EASTM 51-52 (2020): 51-89

Science and Politics in China's Official Water System: the Management of the Qiantang River (1927-1949)*

Li Haijing and Sally K. Church

[Li Haijing is an associate professor at the Water Culture Institute at Zhejiang University of Water Resources and Electric Power, Hangzhou. Having received her Ph.D. from the University of Science and Technology of China (USTC) in 2017, she focuses on the history and culture of water conservancy, especially concerning the Qiantang River between 1927 and 2011. She was a visiting scholar at the Needham Research Institute in 2017-2018, supported by the Li Foundation of New York. Her most recent article, co-authored with Wu Huiyi and Han Cengui, published in Ziran bianzhengfa yanjiu 自然辯證法研究 *36.1 (2020), is on Joseph Needham's investigation of the Qiantang River during his visit to China in 1964. Contact: lavalhj@126.com]*

[Sally K. Church is an Affiliated Researcher in the Faculty of Asian and Middle Eastern Studies, Cambridge, and a Research Associate at the university's Centre of Development Studies and at the Needham Research Institute. With research interests in diplomacy and transport on both the maritime and overland Silk Roads, she has most recently focused on the size of Zheng He's ships, shipbuilding in Nanjing's Longjiang Shipyard, and the diplomatic missions of Chen Cheng to Herat in the Ming period. Contact: skc1000@cam.ac.uk]

* * *

* **Acknowledgements**: The authors would like to express their gratitude to Prof. Shi Yunli 石云里, Prof. Chen Kunlong 陈坤龙, Prof. Christopher Cullen, Prof. Catherine Jami, and the two reviewers, for their advice and guidance. This research has received funding from the following grants: "2020 nian Zhejiang sheng shehui guihua keti: Minguo shiqi Qiantang jiang zhili shi yanjiu," 2020 年浙江省社科规划课题：民国时期钱塘江治理史研究 (Code: 20NDJC211YB); "2019 niandu shuiwenhua yanjiu keti: Qiantang jiang liuyu guhaitang yiji xianzhuang diaocha jiqi wenhua yichan jiazhi yanjiu," 2019 年度水文化研究课题：钱塘江流域古海塘遗迹现状调查及其文化遗产价值研究 (Code: SWH201902); "2017 nian guojia waizhuanju gaoduan xiangmu: Huanghe wenming de haiwai chuanbo yu silu yanxian wenming gongrong yanjiu," 2017 年国家外专局高端项目：黄河文明的海外传播与丝路沿线文明共融研究 (Code: GDW20174100155).

Abstract: Western water science and technology were introduced to upgrade China's traditional water management methods and strategies during the Nanjing decade (1927-1937) under the Nationalist government. The engineering efforts expended to control the Qiantang River were typical examples of such initiatives. The primary strategy to protect areas surrounding the river from the destruction caused by the Qiantang bore was for centuries one of "passive defence", with the construction of defensive seawalls featuring prominently among the methods used. However, the Qiantang tide consistently broke through these defences, and caused devastation. After 1927, while the old defensive methods were not completely discarded, more active strategies of river regulation were introduced, under the combined influence of Western methods, materials and expertise, and Western-trained Chinese engineers who stepped forward to tackle the problem. These activities were interrupted during the war years (1937-1945), but resumed again after the war. During the 22 years from 1927 to 1949, in four discrete stages, different technological solutions were devised, priorities identified, guidelines developed and strategies attempted, with each stage championed by a different engineer in charge. Gradually these efforts formed into what can be called the Qiantang River Project, a concerted effort to apply the knowledge of Western science and technology to change previous "passive defence" methods to "active governance" strategies for river regulation that combined both prevention and control. Efforts at each stage were influenced by factional struggles at the top of the government, and also affected by Western competition for Chinese interests. These developments were all part of the complex interaction of science and politics that took place in the management of the Qiantang River between 1927 and 1949.

Introduction

Since 1840, the introduction of Western water conservancy science and technology has had a profound impact on Chinese water conservancy construction methods. Western hydraulic experts and specialised Chinese engineers educated in Western water science began to dominate hydraulic engineering in China. This paper, which builds on a previous paper published in 2017 in Chinese,[1] describes one example of this phenomenon: the engineering efforts carried out in the Republican period to control the

[1] Li and Shi (2017). This research was funded by the Li Foundation of New York and the Needham Research Institute, as well as the China Association for Science and Technology's "Data Collection Project on the Academic Growth of Older Scientists" (Item number: CJGC2016-GKD09).

Qiantang 錢塘 River. These efforts took place in four stages, each directed by a different engineer who attempted to apply Western scientific knowledge and expertise to a single problem: controlling the Qiantang River to prevent flooding and the resulting damage to the surrounding areas. In each case, the engineering work centred mainly on the Qiantang estuary.[2]

Because these efforts all had the same goal, and were similar in other aspects, we argue that they led to the gradual formation of what might be called the Qiantang River Project. All four stages of this project shared a number of common features and methodologies: in addition to facing certain international tensions and conflicts between science and politics, they can be seen as the gradual evolution of a single project to apply Western technology, knowledge and expertise to the control of the Qiantang River, even though the precise measures recommended in each stage, and the individual experiences of the engineers in question differed in certain ways. Because the proposed measures were cumulative, with each subsequent stage for the most part incorporating and building on the suggestions made in the previous stages, we argue that they can best be analysed as stages in a single project.

This paper takes a slightly different approach from the 2017 Chinese paper. It traces the evolution and development of the Qiantang River Project through four key stages during the period from 1927 to 1949. The first three stages took place between 1927 and 1937. Then work on it had to be halted because of the Anti-Japanese War (1937-1945). It resumed after 1945 and work on the fourth stage took place between 1945 and 1949. Each stage was led by a different Western-educated specialist in hydraulic engineering, who worked together with the Chinese government to reduce the negative impact of the Qiantang bore on the coastal and inland areas of Zhejiang province around Hangzhou. The measures taken were based on scientific analyses of the problem and knowledge of existing solutions, but they were not purely a matter of science and technology. Because this was such a turbulent time, political issues often entered into the equation. In each case the interaction between science and politics helped to shape the direction that the project took, often presenting obstacles to progress. However, the obstacles were ultimately overcome. The project evolved gradually into one that was successful in creating a new strategy and set of guidelines for the control of the Qiantang River, and formed the basis for measures that are still in use today.

The Qiantang estuary is located in the coastal area where the Qiantang River meets the East China Sea. One of the most prominent features of its

---

[2] The Qiantang estuary lies south of the Changjiang (Yangzi) River estuary and north of the hilly region of Zhejiang from Wenyan 聞堰 to Ganpu 澉浦. See Han *et al*. (2002).

natural landscape is the Qiantang tidal bore. The Qiantang bore is not unique—there are about 450 estuaries and bays in the world with tidal bores.[3] According to the height of the tide and its speed of travel, some scholars have ranked the Qiantang bore first among the top ten in the world. The others are the bores of the Amazon River (Brazil), the Seine River (France), the Petitcodiac River (Canada), the Severn River (UK), the Gironde River (France), the Shubenacadie River (Canada), the Turnagain Arm (USA), the Salmon River (Canada) and the Hoogly River (India).[4] Among these, the Qiantang tide was described by Commander W. Usborne Moore as "the strangest, rarest, and most wonderful sight in the world".[5] The exceptional height and speed of the bore are the result of the interaction of the tide-generating force of the earth-moon-sun system with the horn-shaped estuary and large sandbars at the mouth of the river.[6]

Apart from being a fascinating phenomenon of nature, the Qiantang River and its surrounding region has a distinctive economic status in China.[7] To the north is the Hang-Jia-Hu 杭嘉湖 plain, and to the south the Xiao-Shao 蕭紹 plain. According to economic and social statistical data from 2005, the land area of these two plains combined is equal to 19,200 sq. km, constituting 19% of the arable land of Zhejiang province. The total population of these two plains is 15.2 million, accounting for 35% of Zhejiang province. The GDP of the two plains accounts for 51% of the province's GDP according to early twenty-first century data,[8] and the Qiantang estuary has been one of the most economically developed areas not only in Zhejiang but in China as a whole.[9] On the other hand, the Qiantang tide has caused many natural disasters and flooding. From 619 to 1948,

---

[3] Chanson (2011).

[4] Sentinelles Petitcodiac Riverkeeper (2001); Pan (2007).

[5] Moore (1888).

[6] Chen *et al.* (1964); Harris (1988); Dalrymple *et al.* (1990); Kunte *et al.* (2005); Yu *et al.* (2012).

[7] The Hang-Jia-Hu plain is named after three cities: Hangzhou 杭州, Jiaxing 嘉興 and Huzhou 湖州. It is located in the northern part of Zhejiang province, south of the Taihu river basin (Taihu liuyu 太湖流域), which is the largest plain in Zhejiang province. Its geographic scope includes the area south of the Taihu, the north of Qiantang River and Hangzhou bay, and east of Tianmu 天目 mountain. Its administrative scope includes Jiaxing, most of Huzhou 湖州, and northeastern Hangzhou; it is part of the Yangtze River plain. The Xiao-Shao plain (Xiao-Shao pingyuan 蕭紹平原) is named after Xiaoshan 蕭山 and Shaoxing, also in Zhejiang province. It consists of the districts of Xiaoshan, Binjiang 濱江 and the city of Shaoxing.

[8] Zhejiang sheng tongji ju tongji nianjian (2006).

[9] Zhejiang province is the main source of China's national financial income. Its GDP ranked fourth in China in 2005.

disasters of this kind have been recorded approximately 183 times, twelve of which took place in the Republican period.[10] For example, in June 1932, the area between Qingtai Gate 清泰門 and Qibao 七堡 in Hangzhou lost more than 200 hectares of sandy land.[11] Therefore, successive local governments have paid special attention to the Qiantang River, which became a keen focus of attention during the Qing and Republican periods.

Perspectives on the Qiangtang Tide in China and the West

Reports of the unusual phenomenon of the Qiantang bore have been made for centuries. Writing in the first century BCE, Sima Qian 司馬遷 relates in his *Shiji* 史記 (*Records of the Grand Historian of China*) that when the First Emperor of China, Qin Shihuang 秦始皇, travelled to this region on an Imperial Progress in the third century BCE, he did not dare to cross the Qiantang River because of the ferocious tidal bore.[12] Local officials also began to look for solutions early on. Liu Daozhen's 劉道真 *Qiantang ji* 錢塘記 of the Eastern Jin (Xijin 西晉, 265-316) period contains the earliest record of the construction of a seawall on the Qiantang River. According to this text, a person named Hua Xin 華信 constructed a seawall of earth and stones to control the tide.[13] Disasters on the Qiantang River are mentioned in Tang, Song, Ming and Qing sources. They often posed threats to the Taihu plain, one of the rice-bowls of China and it has been a priority for the both central and local governments to avert these disasters throughout Chinese history. Before the twentieth century, the Chinese government pursued an essentially defensive policy, preventing the flooding of arable land and devastation of granaries by building defensive seawalls along the northern and southern banks of the river. Limited by the state of its technological development at that time, China could not completely eliminate the tidal bore. The result was that many sturdy seawalls were built, now called the "Great Wall of the Sea" (*hanhai changcheng* 捍海長城).

When Westerners first saw the bore, on the other hand, they tended to see it as a natural wonder, a unique natural phenomenon.[14] The first Western report of the bore was by Commander W. Usborne Moore of the Royal Navy. When his fleet arrived at Hangzhou bay in September 1888, it was unable to enter the city by water because of the tidal conditions. His

---

[10] Qiantang jiang zhi bianzuan weiyuanhui (1998), pp. 132-133.

[11] Qiantang jiang zhi bianzuan weiyuanhui (1998), p. 135.

[12] *Shiji*, *juan* 6 "Qin Shihuang benji," p. 260.

[13] Wang (1984), pp. 1252-1254.

[14] Nowadays, it is a government requirement that if immersed structures are to be built on the Qiantang River, the impact of the project on the tide bore must first be studied. Zhejiang Institute of Hydraulics and Estuary specialises in evaluating the influence of such projects. If the project has a significant impact on the tidal bore, it will be disallowed, or a design change may be imposed.

discovery of the Qiantang bore motivated him to carry out a detailed investigation involving extensive research on it, which he described in detail, including its height, time of arrival and many other details. This report is the first modern hydrological survey we have concerning the Qiantang bore.[15] In 1923, A. C. Moule published a survey of the knowledge of and legends surrounding the Qiantang tide as recorded in Chinese historical materials.[16] Joseph Needham examined Moule's research and made an in-depth study of ancient Chinese perceptions of the tidal bore, comparing Chinese and Western understandings.[17] In 1964, Needham visited the Qiantang River and investigated the Qiantang seawall personally. His account of the history of the construction and development of the engineering on the Qiantang seawall was based on these investigations.[18]

Many other twentieth-century scholars from the fields of natural and social sciences have studied the tidal bore and the ancient seawall of the Qiantang River. Several Chinese scholars have written monographs on the history of water conservancy in China, all of which dedicate a section or even a chapter to the Qiantang tide.[19] Chinese scholars have also studied the construction and historical evolution of the Qiantang seawall.[20] Mark Elvin and Su Ninghu have published their extensive research on the morphological changes and dynamics of estuaries, and the problem of the sediment from the sea in the Hangzhou bay.[21] Two hydrological engineers, Tao Cunhuan 陶存焕 and Zhou Chaosheng 周潮生, both of whom had worked on the Qiantang River, made an in-depth study of the ancient seawall, and discussed the introduction of Western technology and the development of basic scientific research on the problems posed by the Qiantang River during the Republican period.[22] These studies have focused on the subject from a scientific and technological point of view. However, they have not included the political dimension in their discussion: the problems faced by Chinese engineers who tried to implement practical measures to solve the key problems involved in taming the Qiantang River. Pierre-Étienne Will's study of civil engineers in early twentieth century

[15] Moore (1888), pp. 39-46.

[16] Moule (1923).

[17] Needham and Wang (1959), p. 494.

[18] See Li, Wu and Han (2020); Needham, Wang and Liu (1971), p. 323.

[19] Zheng (1939), p. 2; Zheng (1987), pp. 188-220; Shen and Zhang (1979); Yao (1987), p. 279; Zhou (2002), pp. 381-385.

[20] Zhu (1955); Wang (1988), p. 5; Zhang (1990), p. 5; Chen (2000); Tao and Zhou (2001); Jiang and Tao (2002).

[21] Elvin and Su (1998).

[22] Tao and Zhou (1992), pp. 1005-1010.

China, while mentioning at least one of the key figures involved, does not specifically address the Qiantang bore.[23]

This article therefore includes the political dimension (both national and international) in its study of the evolution and development of the Qiantang River Project. The primary focus here is on the four stages of development that occurred in the Republican period under the Nationalist government based in Nanjing. The period from 1927 to 1937 was one of relative peace and stability when the focus of the development was on infrastructural development and when Western science and technology was available for application to practical problems. The first three stages took place during this period. There was then an interruption from 1937 to 1945 because of the Anti-Japanese War, but work was resumed after the war and the fourth stage took place in 1946-1949. Below we will describe the approach taken in each of these four stages of development, and the personalities involved, as well as the difficulties faced and overcome, with special attention being paid to the interactions between science and politics during these different stages.

Technical Aspects of Qiantang River Defences

The Qiantang bore poses two major risks to the surrounding countryside. The first danger is the bore itself and the floods it causes, which are often powerful enough to put most seawalls at risk of collapse. When the seawall collapses, seawater flows into the inner river and affects the Lake Tai basin (Taihu liuyu 太湖流域), resulting in crop failures, displacement of the population, and losses in government tax revenue.

For centuries, seawalls have been built on the banks of the river to protect the plains and act as defences against the tidal bore. Many different types of seawall were constructed from the Tang to the Qing periods, including earthen walls (*tutang* 土塘), walls made of wooden stakes (*chaitang* 柴塘), walls of mixed earth and stone (*tu shi hunhe tang* 土石混合塘), bamboo-basket and wooden-box stone gabions (*zhulong mugui shi tang* 竹籠木櫃石塘), stone walls (*shi tang* 石塘), and so-called 'fish-scale' stone walls (*yulin shitang* 魚鱗石塘).[24] Throughout this long period, the technology of seawall construction was constantly being improved to meet the needs of daily production and living conditions. New, stronger stone seawalls were

---

[23] Will (2019). We are grateful to one of the reviewers for bringing a number of important studies to our attention. Unfortunately, language barriers have prevented us from using the article by Thomas Harnisch (1999) published in German. We hope that readers able to consult this article will find it useful.

[24] Fish-scale stone seawalls were built on the beach, supported by wooden posts (*muzhuang* 木樁), with a large strip of stone as the body. The stone is attached to a butterfly rivet (*hudie tie* 蝴蝶鐵), with an adhesive made of glutinous rice lime (*nuomi shihui* 糯米石灰), which formed the completed gravity-type stone seawall.

created by Huang Guangsheng 黃光昇[25] (1506-1586) in the Jiajing 嘉靖 period (1522-1566) of the Ming dynasty, but the government did not have enough funds at that time to construct an entire new stone seawall on the north bank of Qiantang River.

The construction of defensive walls against the bore is part of what we are calling a "passive approach" to the Qiantang River. This method continued to be used until the Ming period. With the strengthening of the imperial power in the Qing period, particularly in the eighteenth century, the Qianlong emperor (r. 1735-1796) adopted more aggressive defensive measures than had been used in Ming dynasty, calling it the strategy of "Don't give an inch; work once, rest forever" (*cunbu burang, yilao yongyi* 寸步不讓，一勞永逸) strategy, replacing the policy of "Retreat step by step, don't fight for land against the sea" (*bubu tuirang, bu yu hai zhengdi* 步步退讓，不與海爭地) of the Ming period.[26] Specific measures adopted during the Qing included the construction of a permanent stone seawall and the formation of a sophisticated protection system on the north bank: see Figure 1. There was also another change: the growing importance of the seawall led to its construction being considered a national rather than local responsibility, with funding provided centrally rather than locally. Moreover, the aim changed from protecting the Grand Canal to protecting the entire Hang-Jia-Hu plain 杭嘉湖平原. This trend has continued into the modern period.

The second danger posed by the Qiantang River consists of the changes that occur in the course of the river. Because the channel (*jiangdao* 江道) of the Qiantang River is very wide and the water is very shallow, many disasters have come about when the water has changed course. Historically, the Qiantang estuary consists of three channels: the south gate channel (*Nan da men* 南大門) near the south bank, the middle-small gate channel (*Zhong xiao men* 中小門), and the north gate channel (*Bei da men* 北大門) near the north bank (shown in Figure 2, p. 60). The mainstream of the river often switches from one of these gates to another. The switch occurs at unpredictable intervals of between three and twenty years; sometimes

[25] Huang Guangsheng was a statesman, strategist, jurist, hydrologist and historian, who advocated education. He was appointed Assistant Surveillance Commissioner (*anchashi qianshi* 按察使僉事) in 1541, and presided over the construction of water conservancy projects. He created the technique of building "five vertical and five longitudinal" fish-scale stone seawalls, which reached the peak of seawall construction technology at the time. *Mingdai zhiguan Zhong-Ying cidian* (2017).

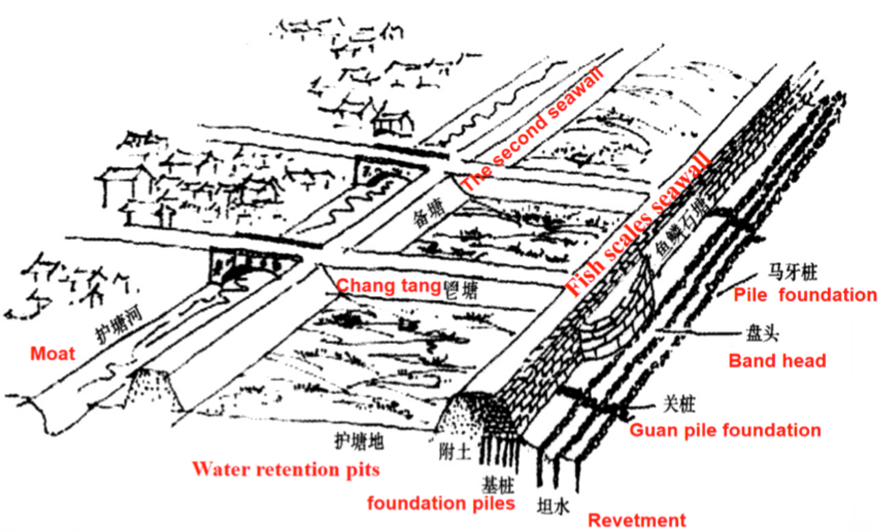
[26] When seawalls were destroyed by the tide, the Ming and previous dynasties constructed new seawalls on river beaches further from the river. The Qing employed different measures and built even stronger seawalls where previous ones had collapsed in order to protect against flood.

every three years, sometimes every five years, sometimes every ten years, and so on. There are records of these changes in local gazetteers (*difang zhi* 地方志), memorials (*zou zhe* 奏折) and official reports (*guan bao* 官報).

When the river channel is stabilised at the north gate, a bar of silt or sand forms on the south bank. Because the overall trend of the mainstream remains uncertain, the local people develop and use the marshland to plant all kinds of crops, build salt fields, and even create settlements. Then, when the main channel suddenly changes again, the sedimentary land on the south bank starts to collapse.[27]

Since 1927, with the introduction of Western water science and technology, Chinese hydraulic experts were no longer satisfied with the defensive approach to the control of the Qiantang bore, e.g. by building seawalls. Instead, they hoped to solve the fundamental problem by proactively controlling the channel. This new approach was a radical change from the past, from passive defence to proactive control. However, they did not abandon defensive measures entirely and the new policy is called "prevention and control" in this paper. Between 1927 and 1949, the implementation of the "prevention and control" policy on the Qiantang River proceeded in four stages, led by four engineers. In chronological order, these were Xu Kai 須愷, Ludwig Brandl, Zhang Zili 張自立 and Zhang Shunong 張書農. The following four sections will introduce their work and their proposals for solving the problem of controlling the Qiantang River.

Figure 1. The overall protection system under the Qing dynasty



SOURCE: Lin (2010), p. 82.

[27] "Zhejiang shuizai ji" (1926).

Figure 2. Sand-Water Situation Map from Renhe (present-day Hangzhou) to Haining in the Qianlong period

SOURCE: Taibei gugong bowuyuan 台北故宫博物院 (Taipei Palace Museum).
NOTE: The Qianlong Emperor required local officials to submit sand-water maps on a regular basis and to report in memorials on the changes in sand and water conditions along the Qiantang River. The darker colours in the illustration indicate long-standing, or "old sand" (*lao sha* 老沙), and the light shades indicate newly formed "new sand" (*xin sha* 新沙). From the changes to the sand along the beaches, it is possible to understand the path taken by the mainstream of the river when it changes course.

1. Xu Kai's Proposal (1927-1928)

Figure 3. Xu Kai

SOURCE: Baidu Baike, URL: https://baike.baidu.com/pic/须恺/4210598/0/9a1151c2767d4b0ae5dd3bc4?fr=lemma&ct=single#aid=0&pic=9a1151c2767d4b0ae5dd3bc4, accessed on 10 May 2019.

Xu Kai was born in Wuxi 無錫 in Jiangsu province. In 1915, he enrolled in the first class of the Hehai Engineering School (Hehai gongcheng zhuanmen xuexiao 河海工程專門學校) in Nanjing.[28] In 1920, he was recommended by his school and the Shunzhi Conservancy Commission (Shunzhi shuili weiyuan hui 順直水利委員會) in Tianjin to work in the Turlock Irrigation District in California. He studied in the Department of Irrigation, University of California, San Francisco in 1922. While in the United States, he conducted field trips to investigate various water conservancy construction projects in Illinois, New York and Chicago. He returned to China in 1924 with a master's degree and then engaged in the planning and designing of the Jinghui canal (Jinghui qu 涇惠渠) in the

[28] Xu Kai is mentioned in Will (2019), pp. 97-100. Also known as Hohai College of Engineering, the Hehai Engineering School was founded in 1915 by the educationalist and industrialist Zhang Jian 張謇 (1853-1926). It was the first institution of learning in China to specialise in water conservancy, and pioneered education in water management.

Shaanxi Bureau of Water Conservancy (Shaanxi shuili ju 陕西水利局),[29] as assistant to Li Yizhi 李儀祉 (1882-1938).[30]

The year 1927, when Chiang Kai-shek 蔣介石 came to power, marked the end of the warlord period. China was now unified and began rebuilding its infrastructure. Because some of the seawall had collapsed, the tidal bore threatened the north-south plains. To address this problem, the Zhejiang government reconstituted the Qiantang River Seawall Engineering Bureau (Qiantang jianghai tang gongcheng ju 錢塘江海塘工程局)[31] to manage both the northern and southern seawalls.[32] We see the formation of this Bureau as the launch of what we have called the Qiantang River Project. The first step taken by the Bureau was to make regulations explicitly requiring that its various sections be headed by engineers, and that hydraulic experts be invited to take charge of the engineering work, thus forming the so-called "expert governance system".[33] In 1927, Xu Kai was appointed as an engineer in the Hanghai 杭海 department of the Qiantang River Engineering Bureau. One of his major achievements was to submit a proposal to the government in November of that year, entitled "An Opinion on the Governance of the Qiantang River" (*Zhili Qiantang jiang yijian shu* 治理錢塘江意見書). In it he suggested the following courses of action:[34]

1. Develop the upstream region comprehensively; and fully utilise hydroelectric resources.
2. Control the channel to prevent the collapse of the south bank. Build spur dikes (*dingba* 丁壩) to reduce the impact of the tide and limit channel shifts.
3. Perform basic scientific research, such as carrying out hydrological, topographic and other surveys.
4. Implement long-term plans for the construction of new seawalls, harbour, and channels.
5. Ensure unified management of all projects so that the construction of the seawall, the regulation of the river and any measurements are carried out by the same organisation.

This proposal received support from the politician He Yingqin 何應欽 (1890-1987), chairman of Zhejiang provincial government (Zhejiang sheng

29 'Zhongguo xiandai shuili renwu zhi' bianshen lingdao xiaozu, bianzuan bangongshi, bianji bu (1994), p. 328.

30 Li Yizhi presided over the construction of the Jinghui canal in Shaanxi province. He was a famous hydrologist and educator from Puxian 蒲縣, Shaanxi, and became an expert in hydrology in 1930.

31 "Choushe Qiantangjiang gongchengju an" (1927).

32 The seawalls on the northern and southern sides of the Qiantang River have historically been managed by two different institutions. This reorganisation has unified the management of the seawalls on both sides of the river.

33 Zhejiang sheng zhengfu weiyuanhui (1928).

34 Xu Kai (1927).

zhuxi 浙江省主席).[35] The Zhejiang government issued a decree "demanding that the engineers carry out research to find a permanent strategy and approach to eliminate disasters on the Qiantang River, by replacing the temporary scheme for repairing and building seawalls".[36] This decree makes several things clear. First, the government did not have a permanent, long-term strategy before this time. Second, politicians were interested in developing a long-term strategy and the government listened to the advice of the engineers and followed their advice to some extent. Finally, the government recognised the prevention strategy of seawall construction and repair as a temporary measure that it wanted to supplement it with other, more scientific measures of controlling the river. This was the beginning of a new era. At Xu Kai's instigation, China's approach to the Qiantang River changed from "prevention" to "prevention and control". This stage is therefore the first step in the formation of the Qiantang River Project.

Unfortunately, Xu Kai was unable to carry out his plans for the Qiantang River. Here, politics came into play. When He Yingqin left Zhejiang to return to the military on 7 November 1928, the leadership of the Zhejiang Construction Department and the Qiantang River Seawall Engineering Bureau changed. That same year, Xu Kai left Zhejiang for Nanjing, where he was appointed professor at the Department of Civil Engineering, Fourth Zhongshan College, Nanjing National University (Nanjing guoli disi Zhongshan daxue gongxueyuan 南京國立第四中山大學工學院).

2. Ludwig Brandl's Proposal (1928-1931)

In August 1928, the Qiantang River Seawall Engineering Bureau was reorganised and expanded to become the Zhejiang Water Conservancy Bureau (Zhejiang sheng shuili ju 浙江省水利局), which was responsible for managing water conservancy in Zhejiang province. Its activities included the engineering works on the Qiantang River, and the reconstruction and repair of the seawall. The Bureau issued a new administrative provision: technological experts were appointed to the posts of director and heads of the various engineering departments, including the Hangzhou-Haining Seawall Department (Hanghai duan haitang gongcheng chu 杭海段海塘工程處), the Yanguan-Pinghu Seawall Department (Yan-Ping duan haitang

[35] He Yingqin studied in Japan in his early years and attended the Japanese Military Academy. He joined the "Alliance Association" (Tongmeng hui 同盟會) founded by Sun Yat-sen 孫中山 while studying in Japan.

[36] Zhejiang sheng zhengfu (1927), p. 40.

gongcheng chu 鹽平段海塘工程處), and the Xiaoshan-Shaoxing Seawall Department (Xiao-Shao duan haitang gongcheng chu 蕭紹段海塘工程處).[37]

Like its predecessor, the newly established Zhejiang Water Conservancy Bureau had the support of provincial political institutions. In this case it was affiliated with the Construction Department of Zhejiang province (Zhejiang sheng jianshe ting 浙江省建設廳). The provincial government appointed Dai Enji 戴恩基[38] (b. 1894) as director, and Ludwig Brandl as chief engineer of the Zhejiang Water Conservancy Bureau.

Born in Vienna in 1874, Brandl acquired a diploma in engineering at the Vienna Technical University. He began working for the Danube Regulatory Commission in 1898, and in 1926 was appointed director of the electricity plant of Vienna's municipality. His work experience made him a good candidate to become chief engineer of the Zhejiang Water Conservancy Bureau. His appointment to this post seems to have come about through his acquaintance with Zhu Jiahua 朱家驊, who went to Germany to study engineering in 1914-1917.[39] Zhu Jiahua was a protégé of Zhang Jingjiang 張靜江 (1877-1950),[40] who had subsidised Zhu's studies in Germany. Zhang Jingjiang was a high-level politician in the Nationalist government who

[37] The Hang-Hai seawall department was responsible for managing the seawall from Hangzhou to Haining; the Yan-Ping seawall department was responsible for managing the seawall from Haiyan to Pinghu; and the Xiao-Shao seawall department was responsible for managing the seawall from Xiaoshan to Shaoxing.

[38] Dai Enji (sometimes written Tai En-chi) was born in 1894 and studied engineering in Germany together with Zhu Jiahua (see below). After returning to China, he taught at Sun Yat-sen University. In 1928, he served as director of the Qiantang River Engineering Bureau and of Zhejiang Province Water Conservancy Bureau. He was general manager of China National Aviation Corporation from 1932 to 1937.

[39] Zhu Jiahua was born in Wuxing 吳興 county, Huzhou 湖州, Zhejiang. In 1908, he met Zhang Jingjiang, who provided funds for him to study mining engineering at the University of Mines in Berlin, enrolling in October 1914. When he returned to China, he became a professor at Peking University. He received Beiyang 北洋 government funding to study abroad at public expense, and went to study in the United States. In March 1920 he transferred back to the Department of Geology at Berlin University of Technology. He became a prominent educator, scientist, and politician in China, known as the founder of modern Chinese geology, and a pioneer in Chinese modernisation. He served in many high positions in the Republic of China, such as Vice President of the Administrative Council and Examinations, Minister of Education, Minister of Transport, and chairman of the Zhejiang Government.

[40] Zhang Jingjiang was born to a wealthy silk merchant family in Wucheng 烏程 (present-day Nanxun 南潯), Zhejiang. In his early years, he supported Sun Yat-sen's revolution and became one of the four Kuomintang (Guomindang 國民黨) elders, occupying an important position within that party.

served as chairman of the Zhejiang provincial government in 1927 and again in 1928-1930. Zhu must have recommended Brandl to Zhang Jingjiang for the post. Brandl was chief engineer from 1928 to 1931. Dai Enji had also studied in Germany, and developed a close relationship with Zhu Jiahua at that time. Dai was one of Zhu Jiahua's main followers, and his career followed Zhu's in tandem.[41]

The government's policy at the time followed the guidelines originally set out by Sun Yat-sen in his General Plan for National Reconstruction (*Jianguo fanglue* 建國方略), which emphasised "promoting what is beneficial and eliminating disasters" (*xing li chu hai* 興利除害). Sun Yat-sen also mentioned making the Qiantang River navigable, and building the province's own eastern port between Zhapu 乍浦 and Ganpu 澉浦 on the coast of Hangzhou bay.[42]

At the request of the government, Brandl carried out a field survey of the Qiantang River, investigating it from downstream at Zhakou 閘口 near the mouth of the Qiantang River to upstream, terminating at Qianyi guan 前驛關 at Longyou 龍游. He studied the different sections of the river, and wrote a report describing the velocity of the flow, the depth, nature of the shoals, tidal changes, and navigation conditions in these sections. On the basis of his investigations, he drew up a "Plan for Managing the Qiantang River" (*Qiantang jiang zhengli jijua* 錢塘江整理計畫), in which he wrote the following:

> The prevention and control project should begin with measuring and surveying, mapping the channel, making hydrological observations, and further collecting data which is basic work for the long-term plan. First, it is necessary to take measurements and do the basic hydrological work, including an aerial survey.[43] Second, a

---

[41] When Zhu Jiahua was acting chairman of the Sun Yat-sen University Committee, and co-director of the Civil Affairs Department of Guangdong Province, Dai Enji was first employed as a designer of the Observatory at Sun Yat-sen University, and then served as mayor of Foshan. When Zhu Jiahua worked as the director of the Civil Affairs Department of Zhejiang Province, Dai Enji was the director of the Zhejiang provincial Water Conservancy Bureau. When Zhu Jiahua was chairman of the China National Aviation Corporation in 1932, Dai Enji served as its general manager. See Chen (2013), pp. B16.

[42] Sun Yat-sen had proposed the construction of an eastern port as part of the national reconstruction he advocated in his book General Plan for National Reconstruction, p. 99.

[43] Ludwig Brandl strongly advised the government to carry out an aerial survey. Therefore the Zhejiang government allocated 10 thousand *yuan* to buy aircraft and related measuring instruments and pieces of equipment from Deutsche Lufthansa, and hired two foreign engineers to do the survey.

> plan for project emergencies and disaster prevention, as well as traffic management is needed.[44]

Here we can see a number of characteristics of the new approach to the Qiantang River Project emerging. First, there is the assumption that they are engaged in a long-term plan, a permanent solution to the problem, a realisation that previous stop-gap measures were not working. Second, it is necessary to take a scientific approach, to do basic research and gather essential data. Third, there are standards and basic requirements for any solid engineering project and the Qiantang River Project is one of them—including taking measurements, doing surveys, and planning ahead for future disasters.

For Brandl, one of the guiding principles for improving the channel was to develop navigation in the lowest reaches of the river, thus maximising use of the river, taking advantage of the opportunities it affords, while at the same time building a dike to prevent the collapse of the river bank, thus retaining aspects of the old method of "prevention". Another of his key aims was to transform the Qiantang River into a environmentally safe river with a fixed width by straightening the river and "narrowing the channel to a fixed width" in order to stabilise the river channel and unify the mainstream. Figure 4 shows the layout of the submerged dam and spur dike proposed in his plan.

Brandl developed his own guidelines, putting forward four steps, which are listed below, with our comments about their implementation:[45]

First, construct many new dikes along both sides of the river. This would allow the sand that comes in with the tidal bore to build up between the dikes and form land, thus narrowing the channel to a controlled width of 1,600 meters.

Second, connect the Qiantang River to the Grand Canal. Affected by the tides, the Qiantang River had been completely isolated from the Grand Canal since ancient times. This made it extremely inconvenient to transport goods from the Qiantang River to the canal, requiring goods to be transported overland through Hangzhou. (Brandl designed three roads to connect the Qiantang River to the Grand Canal,[46] but this plan was never implemented.)

Third, prevent the collapse of the Nansha 南沙 bank. Brandl proposed spur dikes be built out of stone. (Due to the fluctuations of the river channel, the plan had to be adjusted many times.)

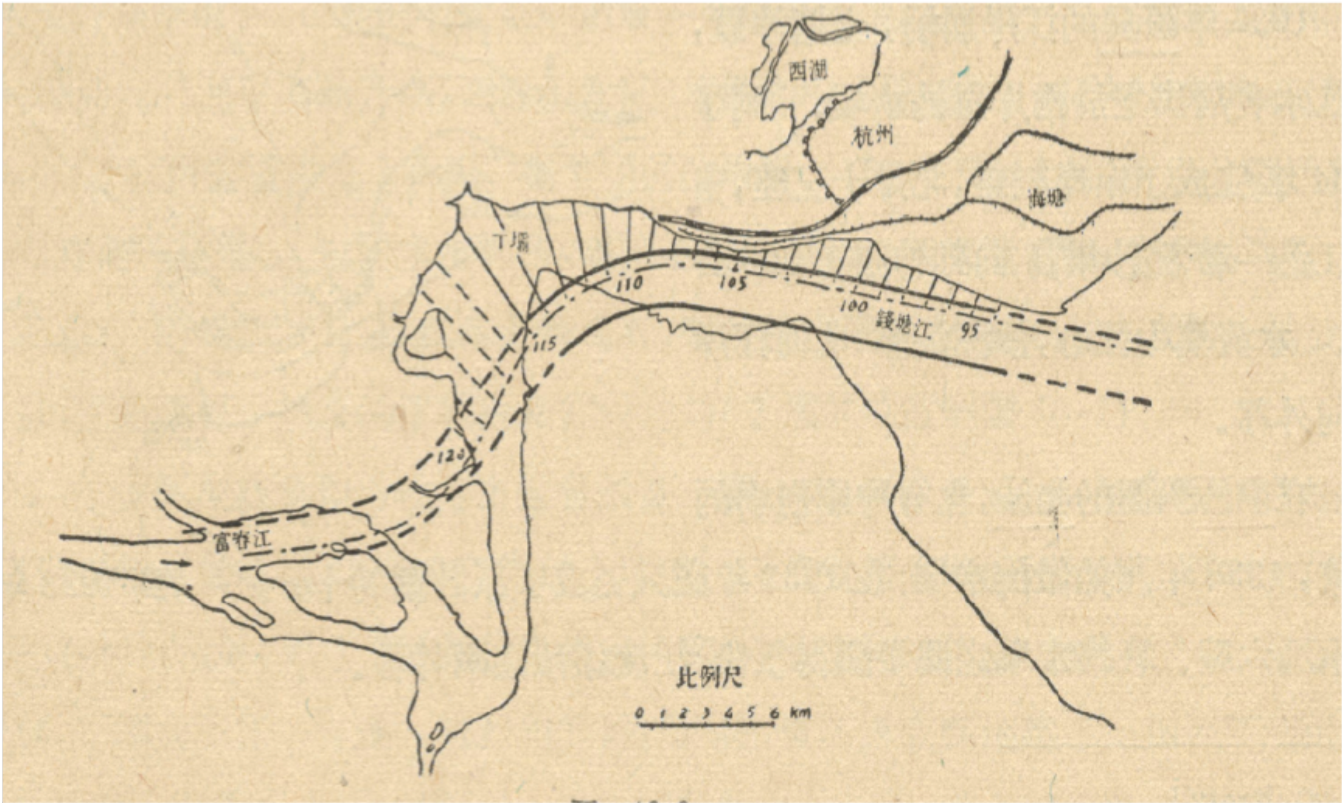
---

[44] Ludwig Brandl (1929), pp. 2-3.

[45] Ludwig Brandl (1929), pp. 24-32.

[46] The southern end of Grand Canal begins in Hangzhou. If the Grand Canal were connected to the Qiantang River, it would be convenient for shipping.

Figure 4. Qiantang River Prevention and Government Plan in 1929



SOURCE: Zhang (1953).

Fourth, protect the seawall in Wenyan 聞堰. At the bend of the Qiantang River, the seawall on the southern bank had long been in disrepair. The foundation of the seawall (literally, its "foot", *tang jiao* 塘脚) was damaged, and the stones were dislodged by the tide, causing the bank gradually to collapse, endangering the seawall. The plan was to build eight standard longitudinal dikes to promote silt accumulation and protect the bank. To build up the bank, it was necessary to protect the seawall foundation.

Brandl left his post as chief engineer in 1931. His departure was probably related to the fact that Zhang Jingjiang, who had been responsible for his appointment in the first place, disagreed with Chiang Kai-shek over political matters and left his post in 1930. This was followed by a change in the leadership of Zhejiang. Shi Ying 石瑛 (1879-1943) became the new director of the Zhejiang Construction Department. It is said that he was suspicious of foreign water consultants because he thought they were paid handsomely but did nothing.[47] Whether this was the cause of his dismissal is not clear. An article in a German newspaper on the occasion of his 70th birthday, presumably based on an interview with Brandl, says, "The outbreak of the Japanese-Chinese conflict abruptly ended the construction work in China, and construction director Ludwig Brandl returned to his homeland".[48] For whatever reason, Ludwig Brandl returned to Germany, and a new chief engineer of the Qiantang River Project was appointed.

Brandl's term as chief engineer marks the second stage in the formation of the Qiantang River Project. Engineers continued to be appointed in key management and advisory positions. They communicated with the government by writing proposals containing their suggestions for dealing with the Qiantang River problem. Their proposals were based on scientific surveys, analyses and studies, and combined strategies based on both prevention and control, while also including planning for disaster. Brandl's contributions were his proposals for narrowing the channel by means of spur dikes, and the aim of developing navigation in the lower reaches of the river. Some elements of his plan were carried out, thus showing that the government took his recommendations seriously. Other aspects could not be implemented. As before, he did not recommend abandoning the age-old preventive measures. Thus the second stage in the formation of the Qiantang River Project continued to advocate prevention while also proposing some new measures for control and development.

[47] Bao (1980), pp. 99-100.

[48] "Pionierarbeit eines Wieners in China: Der erste Deutsche in der Nationalen Hilfkommission für Ueberschwemmungen" (1944). This article is available online at http://anno.onb.ac.at/cgi-content/anno?apm=0&aid=nwg&datum=19440726&seite=03.

3. Zhang Zili's Project (1931-1937)

Figure 5. Zhang Zili

SOURCE: Zhejiang sheng shuili ju (1933).

In 1931, the Zhejiang government appointed Zhang Zili 張自立 (1895-1977) as director and chief engineer in the Zhejiang Water Conservancy Bureau. Zhang Zili graduated from the Department of Railway Civil Engineering at the University of Illinois in the United States. After returning to China, he successively served as an engineer on the Beijing-Suiyuan Railway (Jingsui tielu 京綏鐵路), on the Shunzhi Water Conservancy Committee, in the Hankou Hydropower Company (Hankou shuidian gongsi 漢口水電公司), and as deputy director of the Water Conservancy Department of the Construction Committee (Jianshe weiyuanhui shuilichu 建設委員會水利處).

In 1932, under his leadership, the Zhejiang Water Conservancy Bureau issued another new proposal entitled "Ideas concerning the Reorganisation of the Qiantang River" (*Zhengli Qiantangjiang zhi yijian* 整理錢塘江之意見). This proposal made it clear that the old method of prevention was not to be abandoned:

> There is a close relationship between the prevention and control project and the construction of the seawall. For the convenience of navigation, for the maintenance and drainage of farmland, for prevention of sand collapse, and for the safety of the seawall, emergency projects should be implemented.[49]

Zhang suggested that this implementation should be accomplished in three steps: first carrying out geological and hydraulic surveys, then formulating a fundamental plan, and finally gradually implementing the plan. He emphasised integrated watershed management, and

[49] Zhang (1933), p. 54.

comprehensive development and utilisation, and also proposed prevention and control strategies based on the characteristics of the upper, middle and lower reaches of the Qiangtang River (see Figure 6). The specific contents of the plan were as follows:[50]

First, build a flood detention dam upstream. The plan was to select an appropriate site in the upper reaches of the river where a dam could be constructed to block the water and prevent the river from flooding. This measure would not only be helpful for navigation but also assist downstream flood control.

Second, carry out bank protection and flood control work in the middle reaches of the river. This would prevent the collapse of the two sides and normalise the waterway by means of a submerged dam, a spur dike and bank-protection works. The silted sand at the bottom of the river would then be washed into the sea by the current. The new plan was a redesign of Brandl's original conception, to make the channel straighter than it was before.

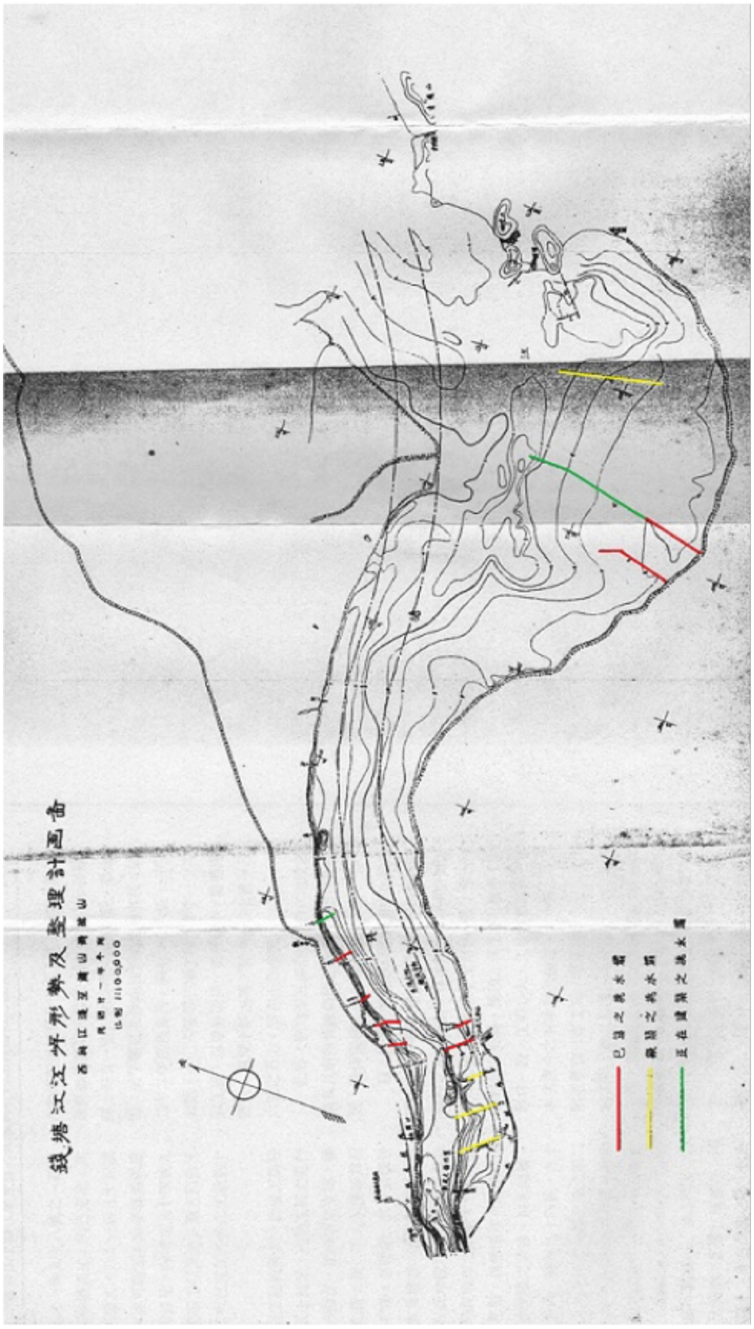
Third, narrow the river channel in its lower reaches. This plan followed Brandl's idea of "narrowing the channel". Zhang hoped that after the project was implemented, it would realise some of its purposes: scouring a deep channel, harnessing the estuary of Hangzhou bay, and facilitating navigation in places where the water level was low.

Fourth, progressing "from the lower to the upper" reaches of the river. Zhang advocated starting the project on the downstream section of the river. In this way the government could obtain revenue by harnessing the downstream sections, which would include developing farming and the salt making industry, as well as land reclamation, which would reduce the burden on the government, and aid the completion of the middle and upper harnessing projects.

This idea of proposing different activities in the different sections of the river corresponds to Zhang Shunong's idea of diversification described below. In addition, Zhang Zili singled out the problem of farmland drainage and irrigation, and introduced a new focus on agricultural production.

[50] Zhejiang sheng shuili ju (1933), pp. 15-22.

Figure 6. The 1932 Government Plan for Prevention and Control



SOURCE: *Zhejiang sheng shuili ju zong gongzuo baogao (Mingguo 21 zhi Mingguo 24)* (1935).

4. Zhang Shunong's Project (1946-1949)

Figure 7. Zhang Shunong

SOURCE: Hehai daxue dang'an guan 河海大学档案馆 (Hohai University Archives), URL: http://archives.hhu.edu.cn/2016/1018/c5330a76532/page.htm, accessed 22 September 2020.

In 1935, Wanghu Zhen 汪胡楨 (1897-1989),[51] then head of design at the Water Conservancy Division of the China Economic Commission (Quanguo jingji weiyuanhui shuilichu 全國經濟委員會水利處), proposed to the Division that surplus funds for work relief (*gong zhen yu kuan* 工賑餘款) should be used to sponsor talented individuals to study water conservancy abroad. Wanghu Zhen was the chief examiner in the selection committee. He interviewed five candidates, including Zhang Shunong.

Zhang Shunong 張書農 (1910-1997) had graduated from National Central University (Guoli zhongyang daxue 國立中央大學) in 1933. The funds he was awarded by the Water Conservancy Division enabled him to study engineering in Germany, and he obtained his doctorate from the Technical University of Berlin in 1940. After returning to China, he worked as an engineer for the Sichuan Guidance Commission (Sichuan daoxun weiyuanhui 四川導訊委員會) and served as a professor at National Central University.

---

[51] Wanghu Zhen was born in Jiaxing county, Zhejiang province. He graduated from Nanjing River Sea Engineering Specialised School (now Hohai University) in 1917. He then studied in the United States, obtaining a Master's in Civil Engineering from Cornell University in 1923, and developed expertise in water conservancy. According to Dai Zeheng 戴泽蘅 (1921-2019), who worked with Wanghu Zhen, Wanghu is a double surname (personal communication to Li Haijing during her interview with Dai Zeheng quoted in Li and Wang (2015)).

Before discussing Zhang Shunong's contributions, we need to look at the events that took place in China from 1937 to 1945 and their impact on the Qiantang River. These include the Anti-Japanese War and the resulting shift in the channel of the Qiantang River due to lack of repair, which resulted in the collapse of the seawall in 1946. At first, Mao Yisheng 茅以升 (1896-1989),[52] who had been director of Zhejiang Qiantang River Bridge Engineering Department since 1934, with the help of Wanghu Zhen, attempted to remedy the situation. They invited Zhang Shunong to draft the specific plan for the Qiantang River Project.

The War Years, 1937-1945

When the Anti-Japanese War broke out in 1937, various government agencies moved north to the mountainous area of Zhejiang province, bringing the prevention and control project of the Qiantang River to a halt.[53] At this time, the old practice of protecting the seawall was resumed, but there is a saying that "the protective seawall does not protect the shore" (*bao tang bu bao tan* 保塘不保灘); it was impossible to keep the river bank from collapsing.

From 1942 to 1946, the main channel of the Qiantang River shifted to the south bank again. As a result, Nansha 南沙 island on the south bank collapsed even further, eventually destroying 2,965 acres of farmland.[54] By the end of June 1947, the newspapers were reporting the situation as follows:

> The collapse of the farmland is extremely serious; the northeast centre of Toupeng 頭蓬 is now at the bottom of the river, Xinwan 新灣 is in a critical condition; meanwhile, more than 124 acres of new land has formed in the area of Zheshan 赭山 mountain on the south bank. ... It has taken hundreds of years to make Nansha 南沙 fertile; without emergency aid, it will sink to the bottom of the sea.[55]

The main channel of the Qiantang River continued to shift southward toward the south gate. As it shifted, the foundation of the southern seawall, from Xiling 西陵 in the Xiaoshan region to Sanjiangzha 三江閘 in the

---

[52] Mao Yisheng was born in Zhenjiang county, Jiangsu. He graduated from Tangshan Industrial Specialised School, managed by the Nationalist government's Ministry of Transport, in 1916. He obtained a Master's in Civil Engineering from Cornell University in 1917, and obtained a Ph.D. in Engineering at the Carnegie Institute of Technology in 1919. From 1934 to 1937, he worked at the Engineering Department of the Qiantang River Bridge as director for bridge construction.

[53] After the government agencies withdrew from Hangzhou, the local gentry organised the civil forces to maintain the seawall.

[54] "Xiaoshan nansha shuilihui qing xiu jiangnan taoshuiba" (1946).

[55] "Zheshan xinsha wanmu chenru haidi, Nansha mingyun jijikewei" (1947).

Shaoxing 紹興 region, was exposed, and the stability of the seawall was threatened.

By the end of the War of Resistance against Japan, in 1945, a 3-km section of seawall had collapsed. Most of the seawalls on the north bank were also damaged. This development attracted the attention of Chiang Kai-shek, who was originally from Zhejiang. The central government allocated emergency funds for maintenance work, setting up an emergency maintenance agency. To repair the seawall, the government reorganised the Qiantang River Seawall Engineering Bureau in 1946, appointing Mao Yisheng director and Wanghu Zhen deputy director and chief engineer.[56] These two prominent engineers were responsible for restarting the Qiantang project after the War and setting the direction for the project, while Zhang Shunong drafted the specific proposals.

On 1 August 1946, Mao Yisheng invited Chinese and foreign experts to form a team and carry out a week-long survey of the Qiantang River. After finishing the survey, the experts submitted research reports and proposals for constructing the seawall, preventing floods and controlling the river channel, thus calling again for prevention and control, rather than just prevention.

In an interview with a newspaper reporter, Mao Yisheng listed the Qiantang River as one of the three major river engineering works in China: the Yellow River, the Grand Canal, and the Qiantang River. In his view, the Qiantang River floods were more disastrous than those on the Yellow River because, after the Yellow River floods, the land deposited in the flooded area becomes fertile soil the following year. However, when the Qiantang River channel shifts, the bank of the river collapses and large areas of river bank immediately roll into the river. Because the river is connected to the sea, it contains salt water, thus once the land is flooded, it is ruined; it cannot be cultivated.[57] After undertaking fieldwork and receiving advice from experts at home and abroad, Mao Yisheng made the following proposal:

> Controlling the collapse of the land is more important than protecting the seawall, and harnessing the channel is more important than controlling the collapse. It is best to encourage the flood waters to flow into a single channel. This will make the river narrow and deep, as well as allowing navigation. The beach will be reclaimed for cultivation. A dam can be built upstream to generate electricity to supply power for Shanghai. If we take advantage of the characteristics of the Qiantang River and allow them to guide our actions on the project in this

---

[56] "Qiantang jiang haitang gongchengju chengli" (1946).

[57] Chu (1946).

> way, twice as much will be accomplished with half the effort (*shi ban gong bei* 事半功倍).[58]

Mao Yisheng thus thought that controlling the channel would produce better long-term results than the continuous effort of repairing the seawall. He also wanted to give priority to the comprehensive development and utilisation of the river as a whole. His general policies set the scene for Zhang Shunong's more detailed plans for controlling the Qiantang River.

Zhang Shunong's Role in Drafting the Project

Zhang Shunong was a professor at National Central University and had investigated estuarine management projects and technologies in other countries of the world. He had also done in-depth research on silt and had devised some mathematical methods of calculation for use on the Qiantang River. It was on the basis of his scientific credentials that the Qiantang River Seawall Engineering Bureau invited him to take charge of drafting plans for the Qiantang River Project. In order understand the characteristics of the Qiantang River, he gathered survey and measurement data, and studied the experience of estuary management in other countries around the world. He also conducted a detailed analysis of the sediment movements, the riverbed, tidal variations, and sand movements. He then drew up the first highly scientific and systematic river action proposal, advocating action in the following areas: diversification, managing the downstream section, and launching an estuary project. His ideas in these three areas are summarised below, along with his identification of the problems and suggested solutions:[59]

A. Diversification

In Zhang's view, there were three problems concerning the Qiantang River: flood control, navigation and reclamation. Each major section of the river would require different actions. He advocated, first, stabilising the riverbed and the main flow away from the seawall—these were the most crucial tasks; second, establishing a harbour between Haining 海寧 and Zhapu; third, gradually reclaiming the shore of the river; and fourth, utilising the tidal upstream of the river to develop tidal power. The latter required further study.

B. Managing the Downstream Section of the Qiantang River

He advocated three methods for managing the downstream section: (a) extending and stabilising the riverbed to remove the silt deposited by the tide in order to maintain adequate water depth; (b) building two long dikes to create a narrow water channel in the estuary; and (c) building a dam that could open and close according to the rise and fall of the tide. These three

---

[58] Mao (1946).

[59] Zhang (1953), pp. 468-473.

schemes needed to be tested according to hydrological and topographic data to make a reliable plan for implementation. Combining (a) and (b) would achieve the desired effect of creating a deep channel.

C. The Qiantang River Estuary Project

Zhang Shunong drafted a preliminary riverbed control plan according to the hydrological data of 1946. The plan stated that the first step would be to transform the sharp bend in the river into a gentle bend, that is, to straighten it. The second was to determine the appropriate width of the different sections of the river. The ideal riverbed should be shaped like a trumpet, gradually broadening out from upstream to downstream to allow for rise and fall of the tide. The third step concerned the incline of the river bed, which has a gentle slope from upstream to downstream, ending at the estuary. The fourth step was to establish river regulation guidelines (*zhidao xian* 治導線). This would involve using the traditional measures for building spur dikes and longitudinal dikes (*shunba* 順壩) to control the flow, and following the guidelines for arranging the dikes. It is worth noting that he adopted a standard width for the river, based on the width of the water at Haining in 1947-1948, when it was at a medium-low level during the wet season. The river width at Zhakou, and the river bed section at Ganpu (*Ganpu hechuang duanmian* 澉浦河床斷面) were kept the same.

Zhang Shunong hoped that the implementation of these measures would produce the following results: (1) Once the riverbed was stabilised, the foundation of the seawall would not be scoured by the tide, which would ensure the safety of the seawall; (2) As the waters gathered into a single channel, the depth would increase, which would promote navigation; (3) The spur dike and the longitudinal dike would form new sedimentary land; and (4) If the guidelines for the proposed river width were followed, this would limit the number of bends in the river, and transform the sharp bends into gentle bends. This programme continued until the end of 1949.

We can see that Zhang Shunong built on and developed a number of ideas suggested by his predecessors, such as narrowing and straightening the channel, building a dam in the upper reaches, and treating the various sections of the river differently (diversification). To this he added other suggestions based on his own areas of expertise and interest, for example, stabilising the riverbed (using his knowledge of sedimentation), deepening and regulating the width of the lower reaches (based on his study of estuaries), and land reclamation. Thus we can see that although there were slight differences in focus and priorities among the different plans proposed in the period we are discussing, the content of the advice given by the engineers to the government was largely cumulative and unified.

5. Hidden Political and Economic Interests

During the Nanjing decade, factional battles at the top of the Nationalist government had a significant influence on the politics of Zhejiang province. Zhejiang was one of the most important economic zones in China, and also, as noted above, the home province of Chiang Kai-shek.[60] The appointment of government officials in this province attracted much attention, and the struggle of high-level political factions in the Nationalist government was clearly reflected there. As we have seen, the Zhejiang Water Conservancy Bureau was attached to the Zhejiang Construction Department. For this reason, changes in the upper levels of government directly influenced appointments of the director and the chief engineers in that Bureau. The following table (Table 1, next page) shows the changes in the leadership of government departments at all levels related to the Qiantang River Project from 1927 to 1949.

We have seen that Zhang Jingjiang was chairman of the Zhejiang provincial government briefly in 1927, followed by He Yingqin, and that the latter was influential in supporting the proposals of the engineer Xu Kai, who launched the Qiantang River Project. The political situation changed when He Yingqin left his post, leading to Xu Kai's resignation. We have also seen that, as provincial chairman in 1928, Zhang Jingjiang was influential in the appointment of Ludwig Brandl, but when he fell out of favour with Chiang Kai-shek and left his post in 1930, Brandl soon left, in 1931. These two examples show the influence of politics on the management of the Qiantang River Project. Of course the war against Japan in 1937-1945 was also a major disruption to the project, which was resumed in 1946.

China's complex political situation also had an international dimension. Western competition for Chinese interests began to emerge at this time, and both politicians and engineers had connections and sympathies with Germany or the United States because of their studies abroad. It will be remembered that Zhang Jingjiang had sponsored Zhu Jiahua to study engineering in Germany. When Zhang Jingjiang became chairman of Zhejiang Province, Zhu Jiahua was appointed Director of the Civil Affairs Department (Zhejiang sheng minzheng ting 浙江省民政廳), while another

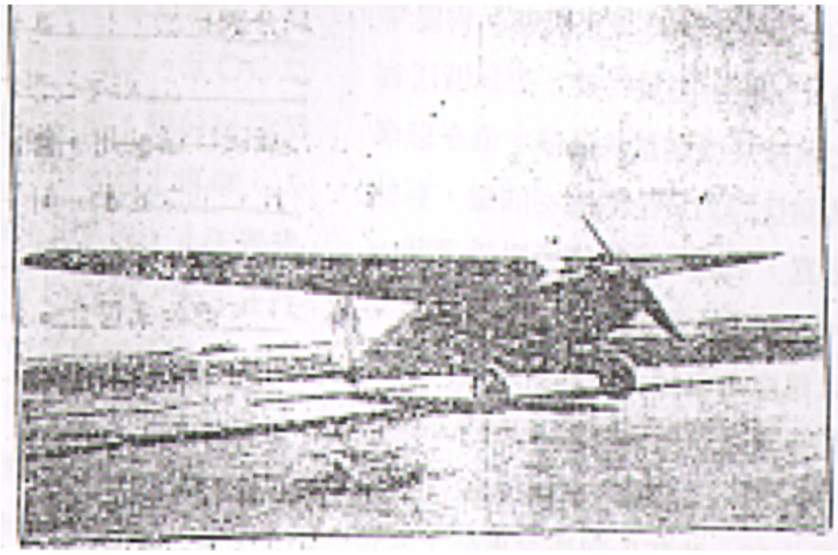
[60] Chiang Kai-shek was born in Fenghua county, Ningbo, Zhejiang, in 1887.

Table 1. Changes in the Posts of Government Officials in Zhejiang province from 1927 to 1949

	1927	1928	1931	1946
Chairman of Zhejiang Province 浙江省主席	He Yingqin 何應欽 Nov.1927-1928 (autumn)	Zhang Jingjiang 張靜江 Jul.1927-Oct.1927; 1928 (autumn)-1930 Zhang Nanxian 張難先 1930-1931	Lu Diping 魯滌平 1931-1935	Shen Honglie 沈鴻烈
Director of the Zhejiang Construction Department 浙江省建設廳廳長	Cheng Zhenjun 程振鈞 1927-1929	Zhu Jiahua* 朱家驊 Zeng Yangfu 曾養甫 May.1929-Nov.1930	Shi Ying 石瑛 Dec.1930-Feb.1932	
Qiantang River Seawall Engineering Bureau 錢塘江海塘工程局 Director of Zhejiang Water Conservancy Bureau 浙江省水利局局长	Lin Datong 林大同	Dai Enji 戴恩基	Zhang Zili 張自立	Mao Yisheng 茅以升
Chief Engineer of Zhejiang Water Conservancy Bureau 浙江省水利局總工程師	Xu Shida 徐世大 Xu Kai 須愷	Ludwig Brandl 白郎都	Zhang Zili 張自立	Wanghu Zhen 汪胡楨

* Zhu Jiahua was director of the Civil Affairs Department (Zhejiang sheng minzheng ting 浙江省民政廳), not of the Zhejiang Construction Department.

Figure 8. Air survey aircraft purchased from Lufthansa in 1930



SOURCE: Gu Shiji (1932), p. 189.

engineer, Zeng Yangfu 曾養甫 (1898-1969),[61] who had studied engineering in the United States, was appointed director of the Construction Department. Zhu Jiahua was one of the Pro-Germany Group (Qin De pai 親德派) activists within the Kuomintang, who played an important role in Sino-German cooperation from the 1920s to the 1940s. The newly established Zhejiang Water Conservancy Bureau was affiliated with the Construction Department, and the provincial government appointed Dai Enji as the director of the Zhejiang Water Conservancy Bureau in 1928. Perhaps because of the connections that Zhu and Dai had with Germany, and/or the influence of Brandl, Zhejiang province purchased a large number of hydrological and meteorological instruments from Germany to carry out the basic survey work on the Qiantang River. The province also procured aircraft from Germany's Lufthansa corporation to carry out the earliest aerial survey in China, and hired two German technicians in 1930.

[61] Zeng Yangfu was born in Pingyuan, Guangdong. He graduated from Beiyang 北洋 University, Tianjin, in 1923. He then studied in the United States, receiving a degree in Mining and Metallurgical Engineering from the University of Pittsburgh Research Institute. Committed to building up China's infrastructure, he was known as "the father of China's civil engineering and water conservancy (transportation) construction" and "the first person to practice Sun Yat-sen's nation-building strategy".

The pro-Germany elements gradually lost favour in the Nationalist Party after 1927. The growing cooperation with Europe and the United States, partly influenced by the marriage between Chiang Kai-shek and Song Meiling 宋美齡 in that year, triggered the development of pro-Americanism in the Nationalist Party. The Pro-America-and-Britain Group began to dominate Chinese politics; its prevalence may have contributed to the removal of Zhang Jingjiang from his post in 1930.

Following this development, there was a change in the leadership of the Zhejiang government, which resulted in a reshuffling of department heads in the major government agencies. Brandl's dismissal in 1931 may have been one of the consequences of this shift; he was replaced by the American-educated Zhang Zili as director and chief engineer of the Zhejiang Water Conservancy Bureau. It was perhaps no coincidence that equipment used for the hydrological and meteorological measurements required for the Qiantang River Project was subsequently procured mainly from the United States and Britain.

As noted above, the Qiantang River Project came to a halt when war with Japan broke out in 1937. After the Chinese victory in the Anti-Japanese War in 1945, and in the face of the severe collapse of the seawall, the central government restarted the Qiantang River Project. Mao Yisheng and Wanghu Zhen were appointed director and chief engineer of the project in 1946. Mao Yisheng invited experts from different countries to study the Qiantang River, and entrusted Zhang Shunong with drafting a plan of governance. These decisions were not influenced by political factionalism. Instead, those in charge drew on various countries' expertise in water conservancy to solve the problem of the Qiantang River.

Conclusion

With the introduction of Western technology and materials into China in the late nineteenth and early twentieth centuries, new technologies and new materials were utilised in the construction of the Qiantang River seawall. However, due to the political turmoil and social unrest of the first quarter of the twentieth century, it was almost impossible for anything but the most basic maintenance of the Qiantang River and repairs to the seawall to be carried out. Between 1927 and 1937, however, China experienced a short period of social stability, when the government was committed to developing domestic production, restoring the national economy and building up the country's infrastructure. During this period, Chinese politicians collaborated with Chinese engineers who had been educated abroad to apply Western knowledge and expertise to the Qiantang River in a concerted effort to solve flooding problem. These efforts contributed to the development of what has been called here the Qiantang River Project, over the course of the four stages described above, which was characterised by (1) the application of Western science and technology to the perennial problem of flood control on the Qiantang river, and (2) a change in approach from a defensive policy of prevention alone to a combination of prevention and more active measures to control the river.

For the most part the details of the plans proposed at each of these four stages were not only similar and but were also cumulative. Of course some of the details of the items suggested differed from one plan to another, and the priorities sometimes varied, but there were more similarities among the proposals than differences. The Qiantang River Project may not have started out as a single project in the beginning, but through its evolution from stage to stage it developed into one. Moreover, the fact that after a seven-year hiatus during the Anti-Japanese War it could be revived with little effort and hardly any major change shows that it was a discrete, unified phenomenon. Thus while the four stages were separate and differently conceived attempts to control the Qiantang River, they were all united in the aim to use Western technology limit the destruction caused by the Qiantang bore.

During the four stages of Water Conservancy leadership described above, from Xu Kai to Ludwig Brandl, Zhang Zili and Zhang Shunong, the historic shift from prevention alone to a combination of prevention and control was brought to fruition. The content of the policy of prevention and control, which took form during this period, was based on the following principles:

1. Narrowing the channel and stabilising the river bed.
2. Emphasising basic research, accumulating data, developing expertise and otherwise laying a solid foundation for future work.
3. Establishing guidelines for regulation.
4. Straightening the river, despite its natural tendency to bend.
5. Adopting different strategies for different sections.
6. Developing the river through comprehensive management, including navigation, harnessing power and exploiting all the river's resources.

These policies were the cumulative result of work done by the engineers who directed the four stages of development described above in this paper.

It was only because the Chinese government adopted the policy of appointing technical experts as political leaders and managers of the project, and thus established an expert management system during the Republican period that Western scientific ideas and hydraulic technology were harnessed to address the complex problems of controlling the river. These experts carried out basic research to explore the characteristics of the river, and apply the understanding gained by these investigations to the discovery of innovative solutions to the problem of the Qiantang River.

During the implementation of the project, political factions and economic interests affected the development of the project. The leadership of the Seawall Engineering Bureau frequently changed. At the same time, the Qiantang project was continuously carried out, based on the "expert responsibility system", which provided valuable management experience in the field of water construction.

Of course, political forces brought economic benefits to both the Pro-Germany and the Pro-America-and-Britain groups. When a faction came to power, the country with which it aligned itself (e.g. Germany or the United States) had the opportunity to promote that country's technology and products in China and to benefit from this process. It is worth mentioning that by promoting the development of modern science and technology in China these foreign political forces had a profound impact on Chinese society. Furthermore, between 1927 and 1949, the expert responsibility system played an important role in settling political and factional disputes and thus ensuring the scientific and orderly management of the Qiantang River Project.

References

Bao Huade 包华德 (ed.)(1980), *Zhonghua Minguo shi ziliao conggao yigao* 中华民国史资料丛稿译稿, No. 12, *Minguo renwu zhuanji cidian* 民国名人传记辞典 (Biographical Dictionary of Republican China), vol. 9, Beijing: Zhonghua shuju.

Brandl, Ludwig (1929), "Qiantangjiang zhi zhengli jihua" 錢塘江之整理計劃 (The Regulatory Plan of Qiantang River), *Zhejiang shuiliju niankan* 浙江水利局年刊.

Chanson, Hubert (2011), "Current Knowledge in Tidal Bores and their Environmental, Ecological and Cultural Impacts," *Environmental Fluid Mechanics* 11: 77-98, DOI: 10.1007/s10652-009-9160-5.

Chen Jiyu 陈吉余 (2000), *Haitang*: *zhongguo haian bianqian he haitang gongcheng* 海塘：中国海岸变迁和海塘工程 (Seawall: China's Coastal Change and Seawall Engineering), Beijing: Renmin chubanshe.

Chen Jiyu 陈吉余, Luo Zude 罗祖德, Chen Dechang 陈德昌, Xu Haigen 徐海根, and Qiao Pengnian 乔彭年 (1964), "Qiantang Jiang hekou shakan de xingcheng jiqi lishi yanbian" 钱塘江河口沙坎的形成及其历史演变 (The Formation and Historical Evolution of the Qiantang Estuary), *Dili xuebao* 地理学报 30.2: 109-123.

Chen Xiaoping 陈晓平 (2013), "Dang tianwen yushang zhengzhi: Zhang Yun he Zhongshan Daxue tianwentai" 当天文遇上政治：张云和中山大学天文台 (When Astronomy Meets Politics: Zhang Yun and the Observatory at Sun Yat-sen University), *Xinxi shibao* 信息时报.

"Choushe Qiantangjiang gongchengju an" 籌設錢塘江工程局案 (The Case of Preparing to Establish the Qiantang River Engineering Bureau) (1927), *Zhejiang jianshe yuekan* 浙江建設月刊.

Chu Yushen 儲裕生 (1946), "Qiantang jiang gongcheng kaocha ji" 錢塘江工程考察記 (Investigation Notes on Qiantang River Engineering), *Shen Bao* 申報, 18 August 1946.

Dalrymple, Robert W., R. John Knight, Brian A. Zaitlin, and Gerald V. Middleton (1990), "Dynamics and facies model of a macrotidal sand-bar complex, Cobequid Bay-Salmon River Estuary (Bay of Fundy)," *Sedimentology* 37.4: 577-612.

Elvin, Mark, and Su Ninghu (1998), "Action at a Distance: The Influence of the Yellow River on Hangzhou Bay since 1000 A.D.," in Mark Elvin and Liu Ts'ui-jung (eds.), *Sediments of Time: Environment and Society in Chinese History*, Cambridge: Cambridge University Press, pp. 344-410.

Gu Shiji 顧世楫 (1932), *Zhejiangsheng shuiliju banli feiji celiang zhi jingguo* 浙江省水利局辦理飛機測量之經過 (The Process of the Zhejiang Water Conservancy Bureau's Aircraft Survey), *Shuili yuekan* 水利月刊, Vol. 2, No. 34.

Han Cengcui 韩曾萃, Dai Zeheng 戴泽蘅, Li Guangbing 李光炳 *et al.* (2002), *Qiantang jianghekou zhili he kaifa* 钱塘江河口治理和开发 (Regulation and Exploitation of Qiantang Estuary), Beijing: Zhongguo shuili shuidian chubanshe.

Harnisch, Thomas (1999), *Chinesische Studenten in Deutschland: Geschichte und Wirkung ihrer Studienaufenthalte in den Jahren von 1860 bis 1945* (Chinese Students in Germany: History and Impact of their Study Visits between 1860 and 1945), Hamburg: Institut für Asienkunde.

Harris, Peter T. (1988), "Large scale bedforms as indicators of mutually evasive sand transport and the sequential infilling of wide-mouthed estuaries," *Sedimentary Geology* 57.3-4: 273-298.

Jiang Wei and Tao Cunhuan (2002), "The Seawall in Qiantang Estuary," in J. Chen, D. Eisma, K. Hotta, H. J. Walker (eds.), *Engineered Coasts*, Dordrecht: Springer, pp. 139-150.

Kunte, Pravin D., Chaofang Zhao, Takahiro Osawa, and Yasuhiro Sugimori (2005), "Sediment distribution study in the Gulf of Kachchh, India, from 3D hydrodynamic model simulation and satellite data," *Journal of Marine System*s 55.3: 139-153.

Li Haijing 李海静 and Shi Yunli 石云里 (2017), "Cong 'fang' dao 'zhi': Guomin zhengfu shiqi Qiantang jiang fangzhi linian de fazhan" 从"防"到"治"：国民政府时期钱塘江防治理念的发展 (From Defense to Control: The Development of the Concept of Prevention and Control on the Qiantang River under the Nationalist Government), *Shanghai Jiaotong Daxe xuebao (Zhexue shehui kexue ban)* 上海交通大学学报（哲学社会科学版） 5: 81-89.

Li Haijing 李海静 and Wang Miao 王淼 (2015), "Qinli Qiantang jiang hekou zhili kaifa guocheng de huiyi: Dai Zeheng, Li Guangbing fangtan lu" 亲历钱塘江河口治理开发过程的回忆：戴泽蘅、李光炳访谈录 (Memories of the Qiantang River Estuary Management and Development Process: Interviews with Dai Zeheng and Li Guangbing), *Zhongguo keji shi zazhi* 中国科技史杂志 36.2: 213-226.

Li Haijing 李海静, Wu Huiyi 吴蕙仪 and Han Cengcui 韩曾萃 (2020), "Li Yuese 1964 Zhongguo xingdui Qiantang jiang de kaocha" 李约瑟 1964 中国行对钱塘江的考察 (Joseph Needham's Investigation of the Qiantang River During His 1964 Trip to China), *Ziran bianzheng fa yanjiu* 自然辩证法研究 36.1: 81-87.

Lin Bingyao 林炳尧 (2010), *Yongchao suibi* 涌潮随笔 (Essays on the tide), Beijing: Higher Education Press.

Mao Yisheng 茅以升 (1946), "Tanggongju juzhang Mao Yisheng tan zhengli qiantangjiang yijian" 塘工局局長茅以升談整理錢塘江意見 (Mao Yisheng, Director of Tanggong Bureau, Discusses Opinions on the Management of the Qiantang River), *Dongnan ribao* 東南日報, 12 August 1946.

Mingdai zhiguan Zhong-Ying cidian 明代职官中英辞典 (Chinese-English Dictionary of Ming Government Official Titles), Academia Sinica, Harvard University, Beijing University (eds.)(2017), *Zhongguo lidai renwu zhuanji ziliao ku* 中國歷代人物傳記資料庫 (Database of Chinese Biographical Material Throughout History), URL: http://db1.ihp.sinica.edu.tw/cbdbc/ttsweb?@0:0:1:cbdbkm@@0.8607418220618995.

Moore, William Usborne (1888), *Bore of the Tsien-Tang Kiang*, London: Hydrographic Office.

Moule, A. C. (1923), "The Bore on the Ch'ien-t'ang River in China," *T'oung Pao* 22.3: 135-188.

Needham, Joseph, and Wang Ling (1959), *Science and Civilization in China*, vol. III, *Mathematics and the Sciences of the Heavens and Earth*, Cambridge: Cambridge University Press.

Needham, Joseph, Wang Ling and Lu Gwei-djen (1971), *Science and Civilisation in China*, vol. IV, part 3, *Civil Engineering and Nautics*, Cambridge: Cambridge University Press.

Pan Cunhong 潘存鸿 (2007), *Qianshui jianduan liudong shuzhi moni ji qi zai qiantang jiang hekou yong chao fenxi zhong de yingyong* 浅水间断流动数值模拟及其在钱塘江河口涌潮分析中的应用 (Numerical Simulation for Discontinuous Shallow Water Flow and Its Application to the Analysis of the Tidal Bore at the Qiantang Estuary), Shanghai: Shanghai University Press.

"Pionierarbeit eines Wieners in China: Der erste Deutsche in der Nationalen Hilfkommission für Ueberschwemmungen" (Pioneering work by a Viennese in China: The first German in the National Aid Commission for Floods)(1944), *Neues Wiener Tagblatt* (*Tages-Ausgabe*), 26 July 1944, p. 3, URL: http://anno.onb.ac.at/cgi-content/anno?apm=0&aid=nwg&datum=19440726&seite=03, accessed 9 April 2020.

Qian Ning 钱宁, Xie Hanxian 谢汉祥, Zhou Zhide 周志德, and Li Guangbing 李光炳 (1964), "Qiantang jiang hekou shakan de Jindai guocheng" 钱塘江河口沙坎的近代过程 (The Fluvial Process of the Big Sand Bar inside the Qiantang River Estuary), *Dili xuebao* 地理学报 30.2: 124-142.

"Qiantang jiang haitang gongchengju chengli" 錢塘江海塘工程局成立 (The Establishment of the Qiantang River Engineering Bureau) (1946), *Mingguo shiqi qikan quanwen shujuku* 民国时期期刊全文数据库 (1911-1949) (Full-text Database of the Periodicals in the Republic of China [1911-1949]).

Qiantang jiang zhi bianzuan weiyuanhui 钱塘江志编纂委员会 (Qiantang River Compilation Committee) (1998), *Qiangtang jiang zhi* 钱塘江志 (Qiantang River Gazetteer), Beijing: Fangzhi chubanshe.

Sentinelles Petitcodiac Riverkeeper (2001), *The Petitcodiac River Tidal Bore: 250 Years of Anecdotes*, Petitcodiac Riverkeeper Inc., URLs: http://petitcodiac.org/our-river/tidal-bore/250-years-of-anecdotes/ and http://petitcodiac.org/wp-content/uploads/2014/03/Bore250Years.pdf, accessed 12 April 2020.

Shen Baixian 沈百先 and Zhang Guangcai 章光彩 (1979), *Zhonghua shuili shi* 中華水利史 (History of Chinese Water Conservancy), Taiwan: Taiwan Commercial Press.

Shiji 史記 (Records of the Grand Historian), Sima Qian 司馬遷, 94 BCE, 1959 edition, reprint Beijing: Zhonghua shuju, 1973.

Sun Yat-sen 孫中山 (1924), *Jianguo fanglue* 建國方略 (General Plan for National Reconstruction), 2011 edition, Beijing: China Chang'an Press.

Tao Cunhuan 陶存焕 and Zhou Chaosheng 周潮生 (1992), "Shilun mingguo shiqi zhili qiantangjiang hekou de fanglue he cuoshi" 试论民国时期治理钱塘江河口的方略和措施 (On the Strategies and Measures for Managing the Qiantang Estuary during the Republican Period), *Zhongguo jindai shuili shilun wenji* 中国近代水利史论文集 (Collection of Papers on the History of Water Resources in Modern China), Nanjing: Hehai Daxue chubanshe.

——— (2001), *Ming-Qing Qiantang jiang haitang* 明清钱塘江海塘 (The Qiantang Seawall in the Ming and Qing Periods), Beijing: Zhongguo shuili shuidian chubanshe.

Wang Guowei 王国维 (1984), *Shuijing zhu jiao* 水经注校 (Annotated Water Classic), Shanghai: Shanghai renmin chubanshe.

Wang Jialun 汪家伦 (1988), *Gudai haitang gongcheng* 古代海塘工程 (Ancient Engineering on the Seawall), Beijing: Zhongguo shuili shuidian chubanshe.

Will, Pierre-Étienne (2019), "The Emergence of the Modern Civil Engineer in China, 1900-1940," in Barbara Mittler, Joachim Gentz, Natascha Gentz and Catherine Vance Yeh (eds.), *China and the World, the World and China: Essays in Honor of Rudolf G. Wagner*, Gossenberg: Ostasien Verlag, pp. 91-110.

"Xiaoshan Nansha shuilihui qing xiu jiangnan taoshuiba" 蕭山南沙水利會請修江南挑水壩 (Nansha Water Conservancy Association in Xiaoshan County Asks to Repair the Spur Dike in Qiangtang River) (1946), *Dongnan ribao* 東南日報, 19 April 1946.

Xu Kai 須愷 (1927), *Luechen Qiantang jiang zhili yijianshu* 略陳錢塘江治理意見書 (Opinion on the management of the Qiantang River), *Mingguo shiqi qikan quanwen shujuku* 民国时期期刊全文数据库 (1911-1949) [J/OL] (Full-text databases of periodicals from the Republic of China period).

Yao Hanyuan 姚汉源 (1987), *Zhongguo shuilishi gangyao* 中国水利史纲要 (Outline of the History of Water Conservancy in China), Beijing: Zhongguo shuili shuidian chubanshe.

Yu Qian, Wang Yunwei, Gao Shu, and Burg Flemming (2012), "Modeling the Formation of a Sand Bar Within a Large Funnel-Shaped, Tide-Dominated Estuary: Qiantangjiang Estuary, China," *Marine Geology* 299-302: 63-76.

Zhang Shunong 張書農 (1953), *Zhihe gongcheng xue (xia)* 治河工程學（下）(River Engineering [last volume]), Beijing: Zhongguo kexue tushu yiqi gongsi.

Zhang Wencai 張自立 (1990), *Zhongguo haitang gongcheng jianshi* 中国海塘工程简史 (A Brief History of China's Seawall), Beijing: Kexue chubanshe.

Zhang Zili 張自立 (1933), "Zhengli qiantangjiang zhi jihua" 治理錢塘江之計畫 (Plan for Regulating the Qiantang River), *Shuili yuekan* 水利月刊 56: 15-22; p. 54.

Zhejiang sheng zhengfu 浙江省政府 (Zhejiang Provincial Government) (1927), "Zhonghua Minguo Guomin zhengfu Zhejiang sheng zhengfu ling jianzi dihao mingling ling Qiantangjiang gongchengju chengyijian chengsong gongchengshi Xu Kai luechen zhili Qiantang jiang shuyou" 中華民國福噢民政府浙江省政府令建字第號命令令錢塘江古城呈意見呈送工程師須愷略陳治理錢塘江書由 (Opinion Letter Submitted by the Engineer Xu Kai luo on How to Govern the Qiantang River, Ordered by the Qiantang River Engineering Bureau, Zhejiang Provincial Government, of the National Government of the Republic of China), *Zhejiang jianshe yuekan* 浙江建設月刊.

Zhejiang sheng shuili ju 浙江省水利局 (Zhejiang Water Conservancy Bureau) (1933), "Liangnian lai Zhejiang haitang gongcheng yu zhengli qiantangjiang gongcheng" 兩年來浙江海塘工程與整理錢塘江工程 (The Embankment Project and the Regulation Project in Qiantang River of Zhejiang Province in the Past Two Years), *Zhejiang jianshe yuekan* 浙江建設月刊.

Zhejiang sheng shuili ju zong gongzuo baogao (Mingguo 21 zhi Mingguo 24) 浙江省水利局總工作報告（民國二十一年至民國二十四年） (General Working Report on the Water Conservancy Bureau of Zhejiang Province, 1932-1935)(1935), Hangzhou: Zhejiang sheng shuili ju.

Zhejiang sheng tongji ju tongji nianjian 浙江省统计局统计年鉴 (Zhejiang Statistical Yearbook) (2006), URL: http://tjj.zj.gov.cn/tjsj/ydsj/gy/.

Zhejiang sheng zhengfu weiyuanhui 浙江省政府委員會 (Zhejiang Provincial Government Committee) (1928), "Zhejiangsheng zhengfu weiyuanhui huiyi si yue er ri di jiu shi qi ci huiyi: Zhejiangsheng shuiliju zuzhi guicheng" 浙江政府委員會會議四月二日第九十七次會議：浙江省水利局組織規程 (Zhejiang Provincial government committee meeting, 97th meeting on 2 April: Water Conservancy Bureau of Zhejiang Province organization regulation), *Zhejiang jianshe yuekan* 浙江建設月刊.

"Zhejiang shuizai ji" 浙江水災記 (Records of Floods in Zhejiang) (1926), *Shen Bao* 申報.

"Zheshan xinsha wanmu chenru haidi, Nansha mingyun jijikewei" 赭山新沙萬畝沉入海底，南沙命運岌岌可危 (Large Quantities of New Sand Sink into the Qiantang River at Zheshan: Nansha's Fate at Stake) (1947), *Dongnan ribao* 東南日報, 22 June 1947.

Zheng Zhaojing 鄭肇經 (1939), *Zhongguo shuili shi* 中國水利史 (History of Water Conservancy in China), Shanghai: Shangwu yinshu guan.

——— (1987), *Taihu shuili kejishi* 太湖水利技术史 (History of Water Technology in Taihu Lake), Beijing: Nongye chubanshe.

"Zhongguo xiandai shuili renwu zhi" bianshen lingdao xiaozu, bianzuan bangongshi, bianji bu 《中国现代水利人物志》编审领导小组、编纂办公室、编辑部 (Editorial Board of the China Hydrology Encyclopedia)(1994), *Zhongguo xiandai shuili renwuzhi* 中国现代水利人物志 (Biographical Dictionary of Water Conservancy in Contemporary China), Beijing: Zhongguo shuili shuidian chubanshe.

Zhou Kuiyi 周魁一 (2002), *Zhongguo kexue jishushi: shuili juan* 中国科学技术史：水利卷 (History of Science and Technology in China: Water Conservancy Volume), Beijing: Kexue chubanshe.

Zhu Xie 朱偰 (1955), *Jiangzhe haitang jianzhushi* 浙江海塘建築史 (Architectural History of the Seawalls in Jiangsu and Zhejiang), Beijing: Xuexi shenghuo chubanshe.