin-scale flood risk management plans for major river basins, including large rivers and some important tributaries of the large rivers. However, unlike past disasters, much of the loss and damage in the July 2016 floods was incurred in small river basins, which in the past had received lower priority for investment and, therefore, did not have sub-basin level plans. Future flood risk management will need to give more priority to these smaller river basins, most of which are parts of much larger river basins, such as in the Yangtze River basin.[13] The government has recently requested ADB to pilot the development of such a comprehensive flood and environmental plan for the Longxi River basin (a small watershed in the Yangtze River basin) in Chongqing municipality (footnote 2). Preparation of flood risk management plans is recommended for whole river basins at an appropriate spatial scale to address outstanding problems in small river basins. These should be nested within larger basin plans that include details of the flood strategy for the main river and its major tributaries.

Development of flash flood forecasting and warning systems. Flash floods are quick and short events with very short lead times for forecasting and dissemination of warnings; nonetheless, even short warning times can save lives. Therefore, flash flood warning systems (FFWSs) are required, where alerts can be triggered by either real-time rainfall threshold values or river water levels. There is potential for ADB to support and help expand the existing government program for implementation of FFWSs. In fact, the government has requested ADB for technical assistance in developing a stand-alone flash flood early warning system in selected provinces, and the project proposal is now in the pipeline for implementation in 2018. ADB support should advocate projects that comprehensively deal with the four key elements for early warning systems identified by the United Nations International Strategy for Disaster Reduction (UNISDR) (footnote 10): (i) risk knowledge (i.e., systematic data collection and risk assessment), (ii) hazard monitoring and early warning services, (iii) dissemination and communication (of risk information and early warnings), and (iv) response capability (i.e., build capacity of government and community to respond effectively).

Environmental and flood risk footprinting and accountability. The footprint is a measure of human impact in the basin level leading to increase or decrease of environmental and flood risk. The accountability system refers to indicators that enable decision-makers to assess the progress not just at an individual project level but at the entire river basin. A system is required to guide the development in the river basin so that individual investment projects fit within the context of broader environmental and economic sustainability and long-term basin development framework. In the flood management context, this will help ensure that the investment in upstream areas will improve condition in the locality and enhance the environmental and flood risk management in the downstream areas; if not, at least will not exacerbate the risk in the downstream areas. Flood footprinting and accountability system is recommended for the whole river basin to address outstanding problems in both sub- and main-river basins.

Role of the private sector. The private sector also suffers significant financial losses from floods. Hence, the crucial role of the private sector in flood risk management should be viewed from a wider perspective, and not just as conventional insurer or reinsurer. There are, in fact, several opportunities for private sector involvement and public–private collaboration in flood risk management, in particular, and in climate change adaptation, in general, which can be integrated into national policies and programs. The private sector, which is at the frontline of flood disasters, can play a significant role in reducing economic

[13] In recognition of this need, in 2009, the government of the PRC launched a new program of special projects to direct more investment to raising standards of protection in small- and medium-sized rivers.

damages as well as in mitigating flood risk. Thus, their potential roles need to be harnessed and adopted in the flood risk management strategies. These roles include, but are not limited to:

(i) **Business safety and resiliency.** Without a proper contingency plan, enterprises and other business establishments in flood-prone areas not only put themselves at risk but also make the local, regional, and national economy highly vulnerable.

(ii) **Social and economic obligations.** Having proper contingency measures to mitigate losses and direct impacts of floods may not be enough, as arrangements and provisions for recovery, rehabilitation, and prompt resumption of public services are more critical, especially for industries in the public utility sectors.

(iii) **Services.** The private sector can take the lead in providing the necessary materials and services not just for development efforts but also for effective flood risk management—e.g., they can facilitate access to readily accessible information and technology during flood events and other disasters through the provision of cellphones and internet services.

(iv) **Infrastructure investments.** The private sector can invest in flood risk management infrastructure or exploit possible opportunities for mitigating the risk arising from flood events, such as river dredging.

(v) **Financing.** Delivering disaster risk financing solutions are one of the tested functions that the private sector has successfully performed globally. Disaster insurance, reinsurance, and catastrophe bonds, which are widely used in business models, are beneficial tools in transferring and distributing risk.

Within the PRC, there are abundant opportunities to act on the recommendations above within the Yangtze River basin to align with ADB's focus on supporting development of the Yangtze River Economic Belt—particularly in the areas of environmental protection, water management, and flood risk reduction. The recommendations will likewise help better orient and provide new benchmarks for future ADB investments and assistance to support an integrated flood and environmental management approach in the PRC. They are also generally applicable to flood risk management in other developing member countries.

Strengthening Flood Risk Management Policy and Practice in the People's Republic of China

Lessons Learned from the 2016 Yangtze River Floods

In the People's Republic of China (PRC), recent flood events revealed that the majority of flood damages does not come from the main stem river but from small- to moderate-sized river sub-basins. This paper reviews recent flood experience in the PRC in the context of national flood risk management policy and practice. The paper illustrates that there is an inextricable nexus between flood risk management, environmental management, and ecosystem sustainability. It also highlights the need for a flood footprint and accountability system for the whole river basin and greater involvement of the private sector in flood risk management.

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ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to a large share of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

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