Research on the Flood Control Problems of Cultural Heritage in Southwest of China -A Case Study on the World Heritage Site Dujiangyan-

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In recent years, frequent flood disasters happened in southwest of China have a great threat to the cultural heritages. This paper takes the world heritage site Dujiangyan as the example, analyzes reasons of floods destroying cultural heritages in southwest of China and discusses the related issues of flood control. Results show that natural environmental changes, impact of modern construction and lacking public participation are main reasons of cultural heritages destroyed severely by floods. And then lack of traditional flood control methods and unsound modern flood risk management system are also reasons for the flood disaster.

Keywords: *world heritage sites, Dujiangyan irrigation system, flood disaster, disaster prevention*

1. Introduction

Southwest of China where gathers lots of cultural heritages accounts for 25 percent of the national territory, including the municipality of Chongqing, the province of Sichuan, Yunnan, Guizhou and the Tibet Autonomous Region. As of July 2015, there are 48 Chinese heritage sites in the List of World Heritage Sites, and there are 13 world heritage sites distributed in the southwest of China, which accounts for 27 percent of the total in China, including four cultural heritages, seven natural heritages, one cultural and natural heritage and one cultural landscape heritage (Fig. 1). These are indispensable parts of Chinese cultural heritages and have important value to be protected.

By observing and analysis, cultural heritages are often built in accordance with the rivers, adding to the special topography and climate environment in southwest of China, which lead to frequent flood disaster such as rivers and mountain flood happened to cultural heritages. In July 2013, the heavy rain in Yunnan province had caused severe floods, leading to more than 600 houses collapsed. In 2010, most regions of

southwest China had suffered from floods, multiple cultural heritages were washed away. In September 2004, the heavy rain happened in east of Sichuan caused once-in-two-century flood which damaged the cultural heritages gravely.

Sichuan province located in the southwest of China has numerous cultural heritages, including lots of cultural relics protection units and the world heritages Dujiangyan Irrigation System and Mount Qingcheng, Mount Emei and Leshan Giant Buddha and so on. On the other hand, there also are many rivers in Sichuan province including Minjiang River, Tuojiang River, Jialingjiang River and Fujiang River. However, Dujiangyan, the world cultural heritage site, built by the Minjiang River, of which the total length is about 750 km, so there is a certain risk of flood. And as a water conservancy project, irrigating nearly 10.26 million mu of farmland, once the flood or floods caused by other natural disasters, it would have disastrous consequences on the irrigation system, surrounding historical buildings, the natural landscape, and even the whole Chengdu plain.

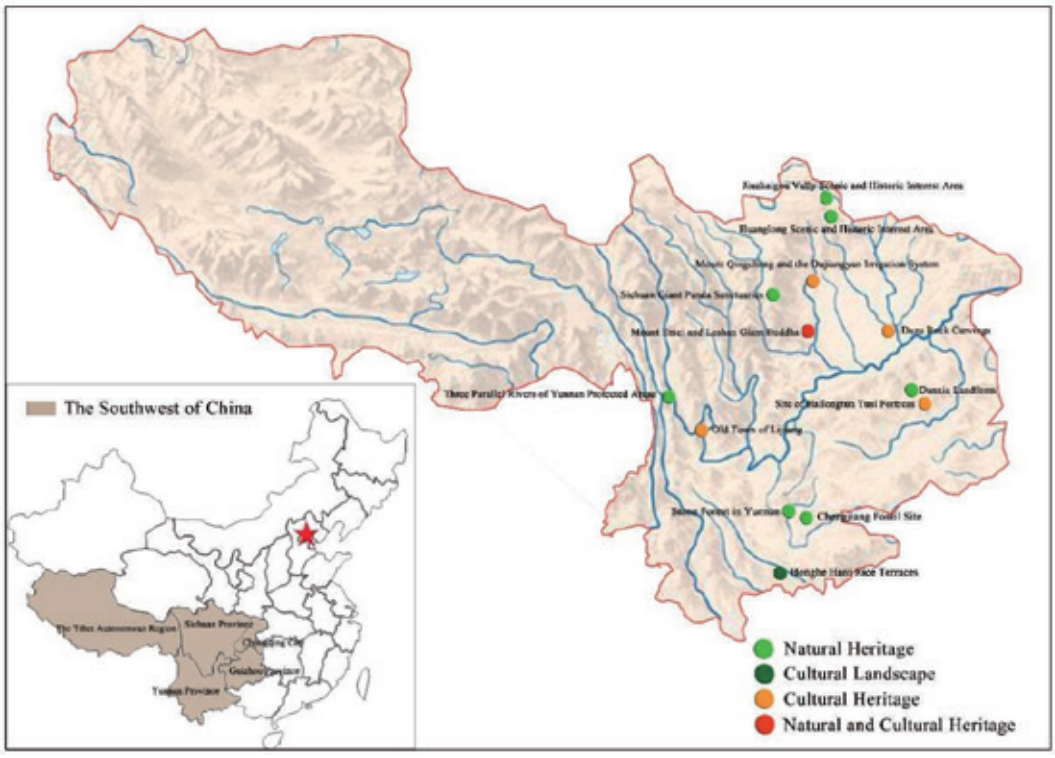

Fig. 1 World heritage sites and main streams distribution in southwest of China[1]

In summary, frequent flood disaster in southwest of China is a tremendous threat to the local cultural heritages in recent years. Analyzing of the flood control problems of cultural heritages in southwest China is of great significance and is also a difficult task in the process of cultural heritages protection. This paper takes the world heritage site Dujiangyan as the example, analyzes reasons of flood disasters which have destroyed the cultural heritages in southwest of China and discusses the related issues of the flood control. By doing this, we hope that we can save cultural heritages from the floods.

2. Overview of Dujiangyan

[1] Made by the authors

Dujiangyan is located in the central Sichuan province, northwest edge of the Chengdu plain (Fig. 2). And the world heritages site, Dujiangyan Irrigation System and Mount Qingcheng, is located in the West of Dujiangyan. Besides, the main body of the Dujiangyan project consists of three main constructions: Fish Mouth Levee, Flying Sand Weir and Bottle-Neck Channel (Fig. 3).

Fig. 2 Dujiangyan City's location in China[2]

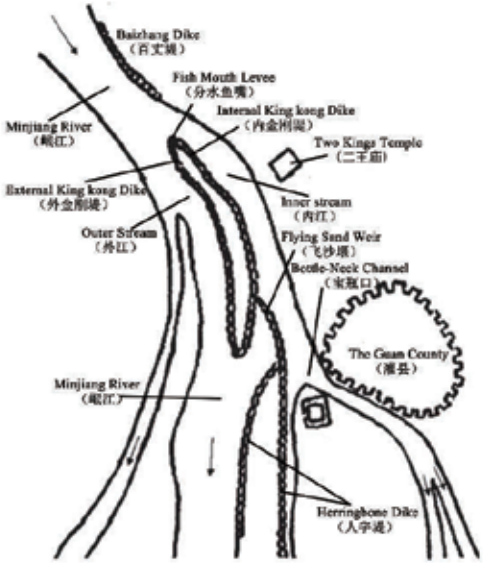

Fig. 3 Schematic diagram of Dujiangyan irrigation system[3]

Long development history of Dujiangyan has left us a Taoist Holy Place Mount Qingcheng, Dujiangyan Irrigation System, Anlan Suspension Bridge, Water Festival and other cultural heritages (Fig. 4). So far, The Dujiangyan Irrigation Project is the longest and is characterized by no dam diversion of grand project in the world (Fig. 5). Dujiangyan's natural environment is very beautiful, and the Dujiangyan scenic spot is compose of pivotal project, Lidui Park, Dragon-Taming Temple, Two Kings Temple.

Eventually, Dujiangyan Irrigation System was chosen by the State Council in 1982 as a Major Historical and Cultural Site Protected at the National Level, and Dujiangyan City was chosen by the State Council in 1994 as the National Famous Historical and Cultural City with its profound historical culture and beautiful natural environment. What's more, Dujiangyan Irrigation System-Mountain Qingcheng was selected by the United Nations as a world heritage site in 2000.

Fig. 4 The holy land of Taoism Mount Qingcheng[4]

Fig. 5 Dujaingyan water conservancy project[5]

[2] Made by the authors
[3] Made by the authors

3. Floods of Dujiangyan Irrigation System

(1) Typical flood events

As the world heritage site, Dujiangyan project is under tremendous threat of flood for a long time, causing great threat to the protection of cultural heritage (Tab. 1). There were twice typical floods that were the Wenchuan Earthquake and the Diexi Earthquake respectively (Tab. 2).

Tab. 1 Correlation table of floods happened in Dujiangyan project over the years[6]

Year	1943	1949	1964	1966	1977	1992
the maximum daily average flow rate（m^2/s）	3480	3260	3260	2870	3060	2840
Baizhang Dike		100m			120m	
Fish Mouth levee		Weighted bamboo baskets washed out	The spats washed out			
Kingkong Dike	Completely washed out	Stone ridge washed	153m		70m	
Two Kings Temple		Shun dam collapse	Shun dam washed out	Shun dam washed out		
Flying Sand Weir	Broke up	Broke up	80m		200m^2	
Herringbone Dike	Broke up	Broke up	40m			
Shaheihe Canal	The entrance washed out	Silted up	Silted up		Silted up	
The rests of the other dikes						18 dikes washed out

Fig.6 slight crevices on the Fish Mouth Levee[7]

Fig.7 Dujiangyan washed out after Diexi Earthquake[8]

Wenchuan Earthquake in 2008 caused flood crisis for the Dujiangyan project. Fortunately, although the

[4] http://travel.qunar.com/p-jq704547-qingchengshan
[5] http://www.chinareviewnews.com/doc/1006/4/4/8/100644858.html
[6] Made by the authors
[7] http://eblog.cersp.com/userlog27/193911/archives/2008/921884.shtml
[8] http://www.xhgmw.org/html/houyi/wangshi/2014/0716/5239_4.html

main body of the Dujiangyan project was in good condition, only the Fish Mouth Levee had been some cracks (Fig. 6), and with an urgent repair on the project made by emergency worker, the pressure on the dam had been in a timely manner to relieve making many cultural heritages from the floods. However, not every flood disaster can avoid. In 1933, an earthquake happened in Diexi where is located in the upstream of Minjiang River, forming various barrier lakes, but the dams breached eventually, leading to flood levels higher than normal levels of about 12 m, and Dujiangyan hinge had been washed out made the project got a heavy toll (Fig. 7).

Tab. 2 Correlation table of floods produced by the earthquake in Dujiangyan project[9]

Name of the earthquake	Wenchuan earthquake	Diexi earthquake
Occurrence time	12 may,2008	25 oct.,1933
The earthquake level	8.0	7.5
The epicenter distance from Dujiangyan project（km）	20	180
Earthquake's impact to cultural heritages	A number of historical buildings in Two Kings temple collapsed, both of roof on the major building of Dragon-taming Temple and water gate of the outer stream damaged	Ancient wall, Call-Officers-Roll Platform and the other historical buildings in ancient Diexi city damaged badly
Types of seismic secondary disaster	Floods, landslides and debris flows etc.	Floods, bedrock dislocated layer and debris flows etc.
Flood crisis produced by earthquake	Watercourse in jam forming barrier lake	Mountain collapsed forming a series of barrier lakes such as Big Haizi, Small Haizi and so on, all barrier lakes broke up finally
Flood disaster rescue measures	Discharged timely for barrier lakes and Zipingpu reservoir	Didn't have any measures all through
Death toll in floods (numbers)	0	2500
Damage to the project caused by flood	Three main engineering in good condition but water box of outer stream paralyzed and had slight crevices on Fish Mouth Levee	Head of hub washed out completely
Return to normal operation after flood disaster	13h	1 year later

(2)The Reasons of flood disasters

a) Changes in the natural environment

In recent years, excessive destruction of forest and vegetation cause water conservation reduction in southwest China. As a result, sediment concentration of various watersheds increase and floods have being in intense. And the Minjiang River Basin where Dujiangyan Ctiy is located in is one of basins suffered from flood disasters frequently. The reduced vegetation, ecological environment deterioration become the key reason for the flood disaster (Fig. 8). Meanwhile, due to the complexity of geological structure of the upper reaches of the river, earthquake activity is frequent and rainfall intensity is big, where becomes a high incidence zone of landslide, collapse, debris flow disasters and so on. Hence, Dujiangyan project, located in the downstream and as the outfall of heavy-rain confluence area, is highly susceptible to the flood disaster.

b) Impact of Urban Construction

Site selection and construction of ancient Dujiangyan project conform to nature, make full use of natural

[9] Made by the authors

terrain and the river regime, which has realized the automatic water diversion, flood discharge and sediment delivery, being in the concentrated reflection of Nature and Humanity's ideology in Chinese traditional culture. At the same time, Dujiangyan project has great flexibility in the layout. For example, the Fish Mouth Levee will bring different amount of water according to different seasons, the Flying Sand Weir assembled by weighted bamboo baskets will drain out silt and excess water to the outer stream when the water is too large, achieving the perfect combination of nature and engineering.

Modern Dujiangyan project's construction, however, was usually less considered to adapt to the regulation of natural environment, which caused a threat to the aquatic creatures, mountain forest vegetation, resettlement and many other local environmental and social issues, in turn raised the risk of flood disaster (Fig. 9). In addition, there is a more acute contradiction between the engineering construction and the protection of cultural heritages. The plan of Zipingpu Reservoir-Fish Mouth Levee Project will be built on the original irrigation system site and replace it that has a long history.

Fig.8 Environment deterioration at Minjiang[10]

Fig.9 Damage to the forest caused by construction at Minjiang[11]

c) Loss of Traditional wisdom

For ancient Dujiangyan project, its repair and maintenance all use of local bamboo, wood, pebbles and other traditional materials such as Macha (a wooden frame with three feet to block water), weighted bamboo baskets, pebble levee and so on. And flood control experiences are widespread to folk in the form of popular proverbs making the local people familiar with to pass on from generation to generation. The traditional technology and ideas are the main reasons of Dujiangyan irrigation system and the surrounding irrigated areas in good condition after 2000 years.

Now, as to flood control, China has promulgated some related law norms and standards, including *Flood Control Law of the People's Republic of China*, *Criterion of Flood Control*, *Rules Flood Control Planning* and *Design Code of Urban Flood Control Engineering*. However, there are few of them involved in the contents of cultural heritage. Just like *Criterion of Flood Control*, it stipulates the return period of world-level cultural relics being equal or greater than 100 years while it doesn't take the protection of traditional flood control technology and ideas into account and can't take root in the hearts of the people to participate in protecting. There are various types of cultural heritages which are similar to the Dujiangyan project widely distributed in southwest China where the flood disasters give priority to with storm floods and small range of flash floods with complicated conditions and lack a certain targeted guidance.

d) Defects of Modern Regulation System

[10] http://www.360doc.com/content/10/0519/17/1340465_28420428.shtml

[11] http://www.360doc.com/content/10/0519/17/1340465_28420428.shtml

Most of cultural heritages in southwest China are traditional wooden structure building and a number of water conservancy projects are built with bamboo, wood and pebbles as materials which are highly susceptible to the influence of natural environment. Combined with antique construction, historic buildings and water conservancy projects are varying degrees of damage. If there is no daily maintenance and preparation for disasters, the cultural heritage will be unbearable when it encountered large floods.

Dujiangyan project, in more than two thousand years of history, repeats the process of experiencing floods and drainage basin regulation. It is not hard to find that a comprehensive flood control system and sound daily management plays a vital role for flood control of cultural heritage. For example, in Wenchuan earthquake and Diexi earthquake, both similar disasters have produced two very different results after many years, in which the flood management played a key role. And through long-term accumulation, in China, modern flood management system has been basically formed at present, but there still exist many problems.

4. Flood Control Related Issues of Cultural Heritages

(1)Inheriting the Ancient Wisdom of Flood Control

To inherit the ancient Chinese traditional ideology of flood control, we must harmonize the connections between engineering construction, natural environment, and protection of cultural heritages. The site selection and construction of flood control engineering should make full use of natural terrain, follow the law of nature, avoid the disaster-prone, conserve water and soil and reduce the damage to the surrounding natural environment. In the meanwhile on the basis of meeting the basic requirements of flood control engineering construction, minimize the damage to the surrounding cultural heritage and draw up a detailed plan for cultural heritages protection and flood control management, put forward targeted guidance that is suitable to the local conditions.

In addition, inheriting Chinese traditional ideology, meanwhile, we inherited the traditional flood control technology selectively. Not only flood control do the technology experiences of cultural heritage take the form of professional norms, but also widely publicized in the residents in the form such as popular phrases, proverbs and so on and even training part of volunteers regularly in the professional aspect, which is the inheritance of Chinese traditional culture of flood control and is also respect for the traditional flood control technology. Flood risk management of cultural heritage is not just depend on the government and should let more strength to participate in including local enterprises, non-governmental organizations, communities and citizens, enabling everyone to know floods, increasing flood control awareness and taking part in part of the construction. By doing this, can we protect ourselves, other people and cultural heritage finally when the flood comes in.

(2) Building a Sound Modern Flood Control System

Before flood disaster, we should take systemic engineering and on-engineering measures for cultural heritages to diminish the flood risk. Combine the constructions of flood control and drainage with the other engineering constructions for cultural heritages forming the integrated flood control system and strengthen the construction of the surrounding green space and wetland in order to make sure that cultural heritages have certain natural flood control ability. In a flood disaster, drawing lessons from foreign advanced experience, applying modern information technologies to realize real-time prediction and monitoring changes in rainy process, meanwhile strengthen the flood forecast of the cultural heritages and alarm in time so that we can evacuate the relevant person urgently. Related departments of cultural heritage should rescue cultural heritages in time to reduce the damage as far as possible. After a disaster, conducting a detailed

investigation on the damaged part of the cultural heritage and formulating specific restoration or reconstruction schemes are necessary in order to carry out the disaster relief work orderly.

5. Conclusions

In brief, the main reasons of floods in southwest China which destroyed the cultural heritages are the changes of natural environment, the impact of urban construction, the lack of public participation and the loss of traditional concepts and technologies of flood control and the more important reason is modern flood risk management system still being not perfect, hence it is necessary to build a comprehensive flood control management system. Furthermore, we should make reasonable conservations and flood control management schemes to adapt to the local conditions according to the different features of cultural heritages in various places, not only does historical heritages keep original, but also it improves the safety of flood control. At the same time, to deal with the connections between engineering construction, natural environment, and protection of cultural heritages, we must combine the traditional ideology of flood control with modern flood control technology building a suitable flood control management system that covers the hole process in flood disasters for cultural heritages in different areas, which is of great significance to the protection work of Chinese cultural heritages in the future.

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References

1）Yu hui: Research on value analysis and protection of historical and cultural cities in post-disaster in Wenchuan earthquake area, D. School of Architecture and Design in Southwest Jiaotong University, 2012.

2）Wu Qingzhou: Flood control experiences and references of Chinese ancient city, J. City Planning Review, Vol.26, No.4, pp.84-92;

3）Li Keke and Li Peihong: Dujiangyang Irrigation System— the bright pearl of China's traditional water conservancy culture, J. China Water Resources, No. 18, pp.75-78, 2004.

4）Wang Xingkui ,Qu Zhaosong,Zhang Shanghong and Zheng Jun: Strategy discussion about Dujiangyan project's flood control, J. Journal of Hydroelectric Engineering, Vol.24, No.4, pp.31-35, 2005.

5）Cao Shuyou,Liu Xingnian,Huang Er,Yang Kejun and Yang Guangfeng: Summary of the research on watercourse restoration and reconstruction in Wenchuan earthquake area, J. Journal of Sichuan University(Engineering Science Edition),Vol.42, No.5, pp.1-9.

6）Li Shasha,Zhai Guofang and Wu Yunqing: The basic experiences of British urban flood risk management, J. Urban Planning International, Vol.26, No.4, pp.32-36, 2011.

7）Li Shasha,Zhai Guofang,He Zhongyu,Wu Yunqing and Chen Jing: Based on risk management perspective Study on urban heavy-rain and flood disaster, C. The collected papers of The 6rd Annual Meeting of Risk Analysis Council of China Association for Disaster Prevention, pp.399-404, 2014.

8）Jin Juliang,Wei Yiming,Fu Qiang and Ding Jing: The discussion about theoretical frame of flood disaster risk management, J. Water Resources and Hydropower Engineering,No.9,pp.40-42,75,2002.

9）China's Word Heritages Writing Group: China's Word Heritages, M. Beijing Language and Cultural University Press, 2008.