Water management in a city of southwest China before the 17th century
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ABSTRACT
Kunming City is the capital of Yunnan Province, China. From the 12th century, it has developed from a remote rural town to become a large city. Successful water management was one of the key dynamic factors in the city’s development. As a result of the location of Kunming City, in its early age it was in a narrow area between the north bank of Dian Chi lake and the mountains, therefore the water management in the history of Kunming City mainly focused on two key projects, one being the Song Hua Ba Dam with the function to control flooding from Pang Long Jiang river, and the other the Hai Kou He river dredging project to control the drainage from Dian Chi lake, therefore shaping a water supply system for the city in the upper basin of the Yangtze River. Pang Long Jiang river is only one large river from the mountains flowing across the city into Dian Chi lake. Therefore the city’s development from its early age (11th century) mainly depended on irrigation and flood control of Pang Long Jiang river basin and the basic water system for the city was formed before the 17th century (Ming Dynasty), the most important period of the city’s water history.

Key words | China, history, Kunming City, water management, water supply

Being situated in southwest China, Kunming City is the capital of Yunnan Province with a current population of 7,000,000. It is also the largest city closest to Southeast Asia and it is planning to be built as a regional international city in the future (Figure 1). Today, 50% of Kunming City’s residents are from other areas resulting in a lack of good understanding of the water situation, especially the history of the water in the city. Also, the rapidly enlarging urban body has disengaged with the traditional water supply design achieved in history. This situation has challenged the city’s water supply and protection of water (Zheng 2008). Rapid urbanization still progresses today, but it is a fact that Kunming City is one of the large cities in China with a shortage of water. Water has become a prominent restrictive factor for its sustainable future. Under such a situation, better water management is required that not just depends on more hydraulic projects but also for a good public understanding of the water situation, including a good understanding of the achievements and lessons of water management from history. The fact that Kunming has developed from a remote town in the 11th century to a large city was basically achieved by successful water governance. Many major hydraulic engineering, which are still in functional conditions even today, are the heritage from the history, especially from Song and early Yuan dynasties (1271-1368 AD). Consequently, a good understanding of the role played by water and the logics of water management on the city’s history is highly valuable, not just for shaping the public identity of water protection but also for managing water supply in a growing city. This paper aims to take Kunming City as an example to understand the role of water governance and the logic of water management on its history as well as discussing what could be learnt from history for today’s urbanization.

INTRODUCTION
Kunming City is located at the north bank of Dian Chi lake (it is the largest fresh water lake in Yunnan province and the sixth largest fresh water lake in China, 306.3 km² in size), having a narrow zone between the lake and mountains.
(Figure 2). Naturally, the location of Kunming City is the upper basin of the sub-water system of the Yangtze River. Water resources in the city consist of the Dain Chi lake and six main rivers, but the water resources in this city are mainly from Pan Long Jiang, the largest river from the north mountains into Dian Chi lake. Historically, the lake was used by the local residents for fishing, transportation and limited irrigation, and after the 1960s it was also used for the water supply of Kunming City. After the early 1990s, the water supply was stopped due to its growing pollution. The foundation of livelihoods for most of the residents of Kunming from its original history to 1960s were agriculture and fishing, but fishing was just for the people settled closely around the lake. Most of the residents relied on agriculture, so these rivers are the most important water resource for the livelihood of the city (Yunnan Provincial Committee of Local-Graphy 1998).

Pan Long Jiang river is the only large river flowing across the urban area of Kunming City. Its basin consists of a series of branch rivers, but the main branch rivers such as the Jin Zhi River and the Yin Zhi River were made in the 12th century. Pan Long Jiang river has a total length of 104 km including 37 km in the urban area. It originates from the north mountains of Kunming City, from a high area (around 2,200 m a.s.l.) flowing into a flat urban area (around 1,800 m a.s.l.). As result of this difference frequent flooding has been recorded. According to historical documents, six large floods have been recorded in the past 700 years, for example, the largest was in 1857 (Yunnan General-graphy, written in the mid-19th century). Documents recorded that flooding water was at a depth of 9.5 m, all houses outside the round-town wall were destroyed and hundreds of thousands of people died. However, on the other hand, Pan Long Jiang river has played an important role in local irrigation and city water supply from the city’s early age. Control and development of the usage of the river has been most important for local governments over the past thousand years. People have to control flood from Pan Long Jiang river and also develop irrigation systems for extending farmland, so many water projects for control flooding and developing irrigation have been implemented in different periods of the city’s history. The key, and largest, hydraulic engineering, Song Hua Ba dam, was built in 1275 (Yuan Dynasty of China). After the dam was constructed, flood was effectively controlled in general, and Kunming City developed as a large city and an economic, political center of Yunnan province. After the Yuan Dynasty, the Song Hua Ba dam had been rebuilt numerous times until the 1980s, so we can say that the history of Kunming City was developed along with this dam, mainly achieved on Pan Long Jiang river’s control and water management.

Dian Chi lake is an inland lake. It receives water from the north mountains mainly by Pan Long Jiang with drainage by the Hai Kou river, the draining mainstream of Dian Chi lake. Hai Kou river starts from the west bank of the lake and flows into the branch of the upper reaches of the Yangtze River. The function of the river was mainly for balancing the water level of the lake due to the water level regularly rising
by receiving water in summer, therefore bringing frequent flooding to the banks of the lake, especially after the Pen Long Jiang river basin was effective in governing, water in the north area of the lake was leaded smoothly by Pen Long Jiang river into the lake but also brought rising water levels and caused more flooding in summer. As a result, impactful drainage of the lake was used to reduce the flooding, so the governing of Hai Kou He river become another main effort for the city’s water management from the 12th century to later centuries. After the river was governed, causing a decline in the water level of the lake, farmland emerged around the lake that also brought great possibilities for the development of the city.

Consequently, as the subsystem of upper Yangtze River, the water system in Kunming area is combined with Pan Long Jiang river, Dian Chi lake and Hai Kou He river. Correspondingly, the water supply system in Kunming City consisted of parts of Pan Long Jiang, Dian Chi lake and Hai Kou He river with its functions of leading water, keeping water and drainage. Historically, hydraulic engineering was mainly focused on: (1) Pan Long Jiang river governance for water supply, control flooding and irrigation; and (2) Hai Kou He river governance for drainage of the lake and balancing water in the lake. Implemented hydraulic projects brought the possibility of extending Kunming City’s size and agricultural development and, finally, population growth. Simultaneously, as a result of the main hydraulic engineering, water management was implemented by local government on the entire period of the city's history, just the becks in the residential area were managed by the local residents (Huang 1974), so water governance (governments takes charge) was the main way forward for water management.

**WATER MANAGEMENT BEFORE YUAN DYNASTY**

Basically, water management recorded in historical documents was very limited before the Yuan Dynasty. The earliest document in the Han Dynasty recorded that some villages with paddy fields around Dian Chi lake existed before the Han Dynasty (200 BC), people governed the Pan Long Jiang river to irrigate paddy fields and grow rice. In the Han Dynasty, the local governor, Mr Zhang Bo, implemented dredges up the Pan Long Jiang river for extending irrigation and keeping floods away. This shows that agriculture and irrigation in this area has been developed for 2,000 years (Ma Yao 2009).

The most important period in early history for governing the Pan Long Jiang river was in the Song Dynasty. In 1040, Kunming City was built to be the east capital of Dali Kingdom, the local Kingdom of Yunnan (Ma Yao 2009). As a result of the establishment of the east capital, many hydraulic engineering projects were implemented for water management. Firstly, the riverbank of Pan Long Jiang river was dredged to control flood and develop irrigation, and secondly, the most important hydraulic projects were two man-made rivers, Jing Zhi He river and Yin Zhi He river. These were built for irrigation and for leading floods from the Pan Long Jiang river (Figure 4).

Jin Zhi He river, with a length of 35 km, starts from the Song Hua Ba dam and is linked to Pan Long Jiang river, flowing down to the lower area of Kunming City before finally flowing into Dian Chi lake. After the Jin Zhi He river was built, the king, Mr Duan, asked people to plant masses of Yellow Flower (local name at the time) along the riverside. The reflection of the flowers in the water led
to the river being called Jin Zhi He, which means the river of golden juice.

Yin Zhi He river, with a length of 17.6 km, originates from the He Long Tian (Black Dragon Spring) and Bai Long Tian (White Dragon Spring) in the northern mountains of Kunming City, also receives water from many becks on the way before flowing into the Pan Long Jiang river. This river irrigates largely paddy fields and especially reinforces much water to the Pan Long Jaing river in winter, the dry season of the year, increasing the efficiency of irrigation in the lower basin of Pan Long Jaing river. The king also asked people to plant largely Argentine flowers along the river sides, so it was called Yin Zhi He, meaning the river of silver juice (Kunming Water Work Bureau 1996).

WATER MANAGEMENT IN YUAN DYNASTY (1271–1368 AD)

In 1273, Mr Sai Dian Chi (Mr Sayyid Ajall 1211–1279) was appointed to be the governor of Yunnan province by the emperor of the Yuan Dynasty. He was an achieved governor during his tenure, but his greatest achievement was in successful water management and irrigation development in Kunming area, and after he died a small temple was built by local people to remember his achievement on water management. In 1274, Yunnan province was established and Mr Sai Dian Chi moved the capital from Dali City to Kunming City (Song, Lian 1956). As a result of this change, water management became important for developing Kunming City, mainly to extend irrigation and control flooding from the mountains of north Kunming City.

In 1275, Mr Sai Dian Chi implemented a series of hydraulic projects to govern six rivers from the mountains.

Treatment in the upper basin of Pan Long Jiang river

Originally, there were 99 springs in the upper basin of Pan Long Jiang river. These springs were the main water sources of Pan Long Jiang river, but there were many channels from the springs to lead water into the areas nearby. In this situation, water not always flowed into the main river in winter but it often flooded the local villages in the rainy season in summer. The work involved treating the basin to make more channels to introduce water from the springs into the branch of the Pan Long Jiang river then into the mainstream. After the project was finished, water from the springs was managed to flow into the upper basin of the Pan Long Jiang river. It benefits the river to receiving more water in the dry season and reducing flooding to the villages nearby in the rainy season.

Song Hua Ba dam construction

The construction of Song Hua Ba dam on the Pan Long Jiang river was a most important hydraulic engineering project for water management in the history of Yunnan. As mentioned above, the lower basin of Pan Long Jiang river was often flooded in summer, but simultaneously there was not enough water to irrigate the paddy fields in winter. For controlling the water of the river, Mr Sai Dian Chi, the governor of Yunnan, decided to build a dam on the river. In 1276, he led the project to build the dam with clay and wood in the place of the link where the Pan Long Jiang river from the mountains flows into the lower area. After the dam was constructed, the Pan Long Jiang
river was governed effectively, flooding was controlled in summer and availability of water supply for irrigation was increased with other projects (Kunming Water Work Bureau 1996). This achievement also brought the possibility of supporting a rapidly growing population and widening of farmland in the early Yuan Dynasty, a rapidly developing period in the history of Yunnan. In later dynasties, the Song Hua Ba dam was repaired or rebuilt continually and it has played an important role in water management of Kunming area from its early age until today (Figure 5).

**Jiang Zhi He river’s continue building project**

As an integrative project of Song Hua Ba dam, Jiang Zhi He river’s continued building project was started at the same time as the dam construction. The purpose of this project was to introduce more water into the Jiang Zhi He river with two functions: draining water from Song Hua Ba dam in the rainy season; and an increase in water supply in the dry season for irrigation. The river was extended to 5 m in width from the dam, flowing down 20 km and the reach near the banks of Dian Chi lake was 3.6 m in width. Along the river, ten floodgates and 360 underground culverts were built to increase the water supply for irrigation, sharing water and drainage in the rainy season. It was an excellent project in its time and many generations have benefited to date.

**Irrigation management**

After the dam and integrative projects were finished, how to manage the irrigation and facilities become an important issue. Therefore, rules of water management were made by the governor for managing irrigation. It was successful in that time and continued for the subsequent hundreds of years.

According to the rules, how to share water for irrigation was to follow the model of shifting drainage. The government department set up some stages of drainage that depended on the floodgates in different part of the river, draining stage by stage. For example, in Pan Long Jiang river, there were five stages (depending on five floodgates) for drainage, the first stage in the Da Zha floodgate opens the gate to draining for 1 day, the second stage in Bo Lo village gate opens the gate for 2 days, the third stage in Xiao Ba opens the gate for 3 days, the fourth stage in Di Zang Si opens the gate for 4 days and the fifth stage in Yan Wei Zha opens the gate for 5 days, so that a draining round for 15 days then water was distributed for irrigation along the river in equal amounts. The local government also made rules to maintain the model working in good conditions and punished what was against the rules (Song Hua Ba Dam-Graphy 1996). The model of drainage in other rivers was the same (Huang 1974). Correspondingly, for water security, 360 sentries with 360 water keepers and horses were set up by the government to inspect the rivers, especially for floods. If there is any accident in the rivers, for example, flooding, debacle of the riverbank, acting against the water rules, they could report to the governmental office immediately, the villagers and soldiers could be gathered in good time to resolve the problem.

**Hai Kou He river management**

Hai Kou He river is the main draining river from Dian Chi lake to the upper basin of the Yangtze River. In the 13th century before it was dredged it was a small river, but even so the local people understood that it was the main drag for drainage of Dian Chi lake (Fang 16th century). Therefore, hydraulic engineering for dredging the river was regarded after Kunming City was established as the capital of Yunnan province in Yuan Dynasty.

The earliest event to governing the Hai Kou He river was recorded by the document in 1273, Yuan Dynasty (Song, Lian 1956). According to the document, Mr Zhang Li Dao, the agricultural administrator of Provincial
Government of Yunnan, forced 2,000 laborers to dredge and extend the Hai Kou He river. The idea of water governing from Da Yu (the first emperor of China in history, he became the emperor due to successful water management) was adopted by Mr Zhang Li Dao in that the implementation of engineering was leading to more water in the river but did not follow the convention of making more and more mounds around the living areas to stop flooding. Based on this, the river was dredged more deeply and broadly, accumulated soil in the river was moved and a new riverbank was built that enlarged Hai Kou He river to a width of 20 m and a length of 10 km after 3 years. After this project, drainage was effectively improved in the river that brought a decline of the water level in the lake from 1,890 m (a.s.l.) in the 12th century to 1,888.5 m, the size of the lake was diminished to 410 km² from 510.1 km², thousands of hectares of cultivable land were formed as a result of this change (Kunming Water Work Bureau 1996).

WATER MANAGEMENT IN MING DYNASTY (1368–1644 AD)

In the late age of Yuan Dynasty, civil wars were fought continually for many years, water conservancy was also obsolesced. In the early Ming Dynasty, the Ming central government moved a lot of people, including soldiers and farmers, from central areas of China to Yunnan for the purpose of consolidating the frontier. Consequently, the population increased rapidly in this period in Kunming area. More than 300 villages were formed around Dian Chi lake but most of them were inhabited in the north area of the lake, farmland was heavily developed simultaneously. As a result of this change, Kunming City required a better water supply for agricultural development and population growth.

In 1618, the Pan Long Jiang river and the other river governed projects were implemented by the local governor. The key project was to rebuild the floodgate of Song Hua Ba dam with stone, replacing the structure of clay and wood. In 1618, Mr Zhu Qing, the water administrator of Yunnan government, led the important project of rebuilding the dam. He suggested rebuilding the dam with a stone structure. His suggestion was accepted by the provincial governor and the rebuilding project was started in 1618 and ended in 1620. After the stone dam was constructed, it was more effective at stopping floods and increased the water supply for irrigation, and it was unnecessary to spend much money and mass labors to repair it frequently. The dam’s rebuilding at the time was a very important event in the history of water management of Kunming City. It has undergone many repairs and flooding, but the dam functioned for 300 years until it was dismantled for the building of the Song Hua Ba reservoir in 1958, today’s main water source of Kunming City (New Yunnan Through History. Printed in 1940s).

In the Ming Dynasty, another important hydraulic engineering was the dredging of Hai Kou He river for drainage of the Dian Chi lake. As mentioned above, the main water resource of Dian Chi lake was from the north mountains via Pan Long Jiang river, along with the successful management of Pan Long Jiang river. The drainage of Pan Long Jiang river effectively flooded into the Dian Chi lake in the rainy season, and reduced the risk of disaster to the living area of Kunming. However, the water level rose in the lake in summer and frequently brought flooding to the waterside areas, especially the north bank closest to the city. Consequently, how to drain water from the lake to reduce the water level in the rainy season has become a new challenge. Basically, Hai Kou He river has been dredged continually since the Yuan Dynasty, but it was still not enough to drain water after the Pan Long Jiang river basin was effectively managed to lead more water into the mainstream, then into the lake which brought rising water levels in the lake. Therefore, continual management of this river is an important work.

In 1382, Mr Mu Ying, the governor of Yunnan province, mustered more than 10,000 laborers to dredge the riverway of Hai Kou He river. In 1501–1502, 60,000 soldiers and 20,000 farmers from three prefectures and four counties were mustered by the governor to dredge the riverway again, as well as to build some new channels for increased drainage and 15 mounds were built to stop flooding along the riverbank. After this project, the water level of the lake was reduced to 1,888 m and the size of the lake was diminished to 350 km². Thousands of hectares of cultivable land were formed by this change. We can see the change from remote ancient times to today in Table 1. It was remarkable that largely farmland was formed due to the diminished size
of the lake after hydraulic engineering from the 13th to the 16th centuries. This situation has been supported by a rapid growth of population, especially in the Ming Dynasty. A mass of forces, farmers and business people were moved into Yunnan and many of them settled down near Dian Chi lake. Available farmland was a very important condition for their settlement, therefore it not just brought the possibility of population growth but has also funded the development of Kunming City to the present time (Figure 6).

In 1509, 1549, 1573 and 1575, the provincial governors led many projects to dredge the riverway continually, built more mounds, channels for drainage and stopped flooding. The project in 1575 was a remarkable project because former projects were only implemented in the lower reach of the river, and this project was in the upper reach. After a survey to the river, the administrator decided to develop the upper reach more broadly to effectively lead water into the main riverway. After this project, the capacity of drainage in the main riverway rose by 50% but expense was significantly reduced compared with the previous works (Kunming Xi Shan District-Graphy 2000). Consequently, the most important age of governing Hai Kou river was in the Ming Dynasty due to the structure of the river management being formed in this period.

**CONCLUSION**

Kunming City has been developed to be the capital city of Yunnan province since the Yuan Dynasty. Originally, the situation of water for settlement, especially for a capital city, was not adequate due to the water supply mainly relying on the Pan Long Jiang river, the only large river in the area. It flooded frequently in the rainy season but water for irrigation was very limited, although the city was located beside Dian Chi lake. In the 12th century, local rulers and governments started to govern water for extending inhabitation and irrigation. Hydraulic engineering for shaping a water supply system and control flooding and balance the water level of Dian Chi lake was included: (1) two man-made rivers were built (Jin Zhi He river and Yin Zhi He river) to regulate seasonal water from the Pan Long Jiang river; (2) the Song Hua Ba dam in the Pan Long Jiang river was built to control flooding; (3) the management of water from 99 springs in the upper basin of Pan Long Jiang river into its mainstream; and (4) the implementation of the Hai Kou He river draining project for drainage of Dian Chi lake. After these achievements, water supply, flood control and irrigation was effectively improved for the city’s development. This water supply system was mainly formed before the 17th century, mostly achieved in the Ming Dynasty (15th to 17th centuries). In the Ming Dynasty, Song Hua Ba dam was rebuilt of stone and the Hai Kou He river dredging project was continued on a large and frequent scale. History shows that some key hydraulic engineering was focused by the government for water management as mentioned above from the 11th to the 17th century, it not just supported the water management successfully but also reflected the wisdom of water management historically.

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**Table 1** | Water level and size of Dian Chi lake

<table>
<thead>
<tr>
<th>Period</th>
<th>Water level (m)</th>
<th>Size (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote antiquity (3 million years ago)</td>
<td>–</td>
<td>1,260</td>
</tr>
<tr>
<td>Tan Dynasty (618–907 AD) to Song Dynasty (960–1276 AD)</td>
<td>1,890</td>
<td>510.1</td>
</tr>
<tr>
<td>Yuan Dynasty (1271–1368 AD)</td>
<td>1,888.5</td>
<td>410</td>
</tr>
<tr>
<td>Ming Dynasty (1368–1644 AD)</td>
<td>1,888</td>
<td>350</td>
</tr>
<tr>
<td>Modern times</td>
<td>1,887.2</td>
<td>309.5</td>
</tr>
</tbody>
</table>

Kunming Water Work Bureau 1996.
The logic of the water management was the led water from Pan Long Jiang river by two man-made rivers (Jin Zhi He river and Yin Zhi He river) to regulate seasonal water and increase irrigation to more areas as well as taking the function of diffuence from Pan Long Jiang to reduce flooding in summer. In 1276, Song Hua Ba dam was built on Pan Long Jiang river to regulate seasonal water in the river. During the flood season, water can be distributed into Jin Zhi He river so that flood controlling was achieved effectively, simultaneously water also can be distributed into Jin Zhi He river and Yin Zhi He river to increase irrigation in larger areas in winter. In the late 13th century, the local government started to dredge Hai Kou He river for draining water and balancing the water level in Dian Chi lake which caused a decline of the lake and also controlled flooding simultaneously. It was the logic of water management in the history of Kunming that had been formed before the 17th century, although many hydraulic engineering products were implemented in later years, but water management was basically based on this logic and its achievements. Consequently, the Ming Dynasty was the most important age for water management on the history of Kunming City as the logic and structure of water management was formed in this age.

It is a fact that successful water governing fundamental in Kunming City's development. From the early age of the city, the local governments always took water as a key factor for the city’s development, especially in the 12th and 13th century. Kunming was still a very remote area in China but some great water projects have been implemented with mass labor and a large budget. After the 13th century, water governing was always emphasized by the rulers when society was in peaceful circumstances without war and natural disaster. It is most important to understand the role of water in the history of Kunming City, especially the unbalanced situation of water (shortage and flooding) in Kunming City since its early age and along with the city's development throughout history, therefore, the city's development continually relied on water governing in periods of dynasties. It is very important for us to understand the real water situation of Kunming City in history. One lesson we can learn from history is that when we think about increasing urbanization, we have to think about the supplying capacity of water of the city. Urbanization has to be balanced with the water resource situation, simultaneously, improvement of the water situation has to be conducted continually in accordance with urbanization. History also teaches us that systemic water supply structure with key hydraulic engineering is the supporting condition of the city, just like the structure mentioned above. How we balance the historic heritage and current requirement when challenged by the rapidly growing urbanization should be a key factor for the city's sustainability.

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