The protection and development of historic Lougang water resource features along Lake Tai

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Abstract. Overcoming the conflicts between protecting water resource heritage features and the sustainable development of modern society is a major undertaking. Lougangs (rivulets) and polders are Lake-Tai-Basin-specific water resource engineering projects that hold a significant historic position. This paper presents background on water resource heritage features, based on the origins and evolution of Lougangs along Lake Tai. Through analysis of their value and current standing, we propose countermeasures for protection and development of the Lougang water resource heritage features along Lake Tai.

1. Introduction

The water resource sector has provided increasing attention to the cultural and scientific values of ancient water resource engineering projects since the designation of the Dujiangyan Irrigation System as China’s first water conservancy world cultural heritage feature in 2000. Over recent decades, hundreds of water resource engineering projects have been the focus of national, provincial, municipal and county-level cultural relic protection organizations. During the last ten years, the West Lake, Hani Terrace, Grand Canal, and other water resource projects have been placed on the UNESCO World Heritage List or the UNESCO World Heritage Tentative List.

In order to learn more about ancient Chinese water resource engineering and heritage features, the Ministry of Water Resources determined plans for a general survey of such projects during China’s first general survey of water resource heritage features which took place from 2010 to 2012. According to the survey results, more than 600 ancient water resource engineering projects of high cultural value maintained function, benefiting communities. Included among first-line water resource systems are many historic relics that showcase ancient hydrological measuring, water rights identification, and memorials. These water resource heritage features are evidence of the advanced nature of the ancient Chinese civilization and are an important part of China’s cultural heritage [1]. As a natural cultural strategy and a water resource management plan are undertaken, issues related to cultural heritage protection and water resource infrastructure construction will increasingly converge and become more closely associated with urban and rural land management, transportation concerns, and historic preservation. Conflicts may occur between the demands of protection and those of development.

“Lougang” is a local term that refers to the densely-distributed and continuous rivulets that discharge flood waters into the West Tiaoxi River and the East Tiaoxi River. Lougangs and polders
are water resource engineering projects found in the Lake-Tai-Basin, and which are primarily distributed in the eastern, northern, and southern regions of Lake Tai and more sparsely distributed in the north and northeast parts of the lake (figure 1).

![Figure 1. Schematic diagram of Lougang and Dike Paddy Field [2].](image)

The water system of the Lake Tai Basin is centered around Lake Tai, and is divided into the upper and lower reaches. The primary sources of the upper reach are the southern Tiaoxi River water system and the western Jingxi River water system. The lower reach is comprised of three rivers: the Wusong River, the Dong River, and the Lou River, which sluice water out to the sea from the northeast, east and southeast, respectively. Both the Tiaoxi River water system and the Jingxi River water system feature hydrologic characteristics of mountain streams, namely torrents with water sources located short distances away. The Lake Tai Basin, in which water levels are generally higher than in fields, is quite vulnerable to flood disasters as a result of its special terrain, which creates large catchments and high levels of ground water. These specific conditions make it imperative to construct and regularly maintain water conservancy, irrigation, and drainage facilities in order to facilitate agricultural harvests. In order to accomplish this, ancient people adopted the unique measures of “latitudinal Tangs” and “longitudinal Lous” in the lower reaches of the Tiaoxi River and Jingxi River to create riptide cushions. These tactics were able to eliminate drought and flood disasters in order to make full use of water resources. The transverse rivulets located on the eastern, southern, and western sides of Lake Tai are known as “Latitudinal Tangs”. The small longitudinal ditches which drain into Lake Tai are referred to as “Lou,” “Gang,” “Pu,” or “Du,” (described in further detail below) and are collectively referred to as “Lougangs.”

Prior to the formation of the Lake Tai embankments, no distinct boundaries existed between the eastern and southern parts of Lake Tai. The embankments in the South Lake Tai began to take shape during the spring and autumn periods (771-476 BC), and ultimately stretched to the Wujiangtang Road during the tenth century AD. In order to meet the many demands of regional flood control which include drainage, irrigation, and shipping, the lakeshore bottomlands and plains have undergone continuous expansion. Over time, the Lougangs along Lake Tai have extended and moved closer to one another. Presently, Lougangs are distributed at intervals of 500-840 meters. Excavation and
maintenance of the Lougangs, as well as land reclamation, farming, and sericulture, stimulate one another for common development, thus forming relatively independent mulberry embankments which exhibit independent irrigation systems and agricultural production systems. The Lougang system which came into existence near the mid-Tang Dynasty (approximately the 8th century AD), was solidified during the Wu and Yue States from the Five Dynasties (10th century AD), and have relatively declined since the Ming and Qing Dynasties (12th-20th century AD)[3].

Huzhou City in Zhejiang Province is home to the oldest, most complete, and ideal Lougangs, which criss-cross the pond and polder system in the Lake Tai Basin. This paper uses the Lougangs along Lake Tai in Huzhou City as an example system, and examines the water resource heritage features of the Lougangs along Lake Tai. The status quo and existing issues in preservation are presented, as well as their scientific value. By taking into consideration the sustainable development of water conservancy and the need to improve both the ecology and the quality of human life, this paper seeks optimized solutions to the balance of utilization, protection of cultural heritage, and reasonable scientific protection of water resource heritage features.

2. Primary content of Lougang water resource heritage features along Lake Tai

In the Lake Tai Basin, beneficial interactions exist among the Lougangs, Latitudinal Tangs (transverse rivulets) and embankments, mulberry fields, fish ponds, and criss-cross ponds, which create a unique ecological system of connected rivers and lakes. The multiple interactions between dredging, manure storage, irrigation, and farming form a unique cultural and natural environment. Lougangs, which are a cultural heritage feature specific to the Lake Tai Basin, have existed over two thousand years of regional political, economic, and cultural history.

The development of Lougangs was synchronous with the construction of the Lake Tai embankments, which have since served as a foundation of regional environmental improvement and agricultural development. Lougangs have been relevant to two thousand years of water control and agricultural development in the Lake Tai Basin, the existence of which has spanned the evolutionary processes of human life and the natural history of the Lake Tai Basin circle. The Lougangs are an important part of China’s water resource heritage. Lougangs and polders are specific to the Tai Lake water resource engineering projects, and have played a crucial role in regional agricultural economy.

The Lougangs and polders were developed in the wake of the construction of Latitudinal Tangs on the shores of Lake Tai. Latitudinal Tang construction resulted in the emergence of relatively independent polder areas and irrigation ditch systems. Under the Wu-Yue Hegemony in the late Warring States period (475-221 BC), military settlements facilitated the formation of the canal system, in addition to the development of polders. By the tenth century AD, an engineering system for the Lougangs along Lake Tai was completely established, and which laid the foundation for regional agricultural development. Throughout the Yuan, Ming, and Qing Dynasties, the Lake Tai Basin became China’s primary area of grain and textile production, and was a major place of origin for tribute grain sent to Beijing and armies through water transport. From the 13th century AD onward, it also served as a major economic center of South China.

The Lougang water resource heritage features along Lake Tai consist of four aspects: the engineering of the Lake Tai embankment, the Lougang and Latitudinal Tang system, the polder and canal system, and other related heritage features (ancient bridges, embankments, and polders surrounded by mulberry embankments). These features are described in table 1 and figure 2.
Table 1. Composition of Lougang water resources along Lake Tai.

| Category                                      | Heritage feature names                                                                 |
|-----------------------------------------------|--------------------------------------------------------------------------------------------|
| Lake Tai embankment engineering projects      | Di Tang (Changhushen Line Waterway), North Latitudinal Tang (Ancient Grain Transport River), South Latitudinal Tang (Litang River), Medium Latitudinal Tang (Zhongtang River, Daishan Gang). |
| Latitudinal Tangs                             | 73 Lougangs, including Daqian Gang, Xiaomei Gang, Xintang Gang–Changdou Gang (former Zhangpo Gang, Hanghuxi Waterway), Luo Lou (Yijiayang Gang to the South), Huan Lou (Huanshen Waterway), Tang Lou (Lake Taijia Project, Pu Lou (Yacun Gang and Xingyao Tang to the South), Baimi Tang (Dongzong Line Waterway). A total of 30 Lougangs including Hu Lou are priority protection targets. |
| Lougang and Latitudinal Tang system           | Dadang Criss-cross Pond, Songxi Criss-cross Pond, Qingdun Criss-cross Pond, Lujia Criss-cross Pond, Changtian Criss-cross Pond, Xishan Criss-cross Pond, etc. |
| Lougangs                                      | Openings, culvert gates, sluice gates, revetments, river ports. |
| Criss-cross pond                              | Yigao Polder, Dalou Polder, Dongqiao Polder, Xulou Polder, etc. |
| Control engineering projects                  | Lateral canals, sublateral canals, ditches. |
| Polders                                       | Sluice gates, culverts. |
| Lougang and polder system                     | Shuangjia Bridge (Qiao Lou, Shangyi Bridge (Yigao Lou, Xiangwang Bridge (Tang Lou), etc. |
| Irrigation and drainage canal system          | Tianhou Niangniang Temple in Daqian Village, General Xu |
| Control engineering projects                  |                                                                                             |
| Ancient bridges                               |                                                                                             |
| Other related heritage features               |                                                                                             |
Temple in Yangduqiao Village, etc.

Sanguan Temple Fair, the release of water lanterns, a rite to the rain and sun gods, dragon boat races, 36 Lou songs (performed by farmers and boatmen to combat drought and to drain waterlogged fields), Jin Lou Barn Lantern, Yang Lou Dragon Lantern, etc.

Worship activities

Inscriptions and historical classical works

Figure 2. Distribution of water resource heritage features of Lougangs along Lake Tai.

2.1. Lake Tai embankment engineering

Construction of and improvements to the Lake Tai embankment system were basic conditions for formation of the Lougang water network and polder construction (figure 3). The Lake Tai embankment in Huzhou City is approximately 65 km long, and has contributed to fundamental change in the regional water environment of the Lougangs and polders. Seasonal flooding of the tidal flats dries out the nearby land, which has created the basic conditions required for the development of irrigation agriculture, the regional economy, and local culture.
2.2. Lougang and Latitudinal Tang system

The Lougangs and Latitudinal Tangs of historic importance include three Latitudinal Tangs and 73 Lougangs in the region (figure 4). The Lougang and Latitudinal Tang system, which uses the Latitudinal Tangs as latitude markers and the Lougangs as longitude markers, is the principal component of this heritage feature. There are also 16 ponds which criss-cross the longitudinal Lougangs, Latitudinal Tangs, and sluices.

Figure 3. Lake Tai embankment constructed during the 14th century.

Figure 4. The Zhu Lou Lougang.
Criss-cross ponds are large areas of water located between Lougangs and Latitudinal Tangs with approximate areas of 200-600 thousand square meters. Examples of large criss-cross ponds include Shengjia Criss-cross Pond, Dadang Criss-cross Pond, Songxi Criss-cross Pond, Qingdun Criss-cross Pond, Lujia Criss-cross Pond, Changtian Criss-cross Pond, and Xishan Criss-cross Pond. These ponds represent critical water tanks and wetlands along Lake Tai.

2.3. Lougang and polder system
The size of the Lougangs and polders generally ranges from dozens to thousands of acres. A large-scale polder merge occurred during the years 1950-1990, and there is evidence of recent construction of small, medium, and modern polders. As a result of these events, on 75 polders (with total areas exceeding ten thousand acres) remain, which accounts for 4.48% of the total number of polders. There are a total of 1181 polders with areas of less than one thousand acres; these account for 70.46% of the total number of polders. All polders encompass complete canals within the fields, inner and outer harbors, and pumping stations.

2.4. Other related heritage features
Other related water resource heritage features include ancient bridges on the Lougangs, water deity temples in the vicinity of the Lougang openings, and water-related worship activities.

3. Analysis of the value of the Lougang water resource heritage features along Lake Tai
Huzhou City is the only area in the Lake Tai Basin with complete and ideal extant Lougangs which are crisscrossed by pond and polder systems. This is the area in which the system originated, and contains the most distinctive characteristics of any system within the Lake Tai Basin. Lougangs and polders combine to form a water resource engineering system designed to respond to the characteristics of the low-lying topography, dense river network, and the conditions of the water and soil resources along the southern shore of Lake Tai. This system was created by ancient indigenous peoples in pursuit of social and economic development who sought to combat natural disasters. This system serves as both a model of China’s traditional water conservancy and as an outstanding representative of harmony between humans and water during periods of ecological, economic, transportation, cultural and social development. This system has played an extremely important role in Chinese civilization and water conservation history.

The Lougangs along Lake Tai are extremely valuable to science and technology. Their features include scientific sites, rational layouts, complete engineering systems, water storage and discharge through gate dams and sluice gates, and comprehensive utilization of water resources. Furthermore, the water heritage system of Lake Tai reflects more than a millennium of development and historical-cultural characteristics including profound cultural values; systems, mechanisms, laws and regulations related to water management; ancient bridges; records; inscriptions; poetry; irrigation festivals; and folk customs. In addition, as the system evolved, it created a variety of colorful ecological environment landscapes, which highlight the complex relationship between water and land and the harmony between humans and water.

3.1. Lougangs (Tangs and Pus) and polders created the farming civilization of Lake Tai
Within the South Lake Tai Basin, the most integrated extant farming and water resource system comprised of Lougangs (Tangs and Pus) and polders dates back to the spring and autumn periods. Based on three millennia of history, this system is an important foundation for Tangs, Pus and polders, in addition to the fish ponds surrounded by mulberry embankments in the Lake Tai Basin. The system not only represents the highest level of water resource engineering technology in the agricultural civilization era, but also created the farming civilization of the Lake Tai Basin known as the “world’s granary.” The system was a crucial means of transport which promoted the area’s reputation as “Wu-Yue Culture,” the “Land of Fish and Rice,” “Silk City,” and “Financial Revenue Stream,” and
provided a solid framework for the sustainable development of an economy and culture in a feudal society which positioned agriculture as the backbone of the country.

The Lougang and polder system in Huzhou City is endowed with an appropriate size, scientific management, and rational layout, and was incorporated into the natural water network while maintaining the integrity of the traditional pattern. The system is comparable to the Dujiangyan Irrigation System of the Zhengguo Canal in terms of uniqueness and peculiarity.

“Densely-distributed and continuous rivulets running to a lake” are referred to as “Lous.” Specifically, these uninterrupted rivulets flow to Lake Tai from south to north to enable flood discharge from the West Tiaoxi River and East Tiaoxi River, and are densely distributed to the east of the Daqian Gang. “Gang” refers to a rivulet located in or to the west of Daqian Gang that is connected to lakes and rivers. “Tang” refers to an “embankment or dike, such as a pond or seawall. Tangs, which are referred to in historical records, are linked to lands with water on the left and right side.” In the Lake Tai Basin, “tang” typically refers to an artificial river water system that runs in an east-west direction and joins with longitudinal rivers. Specific examples include the North Latitudinal Tang, South Latitudinal Tang, Di Tang, Shuanglin Tang, and Lianshi Tang. Pu refers to a “canal that leads to a large river.” In “Water Control,” Wujun Tu Jing Xu Xi states: “a longitudinal Pu is either five or seven li (one li is a Chinese unit of length equal to 500 metres) in length, and a Latitudinal Tang is either seven or ten li long; because embankments are built using soil from Tangs and Pus, Pus and Tangs get deeper and wider, while embankments get higher and thicker, protecting them from water hazards and guiding water to flow into rivers.” In ancient times, Gangs, Pus, and Dus were rivulets and ditches that linked to rivers and lakes. Polders are “also called wei fields (wei meaning embankment); polders are fields surrounded by embankments,” specifically farmlands with "water running outside of embankments and fields taking shape inside of the embankments.” Centuries of manual labor created a chessboard-like water network and polder system that has gradually formed the Lake Tai Basin, featuring “longitudinal Pus (Lous) and Latitudinal Tangs” interlinked with one another [3].

3.2. World cultural heritage value
Lougangs and polders play an important role in water conservancy. According to Kai (2007), “There used to be polders south of the Yangtze River; in each polder, there was a big city that occupied an area as large as dozens of square li, with waterways inside and sluice gates outside. In the event of droughts, the gates opened up to let in river water, while in the event of deluges, the gates were closed to shut out floods”[4].

The Lougang and polder system has created a unique urban and rural settlement system in the southern region of Lake Tai City which features fortification by ditches, the creation of mulberry silk fabrics, farming and fisheries, as well as a network of intertwined canals [5]. These elements have given the area south of the Yangtze River a reputation as a “land of fish and rice” and “the world’s granary” and have influenced the rich cultures of the Wu and Yue feudal states.

“Polders” and “enclosed fields” have several important differences. Polders are intended to manage farmland under flood control. Water and farmland are inseparable and complement one another, as seen in traditional Chinese philosophical concepts such as “harmony between man and nature” and “adroit utilization according to circumstances.” Enclosed fields can destroy the natural ecological environment by taking land away from rivers and lakes, thus resulting in damage to lakeshores, decreased water area, and the blockage of watercourses. The Lougang and polder system continues to function into the present day as an important part of the renowned history and culture of Huzhou City, and holds important historical and cultural heritage value. Its significance and value are comparable to that of the Dujiangyan Irrigation System.
3.3. The Lougang and polder system has witnessed the development of and changes to the northern region of Zhejiang Province

Human civilization on the south bank of Lake Tai developed along endorheic rivers and inlands. The peoples of this region were reliant on the natural topography, and included the Majiabang culture and Songze culture in the swampy areas, the Liangzhu culture along the rivers and mountains, and Gu City in the Warring States. Prior to the construction of hydraulic facilities including the Beijing-Hangzhou Grand Canal and the Lougangs and polders, the early settlers of Huzhou City attempted to construct criss-cross ponds throughout Lake Tai. These efforts artificially transformed Tingzhou Township, and gradually integrated water resource development with city management, farming, fishing, and hunting. This formed symbiotic, interdependent relationships among the cities, townships, forests and fields, that shaped the urban and rural development with the unique economic and social characteristics of Huzhou City.

In the South Lake Tai region today, the Lougang and polder system combined with water environmental governance continues to play a role in storage, drainage, farming, and irrigation, and forms an important component of lakefront eco-conservation efforts, holding considerable historical significance.

3.4. An important part feature of the water network system in the Lake Tai Basin

Ling Jiexi, a famous Qing Dynasty hydrologist and author of the Southeast Water Resources Strategy, reported that the Latitudinal Tang system on the south bank of Lake Tai covered an extensive area with Jinshuanglin Tang as the southern boundary, the lakeside as the northern boundary, Huzhou City as the western boundary, and Nande as the eastern boundary. Huzhou City was located at the center of this water system and Lake Bilang, situated to the south of the city, was a water storage hub that gathered inflows from several counties. Tang lines and Lougangs divided the flows in order to discharge the water. Water resource patterns of the entire area functioned in concert with one another. The water system of the Lougang and polder area was downstream of the East Xitiaoxi River and West Xitiaoxi River, at the end of the river which flowed into the lake. Dai Biaoyuan, a Yuan Dynasty poet, described this in his poem entitled “Huzhou:” “Tianmu Mountains are clustering, and water flows into different Gangs around Lake Tai.” This is a vivid portrayal of the water network system [6].

Huzhou City is located at the junction of the East Tiaoxi River and the West Tiaoxi River. Its inflows come from the west and south of the city, and gather at the Longxi Gang. These inflows run through the eastern and northern gates of the city, down to the Lougang and polder system at the lakeside, and lead to Lake Tai. Huzhou City gathers inflows from the south of the city, and divides the inflows into discharges. These features make the ancient city of Huzhou a gateway from the Tiaoxi Rivers to the lake and acts as a water allocation hub.

3.5. Unique urban and rural water pattern: mountains integrated with water featuring urban and rural symbiosis

Water diversion in the ancient city of Huzhou formed a water city pattern found only in the southern regions of the Yangtze River. This system consisted of inner, middle, and outer rings of moats and multiple land and water gates, namely “three interlinked rings” and “six gates and six joints.” It had a total of six water gates and a city pattern. The Yuliang River (known today as the People Road) forms the axis of the city. This system is not found in any of the other water cities south of the Yangtze River.

The countryside exhibits many more water features than urban areas. This is exemplified by the old saying, “you will come across a bridge every ten steps.” According to the “Huzhou City Annals” compiled in 1993, Huzhou City had over 8,200 bridges in 1990, with an average density of 1.43 bridges per square kilometer; this is more than twice the number of bridges found in Venice, Italy, which is known as the “City of Water”.

Throughout the urban and rural areas of Huzhou are nodes of an agricultural water conservancy ecosystem that comprises the entire Tiaoxi Watershed, separated only by a strip of water. These form part of a complete water system that has been an integral part of the socio-cultural fabric of the region
from ancient times to the present. This integration of mountains, water, cities and the countryside still remains intact, as a model of traditional urban and rural integration in the southern regions of the Yangtze River.

3.6. A compound ecosystem carrying rich resource elements
Invented by the early settlers of Lake Tai, Tangs, Pus, and polders are unique creations that turn sludge into fertile soil. They also represent a major feat of systematic engineering that integrate water conservancy, economy, ecology, and culture, and played an important role in the creation of the cultures of the Wu and Yue Feudal States. They are forbearers of the unique Lougangs and polders located on the western and southern banks of Lake Tai, and are based on the original water network which included natural embankments and piers. These features are located on the southern bank of Lake Tai and feature unique designs and layouts, and demonstrate the ideals of water engineering construction and plains-area water network management. Lougangs and polders are comprehensive historical and cultural resources of the compound ecological system.

3.6.1. Spatial structure of Lougangs and polders. Lougangs and polders allowed for the creation of a farming civilization on the lakeshores of South Lake Tai. The primary elements of the cultural landscape in this region are Lous, Gangs, embankments, fields, bazaars, sluices, stone bridges, temples, pavilions, water tankers, quays, and revetments. The countryside distinctively integrates natural and artificial facilities [7].

3.6.2. Distribution of cultural relic resources. Cultural resources on the lakeshores consist mostly of rural construction and include villages, bridges, dwellings, memorial archways, and ancient ruins. There are few intact ancient villages. The geographical dispersion of the villages make them difficult to protect, which increases the importance of protecting the historical environment of the cultural relics. After the third national survey on cultural relics, a number of traditional constructions were added to the protected list. This adds to the significance of exploration and enhancement of the historical and cultural values of lakeshores. There are examples of renowned cultural heritage in the Lougangs along Lake Tai, such as the Cliff Inscriptions of Huanglong Hole, Bachelor Fei’s Cemetery at Taishi Bay, Bailian Bridge, Daqian Chastity Memorial Archway, and ancient lake bridge groups.

3.6.3. Distribution of tourism resources. Rural tourism resources are divided into two categories: natural human and rural human landscapes. These resources can be divided into eight districts, according to their distributions and agglomerations along the lakeshores: Jia Pu, Sheng Jiadang, Xintang, Bianshan Mountain, Daqian, Huan Lou, Yigao, and Yangxi. The largest number of tourism resources are intensively grouped to the east of Bianshan Mountain [8].

4. Evaluation of current situations

4.1. Evaluation of current preservation efforts
Lougangs are ancient water resource engineering projects that continue to function. Those located in Huzhou City remain the regional backbone of irrigation, flood control, and flood drainage irrigation projects. In recent years, issues have resulted from urbanization including blockages of the Lougangs, excessive gardens, and intensive real estate development. These issues affect the functional performance of the Lougangs and destroy the historic landscape.

4.1.1. Lougangs. The overall Lougang system pattern still exists. The watercourse is an average of approximately 2-3.5 meters wide. The northern ends of the Lougangs primarily lead to Lake Tai, or are indirectly connected to Daishan Gang or Di Tang.

The siltation in the Louongs is gradually worsening as a result of nearly 30 years of the present market economy and the dredging up of river sludge with nets and other traditional dredging measures.
A number of the Lougangs connected to the lake exhibit signs of decline. In the 1990s, there was a total of 73 Lougangs connected to Lake Tai; by 2000, that number dropped to 47, and in 2015, only 39 Lougangs existed, of which 34 did not lead to the lake. Portions of the embankments, ancient bridges, and water deity temples located on the ancient Lougangs have been ravaged, and lake inlets for Lougangs have been blocked. This is the result of lacking water resources, limited protection for cultural relics, and insufficient mutual cooperation between urban construction and other departments that impact the Lougangs. Ancient lake floodgates associated with the Lougangs have disappeared and the ancient stone bridges of the Lougangs have been destroyed. Occasionally, the former silting sections of the lake inlets occupied by the Lougangs have also been used for residential construction.

4.1.2. Latitudinal Tangs. A majority of the Latitudinal Tangs have been blocked and subsequently lost their integrity. Three primary Latitudinal Tangs remain largely intact: Di Tang, Northern Latitudinal Tang, and Southern Latitudinal Tang.

4.1.3. Crisscross ponds. The large-scale expansion of urban construction and high-profile engineering projects of recent years have resulted in rivers and ponds filled with mud and the removal of land from waterways in order to satisfy land consolidation and transportation construction needs. This phenomenon is becoming more and more impactful, and has resulted in the weakening of pond functions such as adjustment, storage, and riptide cushions. Industrial development has also introduced water pollution problems.

4.1.4. Water resource engineering facilities. A large number of sluice gates and culverts in Huzhou City have been closed, including Pu Gang, Chen Lou, and Shen Lou; only ten functional sluice gates remain. A total of 18 gates have been disabled, but relics of the watercourses still exist. Only 21 gates retain flood control, irrigation, and transportation functions.

4.1.5. Polders. Urbanization has led to substantial reduction of polders. The traditional farming mode of ponds surrounded by mulberry embankments has disappeared. Under the traditional mode, mulberries were planted on the embankments of ponds and fish were kept in the ponds; silkworms fed on the mulberry leaves, fish fed on silkworm feces, and mulberries were cultivated in the pond mud. The embankment agricultural system is increasingly shrinking. Watercourses and other primary water resource systems have long been in a state of disrepair and subject to severe silting. Environmental pollution also exists, resulting in important historic sites now on the verge of disappearing.

4.2. Evaluation of management status
Water resource heritage features are located in two administrative districts of Huzhou City: Wuxing District and Changxing County. Water systems are under the management of departments at the provincial, municipal, and county levels. Farmland systems are supervised by competent land, resource, and agricultural departments. Heritage feature protection involves the activity of multiple departments including planning, cultural relic protection, water conservancy, and environmental protection, among others. Multi-departmental management involving administrative jurisdictions and administrative subjects can lack professional coordination at the municipal level. Without over-arching planning efforts, unified management and control, and guidance for the protection and utilization of the Lougang water resource heritage features along Lake Tai, harmonious development is difficult to promote.

4.2.1. Foundation of systems. In recent years, the value of the Lougang water resource culture heritage features has been widely recognized by both the government and the public, both of which have begun to pay increasing attention to heritage protection. Massive amounts of manpower, materials and financial resources have been contributed to protection of the heritage features, and
considerable success has been achieved. The social and economic benefits of the Lougang water resource heritage feature protection are remarkably increasing.

4.2.2. **Major issues.**

Lougangs are the purview of the departments of water conservancy, transportation, municipal administration, and cultural relics. The administrative system must be better organized, as it currently lacks targeted management measures. The protected areas are over-developed without approval of the governmental departments, and the first line of heritage management personnel lack necessary professional qualifications. The socio-cultural heritage of the Lougangs will be destroyed by new construction if proper steps for their protection are not enacted immediately.

4.3. **Evaluation of current utilizations**

Lougangs are ancient water resource engineering projects that continue to function into the present day. Latitudinal Tangs and longitudinal Gangs still play a functional role in flood control, flood drainage, water supply, and water conservancy. The polder irrigation and drainage system still functions. Continued work must be done in order to preserve the status and raise awareness of the historic value of the Lougangs. Care must be taken to balance preservation efforts with local development efforts. The general history and culture of Huzhou has a stronger local and international reputation than the Lougangs. Local first-line government organizations and rural communities are greatly aware of the need to protect the Lougang culture. This can be capitalized on while working toward the historic preservation of these important heritage sites.

5. **Countermeasures of protection and utilization**

The overall goals of protection and utilization are to:

- Scientifically protect the remarkable historical and cultural water conservancy heritage features of the region,
- Protect the unique regional agricultural irrigation system,
- Thoroughly understand the cultural influences of Lougang water resources,
- Arrange engineering and non-engineering measures for Lougang water resource heritage feature protection,
- Restore natural and landscape environments in the Lougangs and embankment area,
- Achieve coordinated development of protection and utilization, and
- Realize permanent protection for the Lougang water resource heritage features.

The features discussed below are important to the realization of these goals.

5.1. **Weighing the spatial levels of point, line, and surface in Lougang heritage**

It is important to protect and develop according to a point-line-surface system. In this context, point refers to the use of an opening or a control engineering project of the Lous, or an ancient bridge, as a key node; line refers to a linear engineering system, such as a watercourse or an embankment; and, surface refers to a regional polder system comprised of typical plots interspersed with points and lines. Combining point-line-surface features allows for the protection and utilization of the Lougang water resource heritage features at all spatial levels.

When balancing the technical, economic, social, and landscape aspects of heritage preservation, it is important to identify and distinguish between the different value characteristics of important sections. Systematic protection should be applied to relics and their background environments. Core protection, utilization, and exhibition efforts should focus on specific items, such as the openings of the Lous, criss-cross ponds, key projects, typical polders, historical bridges, cultural heritage, and ancient villages and blocks. The spatial network of the Lougang water resource engineering system should be built using Latitudinal Tangs and longitudinal Gangs as the backbone of watercourses and embankments. When these efforts are combined with the polder system located between Lougangs,
the surface of the Lougang water resource heritage features along Lake Tai will begin to take shape. These steps can be undertaken to develop a systematic, complete, and explicitly-structured heritage plan for protection and utilization.

5.2. *Functions come first with reasonable protection*

Heritage protection and management measures should be based on sustainable development of water conservancy and water transport functions, such as flood control and irrigation. The integrity of the Lougang irrigation system should be maintained, and continued protection of ancient features should be enacted. Preservation of historical information should be maximized, with minimal intervention to the heritage features. Advanced global concepts and technical means of protection should be introduced to promote multi-disciplinary cooperation. The disciplines of water conservancy history, heritage protection, and historical geography should collaborate on in-depth research into the scientific and cultural value of the heritage features. Both engineering and non-engineering protection measures should be employed in water resource feature studies.

The public should be encouraged to participate in the protection of heritage features, and multi-objective development should be promoted and prioritized during the coordination and development of efficient agriculture, ecological agriculture, and tourism agriculture in addition to heritage protection. Furthermore, in the water environment and ecology of the Lougangs and criss-cross ponds, a comprehensive restoration should be performed, with reasonable utilization of lakeshores and planning of greenway or landscape belts that function both for recreation and for the display of the Lougangs.

Traditional construction technology and traditional materials should be used in the maintenance and repair of the Lougang water resources heritage features. Furthermore, maintenance and repair should be undertaken by knowledgeable and qualified organizations for the preservation of water resource engineering cultural relics protection. These organizations should attempt to maintain the status quo.

No restoration efforts should be undertaken at this time to restore the missing components of Lougang heritage features. These steps should only be enacted after careful assessment of the scientific, historic, and cultural value of the missing components. Rehabilitation must be implemented in consultation with experts and with the approval of the municipal government.

5.3. *Adaptation to local conditions and cultural experiences*

A museum devoted to the Lougang water resource heritage features should be established. At this museum, indoor exhibitions will focus on the Lougang heritage features as well as the regional culture and folk customs. There will also be two outdoor display areas for Lougang water resource heritage features, one display area for the Yigao Lou, Chen Lou, Pu Lou and Daqian Gong water management features, and another for polders or fish ponds surrounded by mulberry embankments.

Key Lougang engineering projects must undergo emergency maintenance and repair. Conscientious conservation plans should be made for the water resource heritage features of Lougangs and polders, and further exploration should be conducted into the profound culture. Emergency repairs should be conducted on a number of Lougang hydraulic buildings.

A cultural tourism brand for the Lougangs should be created. Tourism efforts should focus on the construction of greenways, bicycle races around the lakes, and other activities to draw attention to the unique features of Lake Tai [9].

6. *Conclusion*

Lougangs along Lake Tai are part of China’s unique water conservancy heritage system. This system includes the Lake Tai embankment engineering projects, the Lougang and Tang system, the polder and canal system, and other related heritage features. Lougangs along Lake Tai are of important scientific and technological significance because of their rational layouts, complete engineering systems, use of gate dams and sluice gates for water storage and discharge, and their comprehensive utilization of water resources. Furthermore, Lougangs possess profound cultural value and systems which represent
more than a millennium of historical and cultural development. This includes their mechanisms, laws, and water management regulations; ancient bridges; records; inscriptions; poetry; irrigation; festivals; and folk customs. In addition, their evolution created a variety of colorful ecological environments and landscapes which highlight the complexities of the harmony between humans, land, and water.

Lougangs are ancient water conservancy projects which still function and serve as major regional irrigation, flood control and drainage projects in Huzhou City. However, the level of awareness of Lougangs has yet to reach a level that will effectively protect these unique cultural heritage features. This paper offers countermeasures using principles, restrictions, and specific measures regarding water resource protection and utilization that aim to promote the coordinated protection and utilization of the water heritage sites and to realize the permanent protection of the Lougang water conservancy heritage features.

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