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Historical assessment of Chinese and Japanese flood management policies and implications for managing future floods

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ARTICLE INFO

Article history:
Available online 17 February 2015

Keywords:
Flood management policy
History
Irrigation
Structure measures
No-structure measures
Extreme events

ABSTRACT

Floods are among the world's most devastating natural disasters, causing immense damage and accounting for a large number of deaths world-wide. Good flood management policies play an extremely important role in preventing floods. It is well known that China has more than 5000 years of experience in flood management policy beginning with the reign of DaYu and Gun. Although culturally related, Japanese flood management developed differently from that of China. Under rapid development of civil engineering technology, flood management was achieved primarily through the construction of dams, levees and other structures. These structures were never adequate to stop all floods, and recent climate change driven extreme events are ever more frequently overwhelming such infrastructure. It is important to take a historical perspective of Japanese and Chinese flood management in order to better manage increasingly frequent extreme events and climate change. We present insights taken from an historical overview of Japanese and Chinese flood management policies in order to guide future flood risk management policy.
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http://dx.doi.org/10.1016/j.envsci.2014.12.015
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1. Introduction

Floods are the cause of devastation worldwide, with frequent occurrence in Asia, particularly in China, Japan, India and Thailand. Flooding has become increasingly frequently in China and Japan in recent years concurrent with observations of global climate change and increasingly frequent extreme weather events. As the occurrence of floods has become common, flood risk and flood prevention have raised public, political and scientific awareness. Moreover, floods are major drivers of pollutant export from sewage, farm chemicals including pesticides and fertilizers, and other sources (Luo et al., 2011b; Duan et al., 2013a, 2013b). There is a growing awareness of the significance of flooding on human health through direct and indirect impacts. Urbanization and extreme weather events leading to greater runoff, higher peak discharges, more rapid response times, and variations in sediment production (Bledsoe and Watson, 2001; White and Greer, 2006; Luo et al., 2013) have intensified flood risks (Pfister et al., 2004, Duan et al., 2014). Predicted climate change will significantly increase water-related risks (Muller, 2007), especially increasingly frequent and intense extreme rainfall events (Browning-Aiken et al., 2007; Mujumdar, 2008). Dams, dykes and levees are often used to reduce flood risk (Lind et al., 2009) and the effect of dam projects on flood management has been assessed in other studies (Hayashi et al., 2008; Luo et al., 2011a). Optimum multi-objective and dynamic control of flood limited water level for reservoir operation has been used to provide a practical way to reduce flood risk (Dittmann et al., 2009; Li et al., 2010). River channel network design has also been used to relieve flood risk (Cui et al., 2009). A risk analysis model was presented to evaluate the failure risk for flood management structures using design floods (Wu et al., 2011). Taking a national viewpoint to review flood management measures and policies offers the benefit of identifying proven effective measures.

Following the devastating 1997 flood that affected many residents in the Red River Basin, historical Canadian flood control policies were reviewed to order to modify flood management approaches and led to the use of flood forecasting, planning of new structural and non-structural flood control measures and emergency operations of existing flood protection systems (Simonovic and Carson, 2003). The social aspects of flood risk perception that shape flood response were analyzed and integrated flood risk management suggested as a suitable way to cope with flood disasters in central Vietnam (Tran et al., 2008). An assessment of floodplain residents' preferences for outcomes of water level management was conducted in Bangladesh using a questionnaire as part of a maximum difference conjoint (MDC) model (Rasid and Haider, 2003). They found that survey respondents have clear ideas regarding flood prevention of their homes and courtyards as well as varied flood depths in rice fields. Hierarchical structure and geographic information system (GIS) were used for flood risk analysis in Taiwan (Chen et al., 2011). A structural master plan of flood mitigation measures was developed via economic evaluation of trade-offs between construction costs and expected value of damage reduction in south-west Iran (Heidari, 2009). Recently, the social perception of floods and flood management has become an important topic for flood control (Lara et al., 2010). However, few historical assessments or comparative analyses of flood management policies have been conducted at national scale. Furthermore, systematic assessment of flood management policies at a national scale has not been conducted for China or Japan. Such an exercise is essential to effectively guide flood management policy.

Flood management in China and Japan has always aimed to control stream-flow for municipal and commercial use while preventing flood disasters. China has a long history of flood management measures beginning with DaYu and Gun's flood management policy (Gu, 2006). For example, the Dujiangyan Irrigation System is a flood management measure that underscores China's long-standing effort to harness water resources. Dujiangyan is an irrigation infra-structure built in 256 BC during the Warring States Period of China by the Kingdom of Qin. It is located in the Min River in Sichuan Province, China, near the Province capital Chengdu. It is still in use today and irrigates over 5300 square kilometers of land in the region. Dujiangyan has a flood management system, an urban water supply system and a sediment transport system (Cao et al., 2010). After a major flood in 1998, the Chinese government changed course on flood management policy, shifting from the exclusive use of structural approaches to using a combination of structural and non-structural approaches. Japanese flood management began with the policies implemented during the Yayoi period (300 BC–AD 300). In 1960, there was an effort to move away from concrete dams and focus instead on the hydrologic function of "Green Dams," which rely on the flow retarding capacity of forests to reduce flood risk (Takara et al., 2004; Calder, 2007).

In this paper, we present a historical assessment of flood management policies in China and Japan, and explore the different characteristics of floods in the two countries. In addition, we provide case studies to identify advantages and disadvantages of policies with respect to historical, engineering and hydrologic dimensions of flood management. This study provides commentary to assist policy-makers and researchers in making flood management plans under the specter of future extreme events and climate change.

2. Methodology of the historical assessment

The detail methodology of the historical assessment in this study is presented in Fig. 1. We selected China and Japan as target study sites for the historical assessment of flood management policies. This study provides an overview of historical floods in these two countries. The hydrologic and geologic characteristics of China and Japan are compared with respect to their flood histories. This is followed by a historical review of the flood management policies of China and Japan. Some traditional flood management policies were selected for case studies in both countries. The case studies are used to assess the advantages and disadvantages of historical flood control policies with respect to historical, engineering and hydrologic dimensions of flood management. Finally, historical flood management policies are discussed given the modern context of extreme events and climate change. First, general history books for China and Japan were selected. Other historical documents such as books, drawings, newspaper

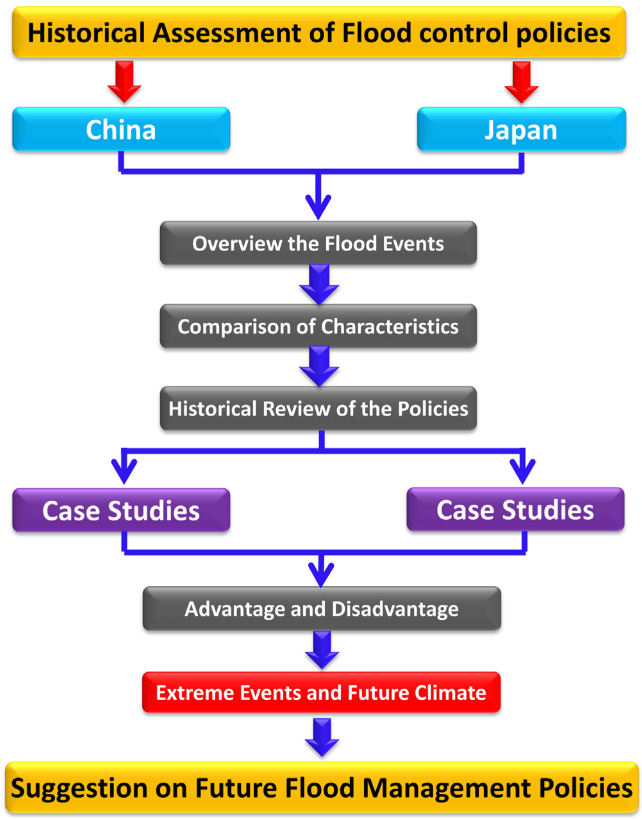

Fig. 1 – Process of the methodology for the historical assessment.

and pictures focused on Chinese and Japanese water management and flood control were selected and reviewed. Detailed information from the same period from different sources was compared and contrasted in order to extract reliable information on water management. Insights into best land management strategies and traditional flood management policies were obtained from the analysis. The description of the study regions has been introduced in the section 3 of flood events in China and Japan.

3. Flood events in China and Japan

Asia's population and rapid development make Asian cities uniquely vulnerable to catastrophic economic loss during flood events. In particular, the enormity of the economies of China and Japan make them susceptible to large effects from increasing risks of flood disasters. Despite 5000 years of Chinese flood management policy, floods remain an ever-present threat. The earliest recorded flood disaster in China occurred around 2000 BC. Recent urban floods have occurred in south China, especially Guangzhou city at the end of April 2010. This flood led to enormous economic loss, the displacement of 1 million people and the complete disruption of transportation and telecommunications. The three floods with the highest death tolls occurred in 1887, 1931, and 1938 during what is known as the black war period of China (Table 1). The death tolls from each of the three flood disasters were over 500,000 people. In the modern era, the death tolls of flood disasters have decreased, but economic loss has increased, and the main flooding area in China has shifted from the Yellow River basin to the Yangtze River basin as shown in Table 1.

Three main factors contributing to frequent flood disasters in China

(1) *Land use practice*. The Chinese environment and ecosystems have changed significantly through its long history. Agricultural area per person decreased from 0.7 ha during the Northern Song Dynasty to 0.2 ha during the later Qing Dynasty (China National Consultants Group, 2002). With continuous population growth, the farmland per person was less than 0.1 ha in 2000 (China National Consultants Group, 2002). These changes reflect the ongoing urbanization of historically agricultural areas. To make more farmland for food production, the areas of some big lakes such as Dongting Lake, Boyang Lake, Tai Lake, etc. were reduced remarkably. Forest area was reduced through urbanization and agricultural cultivation at the same time. The loss of water storage was one consequence of the land-use changes described above.

(2) *Human settlements*. Under economic development and population growth, people from villages moved into urban areas (Nie et al., 2012). Increasing urbanization caused an increase in impermeable land use types. At the same time, lake area and forest area were converted to urban zones and farmland was urbanized. Increasing impermeable surfaces caused increases in flood flow and earlier peak discharge. As a consequence, probability and severity of flood risks increased in urban areas.

Table 1 – Recent flood events in China and Japan (Luo et al., 2010).

China			Japan		
Flood event	Number of death (person)	Economic loss	Flood event	Number of death	Economic loss
1887 Yellow river	900,000–2,000,000	NA	1742 Inunomansui	2800	NA
1931 China	2,500,000–3,700,000	NA	1885 Yodo river	NA	NA
1935 Yangtze river	145,000	10.0 billion CNY	1910 Kantou	900	NA
1938 Yellow river	900,000–2,000,000	NA	1934 Muroto Typhoon	3066	NA
1954 Yangtze river	30,000	NA	1938 Hanshin	600	NA
1998 Yangtze river	3656	135.4 billion CNY	1959 Vera Typhoon	5098	NA
2010 China	3185	275 billion CNY	1982 Nagasaki	299	3000 billion (JPY)

(3) *Climate change*. The distribution of rainfall in China is quite uncertain. Spatial rainfall distribution decreases from the southeast to the northwest. Due to climate change, rainfall events have become more uncertain in recent decades. Despite the uncertainty, rainfall events have become shorter in duration and higher in intensity, leading to greater frequency of urban flash floods.

The heavy rainfall and the shorter and small river basin in Japan are the main factors effected on flood disaster compared with the case in China (Nakagawa et al., 1996). Konkoku floods, the oldest recorded flood events in Japan, occurred around the middle of the 7th century. Disastrous flood events happened essentially annually during the rainy periodfrom 623 and 741 A.D. Floods threatened Kyoto and destroyed the Barada bank in 750 A.D. Economically catastropic floods also occurred in Kinugawa and Aratamakawa in 758 AD and 761 AD. The 772 AD Yodo river flood caused the Barada bank to break again. During 796 to 1530 A.D., more than 48 floods occurred in the Kyoto area, including 19 in Kinki following a long period of rain. Enormous mortality and destruction resulted from floods in years 858, 1231, 1486, and 1530 A.D. Japanese floods frequency increased after 1530 with the 1542 Kamanashikawa flood, 1604 Kantou flood, 1610 Toukaidou flood, 1624 Tonekawa, Arakawa, Chikumakawa flood, 1650 Kyushu Kinki Toukaidou flood, 1681 Takamatsu flood and the 1694 Fujikawa Chikumakawa flood. More than 100 Kunkoku floods occurred between 1530, the largest of which killed more than 10,000 people. The 1742 Inunomansui flood disaster (see Table 1) killed 2800 people. The Muroto Typhoon of 1934 and the Vera Typhoon of 1959 led to major floods and killed more than 3000. The Tokai Flood in 2000 caused 10 fatalities and 115 injuries. The Niigata-Fukushima Flood on 13 July 2004 resulted in 16 dead or missing victims (Zhai and Ikeda, 2008). More recent floods have two emerging characteristics; they occur during large typhoons with intense rainfall falling over a large area and; damage per flooded area has increased (Luo et al., 2010). Flood management efforts have reduced urban flood inundation but development density due to rapid economic growth has led to increased damage density.

There are three factors that lead to frequent flood disasters in Japan.

(1) *Steep elevation*. Japan's topography is characterized by relatively narrow islands with steep mountain ridges running down the center making the rivers short and steep in elevation.
(2) *High precipitation intensity*. The mean rainfall in Japan is approximately 1700 mm – well above the world average of 970 mm (Inoue, 2007).
(3) *Large, swift floods*. Because river basin areas are small, the rivers are short and steep, and precipitation is high, floods in Japan start and end comparatively quickly (Inoue, 2007). Flood intensity in Japan is much higher than the world average flood discharge per unit area.

4. Historical overview of flood management policies in China and Japan

Governments and researchers in China and Japan have continually worked to improve flood management policies from ancient times to present. We found that flood management technology and policies improved dramatically during periods in which governments attached importance to review flood management history. The following is a brief overview of the flood management history of China and Japan.

4.1. *History of flood management policies in China*

Flood management history in China began with DaYu and his father Gun about 4000 years ago (Fig. 2). Active during one of China's great floods, DaYu was assigned by King Shun and was successful in achieving flood management by dredging channels instead of building levees, as had been done by his father (Gu, 2006). China's history is marked by leadership that attached importance to flood management, development of flood prevention technology and education of flood management specialists. The early Chinese politician Guan Zhong (725 BC–645 BC) advised good leaders to focus on

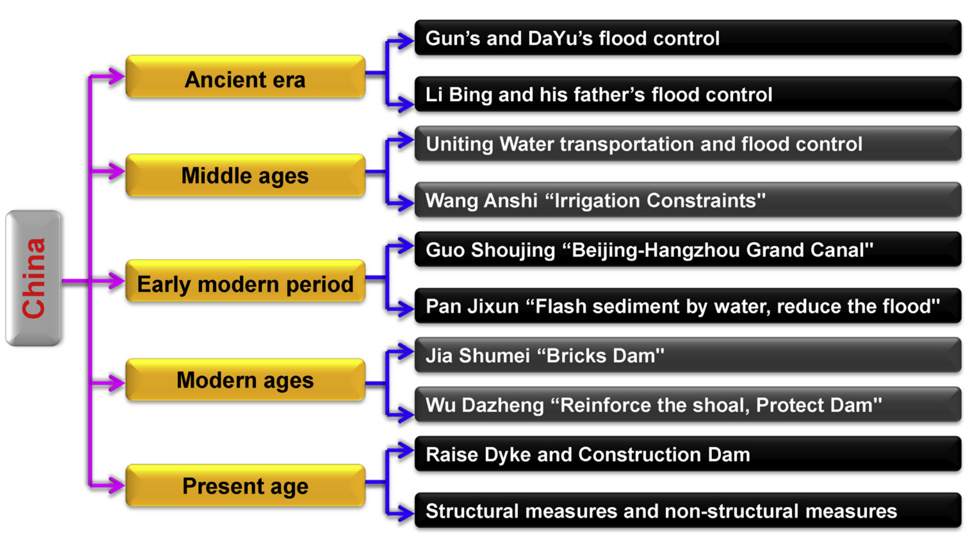

Fig. 2 – Development history of flood management policies in China.

elimination of the five great disasters (flood, drought, wind/fog/hail/frost, plagues, pests). Of the five disasters, he viewed floods as most important and he speculated that, if the five disasters could be eliminated, the people could be governed (China National Consultants Group, 2002). He encouraged the king of Qi country to pay attention to floods and created many theories according to environmental principles (e.g. ''For the character of water, lead it from high to low'') (Gu, 2006). Sun Shuao (630 BC–593 BC) in Chu country was an advocate for agricultural water supply which was achieved by building new channels and the artificial lake Quebei in order to reduce discharge for the flood season. The 12 Division Channels from Zhang river were constructed by Ximen Bao (445 BC–396 BC) (Gu, 2006), a Chinese government minister and court advisor to Marquis Wen of Wei Country during the Warring States period. Qin Shi Huang, the leader of Qin Country, created the Qin Dynasty by unifying the six countries in 221 BC. He believed that the development of agriculture, achieved through water supply and flood management, could lead the country to prosperity and power.

The Dujiangyan Irrigation System (Fig. 2), which remains in use after 2000 years, was designed and constructed by famous flood managers Li Bing and his father. ''In the one side to take water for irrigation, in another side to transport sediment for flood management'' reflects part of Li Bing's flood management theory applied in the Dujiangyan Irrigation System (Fig. 4). The flood management policy aimed to divide the stream flow to reduce flood risk and to irrigate fields (Zhao and Zhou, 2005).

Zheng Guo, a hydraulic engineer born at the end of the Warring States period was assigned by Qin Shi Huang to build Zhengguo Canal north of Xian, Shangxi Province at the end of the Han dynasty.Under the super vision of Emperor Wu of Han (156 BC–87 BC), flood management and irrigation greatly expanded and several specialists emerged including Zheng Danshi, Zhuang Xiong, Shima Qian and Bai Gong. These specialists oversaw the construction of Cao Canal, Longshou Canal, Liupu Canal and Bai Canal. Cao Canal was constructed in the middle ages and combined food transportation, flood prevention, and irrigation (Fig. 2) in a single engineered structure for the first time. Gates/weirs (''Flash-lock gate or Over-flow weir'' method) were added to the Junyi Canal by Wang Jing to regulate the flow of water and allow free passage on the waterway at the end of the Eastern Han Dynasty (Needham and Ronan, 1995).

During the Tang Dynasty, Jiang Shidu became famous for flood management efforts. Among other things, he reopened the Pinglu Canal at Hebei province in 705AD and dug drains that were used to divide floods in Shangxi province in 714AD. Rapid agricultural development and the requirement that officers have flood management expertise was achieved by the Tang Dynasty through an irrigation law called Shuibushi (The Laws by the Water Conservancy Department) (Gu, 2006). This irrigation law includes management and repair of field irrigation systems, channels and levees.

Partly because of its economic might, the Song Dynasty also focused on flood management. Fan Zhongyan was a Song dynasty flood management specialist who's projects included Fangongdi, a levees designed to prevent floods from the sea, and water management of Lake Tai in Jiangshu province. Su Shi, one of the Eight Great Men of Letters of the Tang and Song Dynasties focused on urban floods and lake management. His Sudi levees were built to prevent urban floods at Xuzhou and to promote lake management around Xihu Lake. Wang Anshi published a complete law on irrigation and water conservation (Irrigation Constraints) under the Song government in 1069AD. Irrigation Constraints encourages officers to develop irrigation and support water conservation, to improve the condition of abandoned land, and to develop plans repair and maintenance plans for irrigation systems.

The Grand Canal, also known as the Beijing-Hangzhou Grand Canal, is the longest artificial river in the world. The oldest part dates back to the 5th century BC, although the various sections were finally combined during the Sui

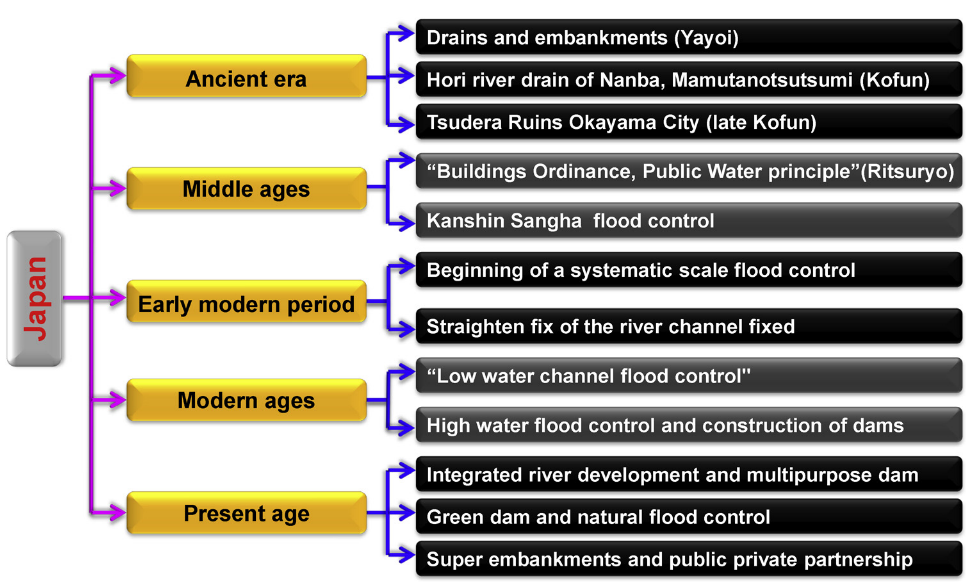

Fig. 3 – Development history of flood management policies in Japan.

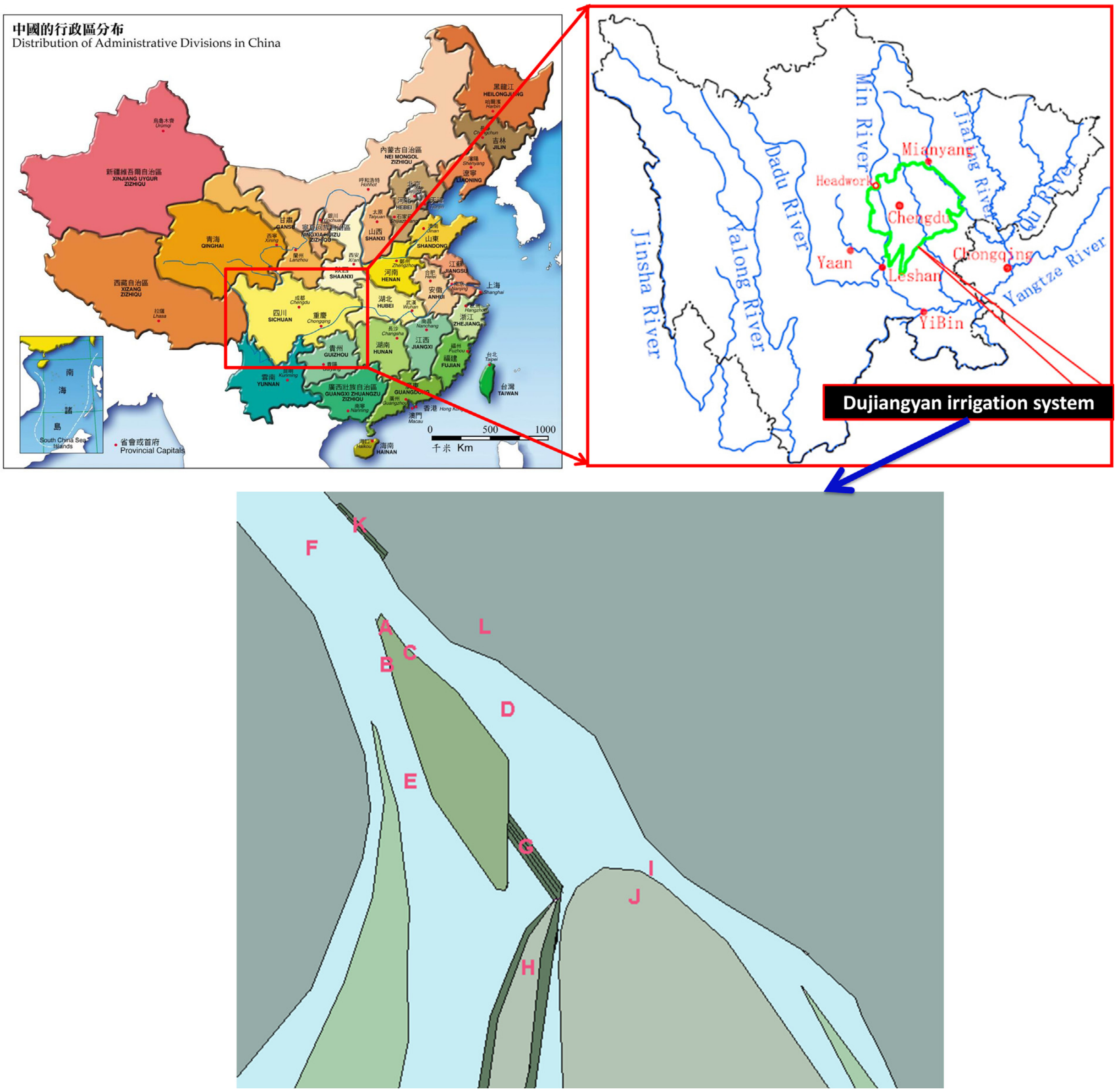

Fig. 4 – Location and structure of Dujiangyan irrigation system (Cao et al., 2010; PTTC, 2013). A: Fish Mouth, B: Outer River Dike (Jingang Dike), C: Inner River Dike (Jingang Dike), D: Inner River, E: Outer River, F: Mingjiang River, G: Feishayan (Drainage Dam), H: Renzi Levee, I: Bottle-Neck Mouth, J: Lidui Park, K: Baizhang Levee (Dike), L: Erwang Temple.

Dynasty. It starts at Beijing, winds through Tianjing, Hebei, Shangdong, Jiangshu and Zhejiang to Hangzhou city. The canal was essential to connect Beijing and Hangzhou because the capital moved to Beijing during the Yuan Dynasty. From Yuan Dynasty era, canals were built to combine flood prevention, irrigation and transportation. The Beijing-Hangzhou Grand Canal from Shangdong to Beijing and improved technology for flood management were implemented by Guo Shoujing. During the Ming Dynasty at the time of the Beijing-Hangzhou Grand Canal's construction, a farmer and irrigation specialist named Bai Ying suggested the construction of the Gangchengba Dam and Daichunba Dam to maintain sufficient water levels for boat transportation. Pan Jixun's flood management strategy for the Yellow River sought to use water to promote sediment transport in the river bed in order to enhance the water storage capacity of the river channel (Zhou, 1996). Xu Guangqi (1562–1633) created the "paddy field water conservancy system" theory (paddy fields and reservoirs upstream could be used for water storage and flood risk reduction) for flood management and irrigation.

During the Qing Dynasty, Emperor Kangxi and Qianlong thought flood management and irrigation were the most important policy issues facing the country. From 1840 to 1900, Jia Shumei introduced methods for building levees using concrete and bricks in order to reduce the risk of breakage and Wu Dazheng introduced policies to reinforce river beaches by constructing masonry levees to protect the structures from scour (Zhao and Zhou, 2005; Cao, 2004). Before 1949, flood management efforts almost stopped as China was embroiled in war. After the establishment of the People's Republic of

China in 1949, flood management efforts depended on civil engineers to raise levees and construct dams (Ross, 1983).

Following the 1998 Yangtze River Flood, the government realized that current flood management policy depended on structures that were inadequate to reduce death and damage during flood disasters (Wan, 2013b). The new flood management policies combined structural solutions with non-structural measures. These policies were published by the Chinese government to adapt to future floods. New structural solutions included construction of the Three Gorges Dam. Non-structural measures were divided into four parts: changing land use, welfare law, moving people away from vulnerable areas and environmental protection. Land use change includes changing agricultural land to lakes, agriculture land to forests and urban land to lakes.

4.2. *History of flood management policies in Japan*

Analysis of the remains of drains and embankments indicates that flood management in Japan began in the Yayoi period (300 BC–300 AD). Flood management efforts really started during the Kofun period (250 AD–538 AD). The Horie canal at Nanba was excavated to drain floodwaters from Kawauchi Lake to Kawauchi bay and the Mamutanotsudumi bank was constructed by Emperor Nintoku to control floods from the Yodo River. The Mamutanotsudumi bank is located near Furukawabashi station of the Keihan Electric Railway. The Tsu temple ruins in Okayama city represent the flood management technology of this period. During the early part of the 8th century, the Nara era government set up by the Ritsuryo-sei (historical law system based on Confucianism and Chinese Legalism in Japan) started to focus on flood management. Under the Ritsuryo-sei, Kokushi and Kunji, officers were assigned to manage river irrigation and flood prevention. Although flood management efforts were effective, the deterioration of the power of Ritsuryo-sei led to declining project scale for drainage and reservoir storage. For example, Mannouike reservoir was built by Kukai, a private citizen and famous Buddhist teacher who studied in China about mainly Buddhism and also scientific knowledge and skills (Musiake and Koike, 2009).

Systematic flood management returned during the Sengoku period (1467 AD–1573 AD). Ruins of the Bunroku bank on the Yodo River constructed by Hideyoshi Toyotomi and the Shingen bank built by Shingen Takeda still remain. The technology of ring levees first appeared at the Kisosansen River from the 13th century.

Entering the Edo period, large-scale flood management technology developed quickly. Famous flood management efforts in the Edo period altered river channels (rapids substitution). River substitution started at Yahagi River from 1605, and was also done at the Tone River during the 17th century. Hourekichisui flood management activities changed the Kisosansen river channels in the middle of the 18th century. By the end of the Edo period, straightening of river channels and setting up flood plains instead of reservoirs was routinely done for flood management (Fig. 3).

In the Meiji period, the new government employed flood management specialists from Europe and other developed countries. Flood management in early modern times can best be represented by the ''Low water flood management'' measures of the Netherlands based on securing flow quantity using spur levees in river channels and dredging the river beds (Fig. 3). ''Low water flood management'' alone proved insufficient to prevent floods. In 1896, Kasen Law was implemented, establishing the principle that directs flood flow to the sea as soon as possible. After that, ''high water flood management'' designed to straighten river channels and build high banks became the dominant flood management measure (Takeuchi, 2002).

In the Showa period, the economy developed quickly. Under the influence of the U.S., flood management was achieved through the integration of rivers and the construction of multipurpose dams. After World War II, large flood disasters began to be considered with reference to typhoons (Musiake and Koike, 2009). In the 1980s, dam construction added environmental benefits to the list of purposes fulfilled by flood management projects (Takahasi, 2011). The Green Dam concept, which depends on forest and grass to control floods, also emerged as an important topic. From the 1990s, natural flood management and some issues outside of flood management and irrigation became important parts of flood management policy (Fig. 3). Meanwhile, floods increasingly threatened densely populated urban areas.

5. Case-study of flood management policies in China and Japan

5.1. *Gun and DaYu flood management policy*

Gun focused on levee construction to control floods, but the floods were so extreme, high water levels ultimately overwhelmed the levees. Although the utility of levees in modern times is clear, levees in that period failed to control floods. DaYu built new channels rather than levees in an effort to lead water to the sea. The new channels were able to reduce the water level and irrigate fields.

5.2. *Dujiangyan irrigation system*

The Dujiangyan irrigation system is discussed specifically here due to its long history and multi-dimensional approach to flood management that includes historical, engineering and hydrological aspects of flood control. Dujiangyan, located in the Min River, Sichuan Province, China, is a combined flood management and irrigation system built in 256 BC during the Warring States Period of China by the Kingdom of Qin (Cao et al., 2010). It is still in use today and irrigates over 5300 square kilometers of land in the region.

The Dujiangyan irrigation system consists of the following three main components:

(1) The main part of this system is Yuzui or Fish Mouth, shown as ''A'' in Fig. 4. It is named for its conical head that is said to resemble the mouth of a fish. It is an important structure that divides the water into inner and outer streams. The division for the inner stream is normally 40–60% of flow during floods. The inner stream carries the river's flow into

the irrigation system, and the outer stream drains the rest, flushing out much of the silt and sediment.

(2) Feishayan or Flying Sand Weir shown as ''G'' in Fig. 4 is about 200 m wide and is designed to direct the water from the inner stream to the outer stream. This component cleans water by drawing out the large sediment to reduce the water level and also ensures against flooding by allowing the flow of the water to drain from the inner to the outer stream. Li Bing's original weighted bamboo baskets have been replaced with modern reinforced concrete weirs.

(3) Baopingkou or Bottle-Neck Mouth, shown as ''I'' in Fig. 4, is the final and main part of this system. It conveys clean water to the irrigation channel and works as a check gate, creating whirlpool flow that carries away excess water over Flying Sand Weir or the narrow entrance near Bottle-Neck Mouth between Lidui Park (J) and Renzi Levee (H) (Fig. 4) to ensure against flooding.

Li Bing and his father's flood management vision is depended on to dredging of the inner river bed deeply to maintain irrigation water storage, while building Flying Sand Weir (G in Fig. 4) to reduce flood risk (''keep the weirs low and the sluices deep'') (Cao et al., 2010). Several strategies can be identified from this system and Li Bing's flood management thought:

(1) *Short and long-term strategy*. This system prevents flood disasters in the short-term, although regular repairs are required for it to work in the long term. System maintenance is based on Li Bing's: ''Every year the system needs a small repair, every five years need a big repair.'' This simple rule helped maintain system effectiveness for the long term.

(2) *Combination of flood management and irrigation*. Fish Mouth works to ''Divide the flow to reduce the flood, draw the water to irrigate the farmland''. Bottle-Neck Mouth is an important component that combines flood management and irrigation. Lidui Park (J) was connected with Bottle-Neck Mouth (I) by a mountain. This mountain restricts the flood waters from flowing. The mountain was cut to draw water for irrigation at Bottle-Neck Mouth. Bottle-Neck Mouth has a mark for controlling the water to prevent flooding during flood season and maintaining water supply for agricultural use.

(3) *Co-ordination of each part with the whole*. Flying Sand Weir can break so that water can flow to the outer stream to protect the whole area from flooding. The headwork structure of ancient Dujiangyan is recognized as a non-dam intake structure. However, historic records show that the division and intake structure actually formed a check-gate dam division system. A temporary low dam and embankment by local natural material (wood-tripods with bamboo-cages) were constructed in ancient times, and used continually in each year's repair until 1974. Bamboo-cages are long sausage-shaped baskets of woven bamboo filled with stones used as a temporary dam under the support of wood-tripods. The structure of bamboo-cages with wooden-tripods is simple and cheap but effective and has been used for over 2000 years. The new construction of the check-gate at the outer stream (Fig. 4B) maintains the river regime of hydraulic head. The new structure also improves water diversion and sediment exclusion for this irrigation system.

Three aspects of the Dujiangyan irrigation system are informative for flood management: (1) continuous, systemic short- and long-term maintenance; (2) multi-purpose structure for irrigation and flood management; (3) integrated components with engineering and hydrological aspects.

5.3. *Structural measures and non-structural measure for flood management after 1998*

Since 1998, the Chinese government has focused on large flood disasters on the Yangtze River because of the notable human populations. Flood management policies have developed to include structural measures and non-structural measures (Wan, 2013a).

5.3.1. *Structural measures*

Both Sun Yat-sen during the period of Nationalist China and Mao Zedong after the founding of the People's republic of china discussed the construction of the Three Gorges Dam in Yichang city, Hubei Province. There has been a great deal of concern about environmental change after the construction of the Three Gorges Dam. The Three Gorges Dam was approved as one of the post-1998 structural measures as the project had apositive benefit-cost ratio. The devastating floods in 1998 showed that reinforcing levees and regulating river courses are important actions to raise flood management capacity. Reinforcing stem levees, constructing high-standard levees and dredging river beds are therefore included in structural measure policy.

5.3.2. *Non-structural measures*

Because of frequent and increasingly expensive floods, the government recognized the need for broader flood management policy. After the 1998 flood, non-structural measures were taken to prevent floods and reduce damage. Non-structural measures include land use planning, welfare rules, moving people out of vulnerable areas and protecting the environment.

Changing land use includes changing agricultural fields to forests and agriculture fields to lakes, and urban areas to forests or lakes. One major reason for frequent water disasters in China is the legacy of serious environmental destruction. Dongting and Poyang Lake in the Yangtze River basin experience increasing sedimentation the majority of which (over 60%) originates in the cultivated hill-slopes in the river's upper and middle reaches. Ecological restoration is necessary in these reaches of the Yangtze to conserve both soil and water quality. Reforestation of farmland, tree-planting and instituting hill-slope stability technology are just some examples of approaches that could reduce the problem. The construction of ring levees to use the important reservoirs Dongting and Poyang Lakes for farmland led to a 40% or more reduction in lake area between 1949 and 1998. As a consequence, these reservoirs lost most of their storage and release function. Recent acknowledgement of the flood management function of these lakes has led to some re-conversion of agricultural area into lake area to reduce floods.

The Welfare rule provided money and equipment for flood victims. Moving people out of vulnerable areas required relocating people who lived in vulnerable zones. The government supplied money and houses for resettled people. Most of these people were living in vulnerable lake areas. This effort has increased the surface area of lakes and reduced economic and social vulnerability for flood events.

Finally, environmental concerns and climate change impacts on flood frequency and severity were considered. Flood management policies need to consider management of extreme events and urban area floods under land-use and climate change (Petersen, 2009) with important implications for flood insurers.

5.4. *Straightened river channels*

Naturally winding river channels change every year. Floods passing through winding rivers propagate more slowly than through straight river channels (Nakamura et al., 2004). Due to the steep elevation of Japanese geography, and the high precipitation intensity described in section 2, floods propagate quickly in these rivers. These hydrologic characteristics of Japan suggested river straightening as a technology to route flow quickly from upstream to prevent floods and reduce sedimentation (Nakamura et al., 2006). However, this method does not provide water storage during dry seasons or droughts. Straightened river channels destroyed ecosystems, river scenery and the natural environment. From the 1980s, protection of riverine systems became an important topic. In 1995, the Japanese Ministry of Construction's River Council proposed a policy on the future of river environment to protect biological diversity and scenic landscapes (Takahasi and Uitto, 2004).

5.5. *High water level plan and flood management*

Maximum water level in each river is identified according to historical records and levee height is determined based on maximum water level (Takeuchi, 2002). Although levees can be effective for flood prevention, levee height must be raised again and again as sediment accumulates in river beds. This approach can be enhanced by combining it with dredging and considering dynamic process such as climate and land-use change.

5.6. *Forestry flood management methods*

As popular support for dam construction collapsed in the 1980s, 'Green dams' (forestry) became a popular option for flood management. Takara et al. (2004) reported that green dams have eight important functions, including ecosystem services, nutrient cycling, earth environmental improvement, flood management, irrigation, local environmental improvement, recreation and production. There is some evidence that the flood management function of green dams can relieve floods in the short-term, but if rainfall continues for more than one week, their effectiveness is limited (Calder, 2007).

5.7. *Super embankments*

In 1987, the Japanese Ministry of Construction's River Council proposed Protection Policies for Extreme Floods for urban areas (Takahasi and Uitto, 2004). These policies were proposed to raise the level of flood preparedness. One proposed method is the super embankment, a practical measure for managing urban floods. Super embankments complement general embankments, which are on the order of 20–50 m in width, with houses and buildings 10–50 m lower than the general embankments (Fig. 5). If general embankments fail during a flood, surrounding houses and buildings which are lower than the general embankments will be inundated. Super embankments (200–300 m wide) raise the ground level around the river to the same level with the top of embankments (Kundzewicz and Takeuchi, 1999). New urban areas including commercial and residential construction are developed on super embankments. Trees and grasses are planted to improve the river environment and gently sloping revetments are constructed (Knight and Shamseldin, 2005). Super embankment projects were carried out at the six largest rivers in Tokyo and Osaka, including the Tone River, Edo River, Ara River, Tama River, Yodo River and Yamato River. Super embankments can provide very strong and safe levees for flood prevention. Construction of super embankments with raised ground level around rivers protects urban areas with property and important business functions from flood inundation. The construction of super embankments is also leading to new urban development by reducing embankment failures and the inundation risk to commercial and residential areas. However, the construction of super embankments is very costly, requiring cooperation between local planning offices and people as well as a lot of time for moving commercial and residential structures.

5.8. *Public private partnership*

Review of historical documents suggest that before 1986, flood control measures were usually thought of in the context of government response, and the public sector (government) is expected to execute structural flood control measures (e.g. embankments, dams) (Takahasi, 2004). However, public sector projects did not protect completely against large-scale flooding. Indeed, it is not possible to control flooding using outdated methods. In areas without public sector protection, people gather together to fight floods with local knowledge and experiences in flood characteristics and control. There is a basic public-private partnership which exists in flood management. By about 1930, the Japanese government has already completed structural flood control measures such as the construction of a high, continuous embankment system as well as maintenance activities like river broadening and dredging (Yoshimura et al., 2005). A lot of dams for water storage and flood risk reduction were constructed during the rapid economic growth between the 1950s and the 1970s. Continuous construction activities around rivers destroyed riparian landscapes and river ecosystems (Takahasi, 2004). Public opinion has since turned against construction of dams and embankments because structural flood control measures have destroyed so much of the riparian environment

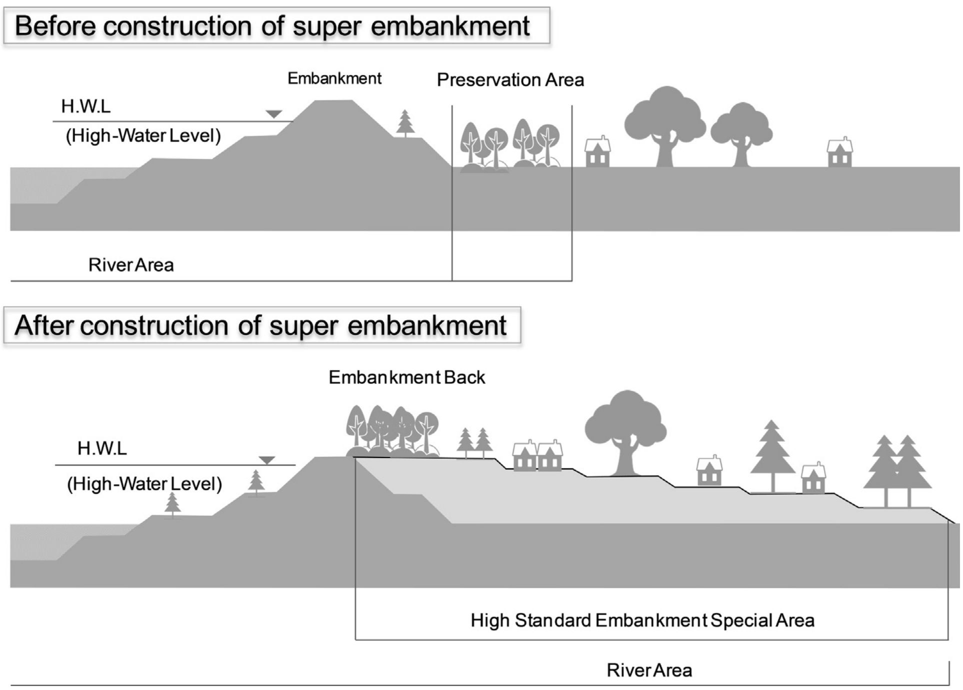

Fig. 5 – The structure of before and after construction of super embankment.

(Yoshimura et al., 2005). Meanwhile, so-called 'hard' flood control measures such as levees and dams have been shown to be insufficient to completely stop flood damage. These measures need complimentary 'soft' flood measures including the suggestions of scientists and researchers and the general public's knowledge and experience in protecting against flood damage. In the River Act revision of 1997 (Takahasi, 2004), the Japanese government recognizes that environmental problems are important and public support is necessary to implement flood control measures that also preserve riparian environments. Modern approaches to developing and managing riverine systems require public-private partnership.

6. Discussion on the future flood management policies

In examining the history of flood management in China and Japan, trends emerged, including structural approaches to flood management in the modern age, the recent transformation from strictly structural approaches to an approach that combines both the structural approaches and non-structural approaches. However, flood characteristics in China and Japan are quite different and these differences have historically which lead to some different flood management policies. For example, high precipitation intensity in Japan and consequent flash floods led water resource managers to focus on straightening river channels. In China, the complex needs of the area surrounding the Dujiangyan Irrigation System led to the development of a multi-purpose non-dam intake structure. More recently, Green dams have been shown to be a useful flood management method in Japan because the forest comprises around 80% of the total surface area of Japan. Development of effective flood management policies in the future will require consideration of both historical flood management policies and considering the future climate conditions.

The methods chosen for flood risk assessment directly affect determination of flood management policies under future conditions. Many approaches have been developed and used for flood risk assessment. A hierarchical structure has been developed for flood risk analysis, and relative flood risk has been mapped using geographic information systems in central Taiwan (Chen et al., 2011). Previous studies defined flood risk due to broken levees or failure of storm water drainage and developed flood maps to provide information to guide land-use planning as well as evacuation. The accuracy of flood risk analysis depends on uncertainties in understanding of system hydrology and most current research focuses on flood forecast errors. An integrated risk analysis model was developed considering the many uncertainties in reservoir routing such as stage-storage uncertainty, time-delay uncertainty, etc. (Diao and Wang, 2010). A robust flood risk assessment relies on local and expert knowledge. Stakeholder information as well as administrative and regulatory conditions hold great importance in flood risk assessment (Scheuer et al., 2013). Uncertainties in different characteristics of the hydrologic, climatic and environmental conditions in China and Japan need to be considered in the context of local stakeholder information and administrative regulatory conditions.

Traditional flood management policy (higher and stronger levees) in the Netherlands has been shown to be the most cost-effective option to protect a very densely populated and economically important area (Brouwer and Van Ek, 2004a). However, investments in land-use change and flood plain restoration can be justified economically in the long-term, if the expected value of the benefits is taken into account, including damage avoided as well as non-market socio-economic benefits such as public safety, wildlife habitat, recreation, etc. (Brouwer and van Ek, 2004b). European approaches for the control of floodplain encroachment vary from 'coercive,' emphasizing strong central government intervention as in France, to 'cooperative,' with power concentrated in democratically elected local authorities in England and Wales (Pottier et al., 2005). The construction of super embankments is another good combined approach for flood control, protecting important residential and commercial areas through redevelopment of the urban flood-prone area around river banks (Kundzewicz and Takeuchi, 1999). Super embankments, though perhaps appropriate for mega cities, are quite expensive and likely unfeasible for most flood-prone areas.

In our case study, "Changing land use" includes changing agricultural fields to forests and agriculture fields to lakes, and urban areas to forests or lakes. It is difficult to change urban areas to forests or lakes due to resistance from urban populations and lack of political will. Super-levees remain an effective option to protect densely populated and economically important cities in Japan from floods. The Dujiangyan Irrigation System is extremely important for flash flood prevention and irrigation under extreme events. Real-time operations using the balanced water level index method (Wei and Hsu, 2008) are suggested in combination with computer simulations of flood scheduling in large scale flood management systems (Wan et al., 2012). Land use change has the significant impact on the river discharge under the reconstructed historical land use (Luo et al., 2013b). The response of river systems to environmental change which including the climate and land use has been modeled and compared with the palaeo-environmental reconstructions (Van De Wiel et al., 2011). The environmental change specially land use change and climate change has taken the most impact on flood disaster. It is necessary to make the balance between the urban development and environment protection such as the case study of "Changing land use" and the Dujiangyan Irrigation System for the future sustainability society.

Nonstructural approaches, natural approaches and other 'soft' flood management strategies, including protection of forests in upper stream reaches and floodplain protection/restoration in downstream reaches can reduce and delay peak discharge. Cooperation between national and local authorities is another important dimension of sound flood management policy. Urban flood management requires new flood management approaches, such as those implemented in Japan: Storing Flood Water in the Retention Basin Protects the Urban Area, Underground River Reduces Flood Water Damage in the Watershed, and Dissemination of River Information by Mobile Browser Phones. Recent integrated flood risk management in urban area follows the stages of a management cycle, through preparedness, readiness, response and recovery/rehabilitation (Tingsanchali, 2012). The other 'soft' approaches include disaster prevention education, public private partnership, etc. Disaster prevention education can help people avoid flood related injury and death. Based on a multi country comparison of data from questionnaires conducted in Japan and the U.S., respondents with disaster education were shown to be better prepared than respondents without disaster education (Tanaka, 2005). Public private partnerships as well as government flood control activities provide security for reducing death and economic loss due to disasters (Linnerooth-Bayer and Mechler, 2007). Recent research has led to new flood management strategies, such as Storing Flood Water in Retention Basins to Protect Urban Areas, Underground River Reduces Flood Water Damage in the Watershed, and Dissemination of River Information by Mobile Browser Phones (JEIC, 2009).

The recent trend of research has been focused on mega-floods and glacier lake outburst floods (GLOFs). Through studying freshwater mega-flood sedimentation, it can improve estimates of flood hydrograph behavior and provide better understanding of the controlling hydraulics and models of flood deposition (Carling, 2013). The glacier lake outburst floods (GLOFs) have been studied the effect of climate change which provide a long-term perspective on GLOFs hazard potential (Benn et al., 2012). The future flood management policies should take the information from the analysis of freshwater mega-flood sedimentation and GLOFs for the flood under the extreme events and climate change.

Despite differences in geography, hydrology and history, flood management in China and Japan has developed as a result of communication and collaboration. Flood control activities in China date back five thousand years. Structural flood control methods such as dykes and canals were delivered to Japan through cultural communication. Through the historical review of flood management, we find that the communication of culture with respect to flood management in China and Japan continues today and with more frequency in recent decades. China is a developing country with rapid urbanization and deforestation. The on-going deforestation in China has led to serious flood management problems, which makes the Chinese government rethink the urban development plan and land use plan in place at the time of the devastating 1998 flood. The Chinese government obtained useful experience in flood management related to reforestation (Green Dam), multi-purpose dam construction, modern monitoring technology, etc. from Japan and other countries.

Results from a number of different scenarios provide information about expected flood frequencies and magnitudes (extent, depth, duration and flow velocities) and can be used to create flood risk maps for readiness. River overbank flow in cities is not an isolated phenomenon. Comprehensive and coordinated approaches to flood risk management can help develop a common understanding of flood risk issues among all stakeholders. Comprehensive and coordinated approaches to flood management are necessary in both Japan and China, especially as extreme events become more frequent due to climate and land-use change.

7. Conclusions

We review flood disasters in China and Japan and identify characteristics of floods and flood management in these two countries. A historical overview of flood management policies in the two countries reveals some effective historical measures such as multipurpose flood management structures and green dams which remain effective methods for managing flood risk. Similarities between Japan and China are shown in the overview of flood management policies, which is expected because of historically close contact and communication between the two countries. Some multi-purpose flood management structures such as the Dujiangyan Irrigation System play an important role in flood management as well as environmental protection and agricultural development. Assessing flood risk in China and Japan requires consideration of differences in hydrology in addition to differences in the climate and environment of the two countries and likely future conditions under climate change. China requires coordinated flood communication systems and citizen education. In Japan, co-ordination of flood management measures is necessary for successful reduction of flood risk. For both China and Japan, it is necessary to work with traditional flood management measures (building higher and stronger levees and multi-purpose flood management structures) in the short-term and to invest in non-structural measures (e.g. changing land use policies and flood plain restoration) for the long-term, while promoting cooperation between federal government and local authorities.

Acknowledgments

This study was supported by the project of "Water and Urban Initiative" at the United Nations University – Institute for the Advanced Study of Sustainability (UNU-IAS), the Japan Institute of Country-ology and Engineering (JICE) Grant Number 13003, Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research (A) Grant Number 24248041. "One Hundred Talents Program" of Chinese Academy of Sciences, National Natural Science Foundation of China (No. 41471460), and the Asia-Pacific Network for Global Change Research (APN) CAF2014-RR06(ARCP)-NMY-Wang.

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