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Engineering the Sea: Hydraulic Systems and Pre-Modern Technological Lock-In in the Harnghzhou Bay Area, circa 1000–1800

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...aestus ab undis
aequoris exesor moerorum litora propter.
[... commotion from the waves of the sea,
that devourer of the walls beside the shore.]
Lucretius, *De rerum natura*, vi. 925–6

SUMMARY

Inner Harnghzhou Bay 杭州湾,¹ on the east coast of China at approximately 30° N., is an unstable macrotidal estuarine system whose geographical configuration has altered dramatically over the last thousand years. An important prelude to this was that the salient on the north coast of the outer bay that 1500 years ago linked the mainland to the Warnghparnshan 王盘山 (or Huarngparnshan 黄盘山), which are today a group of islands about 20 kilometers offshore from from Zhahpuu 乍浦, was scoured away before Sohng times, probably opening the north coast of the inner bay to a more direct attack from the tides. Shortly before +1400² the south-shore coastline immediately north of Yuryaor 余姚 also began to grow northwards, and what had previously been a relatively straight coast running in an east-west direction, with long tidal inlets that often opened into harbours (as at Yuryaor) and lakes, became the

1 The romanization of Chinese used here is based on Lirn Yuutarng 林语堂 (Lin Yutang), *Chinese-English Dictionary of Modern Usage* (1972. Hong Kong: Chinese University of Hong Kong Press) modified to accord with *pinyin*. Thus second and fourth tones are indicated by unsounded post-vocalic 'r' and 'h' respectively, and the main vowel in third-tone words is doubled.

2 The few dates where doubt about the era is possible are labelled with a '–' or a '+' for B.C. and A.D. respectively.

huge depositional peninsula that it is today, shaped something like a Gaussian curve. We have studied this phenomenon in a separate paper.³ Our particular concern in the present paper is the scouring away during the Yuarn and the Mirng of the stalacite-shaped peninsula that descended from the north coast of the inner bay in Sohng times, linking the Dajianshan 大尖山 and Xiaojianshan 小尖山 hills with Mount Zheeshan 赭山, and Mount Zheeshan with Rernher county 仁和县 (one of the two counties containing Harnghzhou city), and its replacement with a stalagmite-shaped peninsula, known today as the Narnsha 南沙, or ‘southern sands’, that built up gradually from the southern shore to include Zheeshan and then Mount Shuushan 蜀山 to its north. This inversion was directly connected with two changes in the mouth of the Qiarntarng River 钱塘江: (1) in 1620 from a southern debouchment just to the north of Mout Kan 龛山 to a central or mid-bay debouchment south of Mount Herzhuang 河庄山; and (2) in 1692–5 from this central debouchment to approximately its present northern exit, though this was not stabilized until almost a century later.⁴ Natural processes have dominated these changes, but human intervention in the form of the building of massive sea-walls, the diversion of rivers and the reduction of their peak discharge by reservoir storage and locks, as well as the reclamation of tidal wetlands, has also affected the long-term re-shaping of the coastlines. The commitment of both local society and imperial government to complex and costly hydraulic systems in this area created forms of what may be termed ‘technological lock-in’, in other words a relative foreclosing of other options on the future use of labor, resources, and administrative inputs, though release from ‘lock-in’ could also sometimes occur as the results of shifts in the patterns of sediment deposition and erosion that were favourable to human economic interests. The present paper summarizes and interprets previous work on the hydrology and hydraulics of this area, and presents a preliminary reconstruction of the geographical pattern of change based on historical documents and maps. It ends with an outline of some of the analytical problems that will need to be addressed in the future. It also shows that, under certain circumstances, geomorphological change — like climatic change — can affect human social and economic life over relatively short periods (typically tens to hundreds of years). The basic conclusion is that long-term economic history without environmental history is, at best, lopsided and, at worst, misleading.

3 Mark Elvin and Su Ninghu, “Action at a Distance. The Influence of the Yellow River on Hangzhou Bay since A.D. 1100”, in M. Elvin and Liu Ts’ui-jung 刘翠溶, eds., *Sediments of Time. Environment and Society in Chinese History* 积渐所至中国历代生态环境与社会发史 (forthcoming, and in also in a Chinese-language edition from Academia Sinica, Tairbee).

4 Taor Curnhuahn 陶存焕, “Qiarntarng-jiang san-mern biahnqian kaaobiahn” 钱塘江三壑变迁考辨 [A critical examination of the changes in the Three Clefs of the Qiarntarng River] (author’s offprint, 1986, from the Qiarntarng-jiang gongcherng guaanlii-jur 钱塘江工程管理局, Harnghzhou) offers a slightly different chronology.

0. *The Geographical Context*⁵

quin etiam refert nostris in versibus ipsis
cum quibus et quali sint ordine quaeque locata;
...verum positura discrepitant res.

[Indeed in my own verses it is a matter of
some moment what is placed next to
what, and in what order; ...moreover,
things differ because of their positioning.]

Lucretius, *De rerum natura*, ii. 1013–4, 1018

Figure 1a is a false-colour image of inner Harngzhou Bay 杭州湾 and its environs. The area shown is approximately 69 kilometers east to west, and the date is 3 March, 1986. The original image is composed of frequency bands (red), 7 (middle infra-red), and 5 (near middle infra-red) of the Thematic Mapper system operated by Eosat.⁶ The elongated depositional shoals aligned parallel to the direction of tidal flow that are characteristic of most macrotidal estuaries (tidal range > 4m) can be seen in the lower part of the channel. Parts of the earlier coastlines appear as discontinuities in the intensity of reflectance, in color, and in texture, on both the northern and southern shores. Figure 1b is a key to the main features in the image. The rapidity of change in recent years may be appreciated by comparing this picture with Figure 2, which is based on the 1:50000 sheet maps prepared of this area by the Japanese Army in (approximately) 1938.⁷

The important geographical features are (1) the Qiantang River 钱塘江 (which flows from west to east into inner Harngzhou Bay), (2) the cities of Harngzhou 杭州 (on the left bank of the river, about mid-way up the left side of the map), Shaohxing 兴 (near the bottom of the map, slightly right of centre, at the junction of the long flattened V formed by the ancient transport canal), and Yanguan 盐官 (Haairing 海宁 in most of late-imperial times) on the central northern coast near the middle of the shallow arc facing the thumb-shaped peninsula of the Nansha 南沙 ('southern sands') that sticks up into the centre of the inner bay, and (3) the hills in and around the Bay that have been the only constant features in historical times. The most evident of the latter is Kanshan 龕山 (also known as Harngwuushan 杭坞山), which is almost dead-centre in the satellite image. To its north, located from south to north respective-

⁵ We should like to offer our thanks to Professor John Chappell of the Research School of Pacific Studies for advice on geomorphological matters, though it should be noted that in a few instances we have, with great hesitation, risked taking a view that differs a little from his, and to Professor Shiba Yoshinobu 斯波义信 of the International Christian University, Tokyo, for generous help with Chinese materials.

⁶ Acknowledgements are due to EOSAT for the data, ACRES (Australian Centre for Remote Sensing) for photo-reproduction, and thanks to Robin Grau and Merv Commons (both of the Research School of Pacific Studies, Australian National University) and Paul Hutton (Division of Water Resources, CSIRO) for help with the image processing on micro BRIAN.

⁷ Kagaku shoin, *Chûgoku tairiku gomanbun-no-ichizu shûsei* 中国大陆五万分の一地图集成 [Collection of 1:50000 maps of the Chinese Mainland] (Tokyo: 1988), 3 vols.



Fig. 1a. EOSAT Thematic Mapper image of inner Harngzhou Bay, 3 March 1986.

ly, are two groups of smaller hills rising out of the alluvial land-surface, the first centred on Zheeshan 赭山 and the second on Herzhuangshan 河庄山, and, lastly, to the northeast of the latter, the low and isolated Shuushan 蜀山. On the northern shore, east of Yanguan/Haainirng are two hills, from west to east, the Xiaojianshan 小尖山 and the Dahjianshan 大尖山. The south-pointing promontory to the east of these two hills culminates in the Tasshan 塔山, between which and the coast a sea-wall was built (or possibly re-built) in the eighteenth century.

The dominant pattern of run-off is from the hills on the south side of the Bay, which feeds not only the Qiarntarng River but also lesser but still important rivers such as the Puuyarng 浦阳江 (which today flows in a northwesterly direction into the Qiarntarng a little distance upstream from Harngzhou city, but which immediately before the mid-fifteenth century took a more northerly course directly into the Bay), and the Caor'er 曹娥江 (which enters the Bay east of the Narnsha from the southeast corner of the

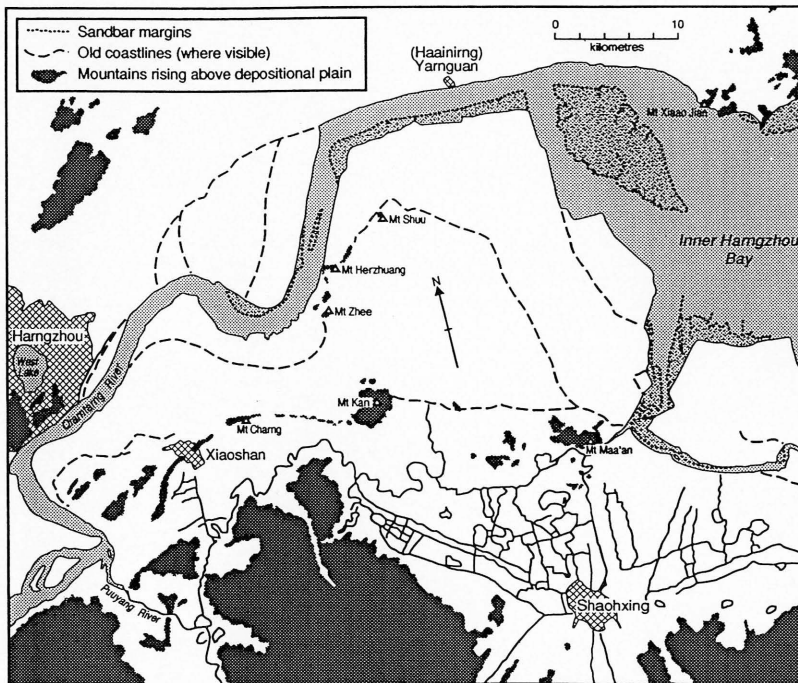


Fig. 1b. Key to the main features in Figure 1a.

satellite image). Smaller streams off the hills also fed the elongated man-made Mirror Lake (Jiahnhur 鑑湖/Jihnggur 镜湖) that lay for a millennium from Later-Hahn to Northern Sohng times on the east and west sides of Shaohxing (then Yuezhou 越州) just south of the slightly later transport canal,⁸ until it largely disappeared through siltation early in the Northern Sohng dynasty. Its traces may still be seen in the image, especially on the western side, having a shape resembling a dragonfly's wings. Five hundred years ago, all three of the major rivers entered the Bay just west of the debouchment of the Caor'er, and the point of confluence was and still is known as Three Rivers' Mouth 三江口, a name that only makes sense in the light of its geographical history.

The present coastline is to all intents completely enclosed within seawalls. The remnants or traces of some parts of earlier seawalls may be seen lying inland. Others have

8 On the canal, which also had irrigation functions, see Shehng Hongyuarn 盛鸿源 and Qiu 我国最早的人工运河之一：山阴故水道 [One of the oldest manmade waterways in our land: the old Shanyin canal], and Yaor Hahnuyarn 姚汉源, "Zhehdong yuhnher-shii kaaolueh" 浙东运河史考略 (A summary of a historical investigation into the Zhehdong Canal), both in Shehng Hornglarng 盛鸿郎, ed., *Jiahnhur yuu Shaohxing shuulih* 鉴湖与绍兴水利 [Mirror Lake and water control in Shaohxing] (Beeijing: Zhongguor shudiahn, 1991). The oldest section of this composite waterway, partly constructed and partly adapted from natural streams, goes back to the — fifth century. As a continuous system across the Shaohxing plain it probably dates from between the early + fourth and the + fifth century.

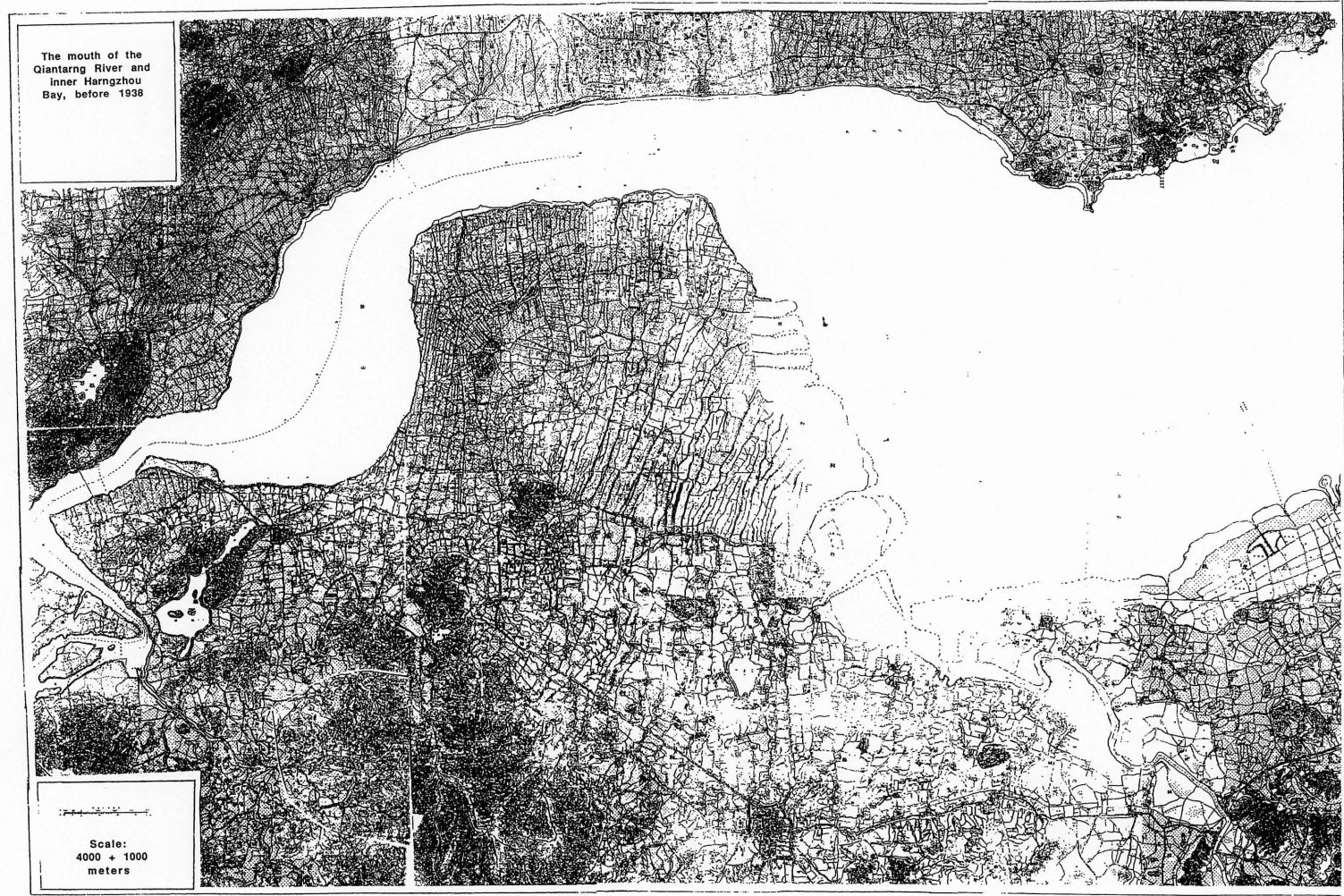


Fig. 2. Inner Hargzhou Bay before 1938 (according to Japanese army maps).

long since vanished under the waves and tides.

The outer bay, as may be seen from British Admiralty chart no. 1199 for 1984⁹ (not reproduced here), has a funnel shape that is the cause of a tidal bore which can exceed 3 m in height and 13 knots in velocity.¹⁰ The Pacific tides, which are twice daily here and of approximately equal strength, approach from the southeast and enter the Bay through the channels separating the islands in the Zhoushan archipelago 舟山群岛 (to the east of, and outside, the area shown in the satellite image).

The basic pattern of change discussed here is summarized in the *Sanjiang-zhar wuh quarnshu* 三江闸务全书 [Complete documents relating to the affairs of the lock at Three Rivers' Mouth] compiled around 1702 by Cherng Mirngjiuu 程鸣久 (style Her-zhu 鹤翥):¹¹

The overall pattern is that the water from the upper reaches of the Zheh River 浙江 [i.e., the Qiantarng] flows out through [one of] three clefts (*mern* 壑, close to the sense of *xihn* 壑 'fissure').¹² There is a large cleft to the south and to the north, and a small central cleft in the middle between them. When the water makes its exit through one of these clefts, the other two are both silted up. They have opened in sequence, changing around among themselves.¹³ The time during which water is passing out through one of them may be several hundreds of years of less than a hundred, but is not to be reckoned in years and months. If we speak with respect to the Sohng dynasty, then in 1094 the water went out through the large southern cleft [implying, but not explicitly stating, that it had taken a different route previously]. More than five hundred years later, in 1620, it went out via the small central cleft, but in less than a century this was silted up, and the cottages, graves, fields, and gardens of the large northern cleft were all given over to the flow of the river. During 1692 and 1693 the current was still slight, but on 2 August 1695 it broke through in tumultuous fashion and became a large river. The sands in such places as Gualih 瓜漈 and Jiuudun 久墩 on the border between the counties of Xiaoshan and Shanyin forthwith lay exposed to the air. In the autumn of 1693, for no reason, they collapsed totally without trace. Fortunately the sands in places as Dongtang Bay 东汤湾 [seawards of the Lock] were actually extended, and the people could not contain their delight. I have heard, however, from those living along the sea-coast that they did not consider this to be a cause for rejoicing, but as something deserving profound anxiety...

The inner bay was thus extraordinarily unstable.

- 9 Hydrographer of the Navy (Taunton, U.K.: 1984): China - East Coast: Ningbo Gang to Changjiang Kou. Scale 1: 300000 at latitude 30°.
- 10 [U.K.] Naval Intelligence Division, *China Proper*, III (Edinburgh: HMSO, 1945), p. 291.
- 11 *Three Rivers' Lock*, *shahng*, j. 2, p. 2a. We are grateful to Professor Shiba Yoshinobu for making available to us a photocopy of this rare work.
- 12 Morohashi 诸桥氏, *Dai Kan-Wa jiten* 大汉和辞典, #342, cites two commentaries that indicate the sense of gorge with walls facing each other like the flaps of a door: '山绝水也' and '水流峡中, 两岸对出若门也.'
- 13 Within the imperial period at least the major southern cleft, or 'sea-gate' (*haaimern* 海门) seems to have been the regular mouth until the seventeenth century.

1. *Previous investigations and their implications*

Propterea quid sit prius actum respicere aetas
 nostra nequit, nisi qua ratio vestigia monstrat.
 [Thus our age cannot look back upon what may
 have happened before unless in some way reason
 shows us the traces of the way that was taken.]
 Lucretius, *De rerum natura*, v. 1446–7.

The origin of modern studies of the Jiangnan 江南 landscape was probably the *Kōnan bunka kaihatsu shi* 江南文化开发史 [History of the Development of Jiangnan] by Okazaki Fumio 岡崎文夫 and Ikeda Shizuo 池田静夫 published in 1940 in Tokyo (by Kōbundō). They cite materials indicating the disappearance of rivers, alterations in the coastline, the building of sea-walls, the excavation of channels called *sha'her* 沙河 to absorb some of the tidal force, and the shrinking of lakes, as well as the reclamation of wetlands and the building of canals. They also draw attention to the early awareness of the Chinese of the double-edged nature of development. They cite, for example, the comment made by the Qing-dynasty scholar Chergn Yaortiarn 程瑶田 on the views of the Hahn historian Simaa Qian 司乌迁:

As regards the construction of induction channels (*yinher* 引河) in order to irrigate fields, this was a technical transformation of drainage ditches (*gouxu* 沟洫), which latter were for the purpose of averting the damage done by floods, whereas the purpose of the induction channels was to promote the beneficial use of water (*shuulich* 水利). When the beneficial use of water is promoted, however, disasters caused by flooding become increasingly fierce, the rivers being unable to scour clear their original channels (*diryuarn* 淤原), so it is a waste of time to ask whether or not the drainage ditches can control them. This is why the Grand Historian [Simaa Qian] spoke so vehemently, in his treatise on rivers and channels, about such channels as being harmful to rivers.

The main text of the 'Treatise on Rivers and Channels' (*Her-qur shu* 河渠书) in the *Records of the Grand Historian* (*shijih* 史记)¹⁴ in fact presents a somewhat mixed picture of the benefits and harm of water control. Nor does it give the causal analysis contained in Chergn's remarks, which may perhaps express more a late-imperial rather than an early-imperial point of view. Simaa Qian's outburst at the end of the Treatise, though it can be read as a simple condemnation, is more plausibly taken in an ambivalent sense: "Great, indeed, are the benefits *and* the disasters (*lihhaih* 利害) of water control!"

In recent times this line of enquiry has been pursued by Kitada Hideto 北田英人 who has suggested that the dyke-protected water-routes (*tarngluh* 塘路) in the southern part of the Lake Taih 太湖 region, probably first built in the + fourth century, sometimes cut across the natural flow of the water, and so increased the severity of the flooding.¹⁵

14 Simaa Qian, *Shiji* (Beijing: Zhonghua shujur, 1959), pp. 1405–1415.

15 Kitada Hideto, "Sei-roku seiki Koshū no tōro keisei to kankyō henkaku" 四六世纪湖州的塘路形成と环境变革 [The formation of dyke-protected water-routes in Hurzhou from the + fourth to the + sixth centuries, and changes in the environment], *Chūgoku suirishi kenkyū* 中国水利史研究21 (1991).

In another article, on “The Natural Environment of Jiangnan and Its Development in Tang Times,”¹⁶ Kitada has described the last third of the + first millennium as a time of transition during which human intervention began to reshape the landscape of this region “albeit on a very small scale”. During this period the rivers in a wide coastal belt, and also Lake Taih 太湖, were subject to tidal pressures. Where these caused the fresh water to back up, the resulting rise in water-level was used for a type of ‘tidal irrigation’¹⁷ since the pallet-chain square-trough pump (*lorngguu che* 龙骨车) was not yet in use, as it was to be under the Song. After the Tang, the southern shore of the triangular Jiangnan peninsula, or in other words, the northern shore of Harnghzhou Bay, “was closed up by sea-walls, and this accelerated the trend towards the silting up of the river-mouths along this shore.” Underlying this infilling was the deposition of sediment from the Yarngzii, carried out into the sea and then back in again by the tides, but the great river was, Kitada argues, clearer at this time than it was to be later. The zone of visible suspended sediment extended only about 11 kilometers offshore. He also suggests that the long-term diversion of the Yarngzii’s waters for farming made it less able than before to scour away its silt. The arguments may be reasonably described as suggestive rather than definitive.

Okazaki and Ikeda also began the modern analysis of traditional Chinese hydrological thinking about the problems faced by the Jiangnan area. It is clear from their work that the Chinese concerned with water control here in imperial time were sharp observers of nature, and that there were significant arguments of principle among them. As an illustration we may use their citation of the comments of the grain transport commissioner Jia Daan 賈奩 (who flourished in the middle of the eleventh century) on the tidal deposition of sediment in river-mouths, a topic of key importance in our later discussion:

I have also heard that in ancient times the inlets (*puu* 浦 that entered the sea from the town of Qinglorng 青龙镇 in Xiuhzhou 秀州 [south of present-day Shanhghai] had 72 loops (*huih* 会 = *huih* 汇), and were serpentine and meandering. There was a profound significance in this, which we may take as being that the water tended in an easterly direction by following the lie of the land. Even though [the streams] were serpentine and meandering, no harm was done thereby to their eastwards flow. If a southeasterly wind blew up, whipping the ocean tides so they poured-in in torrential turbulence, the intervals between [the river-bends] provided something for them to rebound from, and the sediment (*nirsha* 泥沙) did not penetrate far inland. People of these later times have not understood the intentions of the men of old, and are of one mind that [these rivers] should be straightened. Thus, if it should happen that there is an east wind, and the ocean tides pour-in in torrential turbulence, the sediment now travels with their flow straight upstream, there no longer being any obstacle in its way. All creeks and inlets entering rivers, lakes, and the sea are in a similar situation. When one talks, therefore, of ‘clearing them one day and finding them closed up the next’, this is what is being referred to.

16 Kitada Hideto, “Tôdai Kônan no shizen kankyô to kaihatsu” 唐代江南の自然环境と开发, in Goto Akira 後藤明, *et al.*, ed., *Rekishi ni okeru Shizen* 历史に於ける自然 [Nature in History] (Tokyo: Iwanami, 1989), pp. 141-74.

17 The saline wedge, being slightly denser, would also have lain below the fresh water.

The meander zone may, just possibly, have helped to keep the rivers scoured by concentrating the ebb flow in a smaller channel than that of the flood, because of channel cross-sectional asymmetry,¹⁸ but the observation of the effects of reflection as reducing deposition is interesting. With respect to the area surveyed in the present paper, the effects of straightening the course of the Qianqing River 钱清江 on the seawards side of the lock built at Three Rivers' Mouth in 1537 are recorded in the commentary on the maps in *The Three River's Lock*:

If the old map is not included, people will not be aware how excellent things were in past times [the collection of documents dates from before 1702], when the mouth of the lock was always clear. If the new map is not included people will not be aware of recent changes, and of how easily the lock's mouth [now] silts up... The Nine Bends Sands (*jiuqu sha* 久曲沙) are connected with the topographic disposition (*fengshuui* 风水 = geomantic character) of the entire prefecture, but most especially with that of the lock. Now, when there were bends in the sands then the tide did not come straight in, and the sediment was brought to a halt because it followed these curves. Therefore the lock was always clear. The two large bends were subsequently cleared away, and it is certainly the case that the water [now] exits more easily, but the tide likewise comes in more easily, and the mouth of the lock is more easily liable to become silted up. As to the West Bend Spit (*xi huih zuui* 西汇嘴) and the East Charn Spit (*dong charn zuui* 东嘴), these two [extended bars of] sands [at the mouth of the river] appear in the old map as intertwining, and the shape of the sands is long and broad. They constituted the outer defences of the lock. Today the ends of the two sand-bars lie open and exposed, and their shapes are constricted to half of what they were before. The force of the tides strikes powerfully against the lock and harms it.¹⁹

It seems that human intervention was capable of having significant effects, though sometimes not of the kind intended.

Japanese historians of water control in China belonging to the generation after that of Okazaki and Ikeda concentrated mainly on the social and political nature of hydraulic organization.²⁰ In the process much material of value for historians of the environment was also identified. An example is Morita Akira's 森田明 study "Kô Setsuni okeru kaitô no suiri soshiki" 江浙における海渐における海塘の水利织组 [The hydraulic organization for sea-walls in Jiangsu and Zhehjiang provinces], first published in 1965 and reprinted in his *Studies on water control in the Qing dynasty*.²¹ He

18 See, for example, L.D. Wright, J.M. Coleman, and B.G. Thom, "Sediment Transport and Deposition in a Macrotidal River Channel: Ord River, Western Australia", in L.E. Cronin, ed., *Estuarine Research*, vol. 2 (New York: Academic Press, 1975), p. 319.

19 Cherng Mirngjiuu, *Three Rivers' Lock*, *shahng*, j. *shahng*, pp. lab.

20 See M. Elvin, "On Water Control and Management during the Ming and Ch'ing Periods", [a review article of Morita Akira 森田明, *Shindai suirishi kenkyû* 清代水利史研究 {Studies on water control in the Qing dynasty} (Tokyo: Aki shobô, 1974)], *Ch'ing-Shih wen-t'i* 清史问题 3.3 (Nov. 1975). Also M. Elvin, "Introduction", in M. Elvin, Hiroaki Nishioka, Keiko Tamura, and Joan Kwek, *Japanese Studies on the History of Water Control in China. A Selected Bibliography* (Canberra and Tokyo: The Institute for Advanced Studies, Australian National University, and The Centre for East Asian Cultural Studies for Unesco, (Tôyô Bunko, 1994).

21 See note 19 above.

shows that the reasons for the building of the sea-walls that run down the coast of southern Jiangsu and northern Zhehjiang provinces were, first, to exclude saline water from coastal lands formerly used for fishing, salt-extraction, reed-growing, and some limited farming, so that they could be reclaimed for more productive agriculture, and, second, to protect the inhabitants of these coasts from the incursions of high tides. The latter appear to have become a more serious problem in the Southern Sohng dynasty, in the twelfth and thirteenth centuries, for reasons perhaps connected with colder and less stable climatic conditions.

Morita has also made clear the heavy financial and human costs of maintaining the sea-walls. He quotes, for example, the county gazetteer for Huarting 华亭 which states that “the repair and construction of the sea-walls is a huge undertaking and highly expensive, requiring the collaboration of the entire county”. And, again, that “these days the building of the sea-walls is mostly done in the dog-days [approximately late July to mid-August], the workmen steaming and burning in the blazing summer weather, ... gathered together in the disease-inducing heat (*shashuu* 痧暑),²² with one knows not how many of them dying at the foot of the sea-wall.”

Shiba Yoshinobu's 斯波义信 massive *Sôdai Kônan keizai-shi no kenkyû* 宋代江南经济史の研究 [Studies in the economic development of Jiangnan in Sohng times]²³ only touches tangentially on the question of the sea-walls, but emphasizes the importance of the ever more complete separation of the fresh-water and saline systems, as the irrigation of the coastal plain on the south side of the bay expanded towards the sea, and the line of sea-walls and locks became complete, apart from the two rivers that were too large to close off, namely the Qiantang 钱塘江 and the Caor'er 曹娥江. Shiba shows that the separation effected by the sea-walls made it possible for the irrigation system on the Shaohxing plain to survive after the artificial fresh-water reservoir of Mirror Lake, built in +140, had silted up early in Sohng times. At the same time he shows that closure led to problems with the drainage of flood waters from the Puuyang River, or Western Small River (*Xixiaojiang* 西小江), that at this time entered the plain from its western end, and describes the resulting re-engineering of the system of upstream riverine flow undertaken to deal with this.

The most recent work in Japanese on the sea-walls has been that by Honda Osamu 本田治. His article “Sô-Gen jidai Settô no kaitô” 宋元时代浙东の海塘 [The sea-walls of Zhehdong in the Sohng and Yuarn Periods] establishes a preliminary chronology for the sea-walls of this period along the southern coast of the bay. The first reliable record is of a rebuilding in the Tarn dynasty, though there are indications that some sea-walls may have been in existence here much earlier. Honda also traces the slow spread of construction in solid masonry over the centuries following the Sohng. This was at least ten times as expensive in terms of initial costs (though not necessarily more costly when considered in conjunction with maintenance over time) as the older methods using earth, ‘dam-timbers’ (*jiahnmuh* 槿

22 *Sha* has variety of meanings, including colic, a cholera-like illness, and measles.

23 (Tokyo: Tôyô bunka kenkyûjo, 1988).

木),²⁴ and bamboo baskets or wooden coffers filled with small stones or rubble. The materials that he presents make clear the burden of maintenance on labour, organizational capacity, and material resources, especially wood. He cites, for example, a description in the county gazetteer for Shahngyur 上虞 of the rebuilding of 19,940 feet²⁵ of sea-wall that runs as follows:

The method is to use, for every 10 feet, 32 pine-trees (*songmuh* 松木 = *Pinus* sp.) one foot in diameter and 8 feet in length. These are set in 4 rows, unevenly, and sunk deeply into the ground. After this stones 5 feet long, and a half of this in width, are laid at right angles to each other in an interlocking pattern on top of the level stones in 5 layers, all set into each other like dog's teeth, so that they cannot be dislocated. In places where there is a depression in the sands on the seaward side they build 8 layers. The height is over 10 feet. The top is covered with flagstones so as to seal it with their pressure. On the landward side there is a fill of stone rubble to a depth of more than a foot, and then earth is banked up next to it. The base is 20 feet wide, and the top diminishes to a quarter of this.

It may be calculated that this relatively small sector would have needed 6×10^4 pine-trunks and over 10^6 cubic feet of stone. Nonetheless there must have been a significant contrast in durability with the Sohng-dynasty earth-and-brushwood sea-wall at Harnghzhou that Honda mentions (in the article summarized in the next paragraph) as having to be rebuilt every three years.

Honda has also explored the changing geography of Harnghzhou Bay since Sohng times, and the shift in the location of the mouth of the Qiarntarng River. His later study "Tô-Sô jidai Ryô-Setsu Wainan no kaigansen ni tsuite" 唐宋时代两浙淮南の海岸線について [On the changes in the line of the sea-coast of the Liaang-Zheh and Huairnarn in Tarng and Sohng times]²⁶ uses the identification of the historic locations of the sea-walls to determine the approximate lines of the old sea-coasts. He suggests that from the Tarng (and probably much earlier) to perhaps the early-Qing the Qiarntarng River entered the sea north of Mount Kan 龕山 and south of Mount Zhee 赭山, in other words across the base of the present Narnsha 南沙 peninsula on the south side of the inner bay. Mount Zhee was linked by land both to Rernher county 仁和县 (a part of Harnghzhou city and its environs) in the west, and to Haainirng 海宁 (then Yarnguan 盐官)²⁷ to the north. In the late-Mirng and the early-Qing this southern mouth silted

24 On the use of 'dam-timbers' (*jiahn* 樅) for blocking breaches in a dyke, the gaps between them being infilled with vegetable material and earth, see the notes in *Records of the Grand Historian* (Zhonghuar edition), pp. 1413-4.

25 Early in the present century there were several hundred kinds of 'foot' (*chii* 尺 in China. The most relevant for the present topic may have been the mason's foot of either 11.08 or 10.09 inches, and the Board of Revenue foot of 13.18 inches. See [U.K.] Naval Intelligence Division, *China Proper* (1945. Edinburgh: H.M. S.O.), III, 607. In the absence of more precise indications it may be approximated as equal to the English foot.

26 (1981). In Osaka University (research report), *Tô-Sô jidai no gyôsei, keizai chizu no sakusei* 唐宋時代の行政经济地图の作成 [The making of the administrative and economic map of Tarng and Sohng times]. We should like to thank Professor Nishioka Hiroaki 西冈弘晃 for making a copy of this work available to us.

up, and the river moved to the small central exit north of Mount Zhee and south of Mount Herzhuang 河庄山. Then in the early eighteenth century it shifted north of Mount Herzhuang (and of Mount Shuu 蜀山), which is approximately its present course. At the same time the section of the southern shoreline that lies north of Yuryaor 余姚 and east of the mouth of the Caor'er River, which had previously been under attack from the tides, began to accrete sediment rapidly until it had become the semi-circular salient that now stretches north into the outer bay.²⁸

Zhehng Zhaohjing's early 郑肇经 *Zhongguor shuuilih shii* 中国水利史 [A history of water control in China],²⁹ contains a chapter on sea-walls. More recent Chinese work has come in two waves. There was a short burst in the middle of the 1960s, just before the 'Cultural Revolution', and there has been a second one from the early-1980s to the present day. The focus, in contrast to most recent Japanese scholarship, tends to be on technology, economic development, and geomorphological changes rather than on the relationship of hydraulics to social structure.

The basis for the study of the southern shore of Harngzhou Bay was laid by Chern Qiaoryih 阵桥驿 in five articles:

1. "Guudaih Jiahnhur xingfeih yuu Shan-Guih pirngyuarn norngtiarn shuuilih" 古代鉴湖兴废与山会平原农田水利 [The rise and disappearance of Mirror Lake, and agricultural land and water control in the Shanyin-Guihji plain in ancient times] in *Dihlii xuerbaoh* 地理学报 28.3 (Sept. 1962).³⁰
2. "Guudaih Shaohxing dihqu tianrarn senlirn de pohhuaih jir qir duih norngyeh de yingxiaang" 古代绍兴地区天然森林的破坏及其对农业的影响 [The destruction in ancient times of the natural forests of Shaohxing and its impact on agriculture], in *Dihlii xuerbaoh* 31.2 (June 1965).
3. "Lihshii-shahng Zhehjiang-sheeng de shandih keenzhir yuu shanlirn pohhuaih" 历史上浙江省的山地垦殖与山林破坏 [The historical development of the mountain lands of Zhehjiang province and the destruction of the mountain forests], in *Zhongguor shehhuih kehxuer* 中国社会科学 4 (1983).
4. "Luhn lihshii shirqi Nirng-Shaoh pirngyuarn de hurpo yaanbiahn" 绍历史时期宁绍平原的湖泊变迁 [On the changing distribution of lakes in the Nirngbo-Shaohxing plain in historical times], in *Dihlii yarnjiuh* 地理研究 3.3 (Sept. 1984). Co-authored with Lûû Yiichun 吕以春 and Yueh Zuumour 乐祖谋.
5. "Luhn lihshii shirqi Puuyarn-giang xiahyour de herdaoh biahnqian" 论历史时期浦阳江下游的河道变迁 [Changes in the lower course of the Puuyarn River in historical

27 For the sake of consistency, the name 'Haainirng' in the present paper refers only to the department (*zhou* 州) of Yuarn and Qing times, and the county (*xiahn* 县) of *Mirng and Republican times*, not to the present 'Haainirng'. Both before about 1330, and since the People's Republic, the area and its capital city have been called 'Yarn'gaun'.

28 *Yur* is the old Yueh 越 word for 'salt', and presumably Yuryaor, which is now far inland, was once known for its salterns.

29 (Charngsha: Shangwuh yinshuguaan, 1939).

30 'Guih' 會 (会) is also often read 'Kuih'. We follow A. Hermann, *Historical and Commercial Atlas of China* (Cambridge, Mass.: Harvard University Press, 1935 reprint).

times] in *Lihshii dihlü* 历史地理 1 (1981).

The first of these studies describes how hydraulic engineering transformed the Shaohxing plain. The south-to-north flow of approximately twenty small rivers coming off the hills into the bay below was intercepted by the construction of a long and narrow retention basin, the Mirror Lake referred to above. This covered about 206 km². Not long afterwards a canal with an approximately parallel orientation was built from Xixing 西兴 (which faces Harngzhou across the Qiarntarng river) to the bank of the Caor'er River, and later on to Nirngbo 宁波. The purpose of the basin was to retain water from the peak discharge in May to August, and release it to the fields below as needed. To prevent salinization by the incursions of the tide, locks and sluices were installed at the outlets of the drainage channels. These were gradually brought under the control of a single sluice at Yuhshan 玉山 (sometimes also called the Zhuchur Sluice 朱储斗门), located at the present-day town of Dooumertzhehn 陡壘镇.

The lower Puuyarng River (here also known as the West Small River or the Qiarngqing 钱清江) ran out west-to-east roughly parallel with Mirror Lake and the canal, but to the north of it, emptying into the sea at Three River's Mouth.³¹ The Puuyarng was apt to flood the plain and the effects were made more serious by the sea-wall, which blocked easy drainage (the point later developed by Shiba). In 1457-64 the Qixiahn Hill 七贤山, also known as the Qiryahn Hill 磻堰山, south of Lake Xiang 相湖, was therefore cut through and the greater part of the river's water was diverted westwards into the Qiarntarng River just upstream from the city of Harngzhou. Figure 1 shows this cut in the hill clearly (near the southwest corner of the image), to the west of where the present Puuyarng bends west at the town of Lirnpuu 监浦镇, and also the remnants of the former northerly main course, with the residual isolated or semi-isolated oxbow meanders characteristic of shifts of this nature.

After Mirror Lake had silted up in the eleventh century it was apparently too costly to dredge it clear again. One estimate, made at the time, was that it would have needed 5000 men 15 years to dredge it to a depth of 5 feet. (Using the estimated area given above and the approximation of 0.3 meters per Chinese foot, it seems that this implies that one man could remove over 11 cubic meters of sediment a day, which seems high, though perhaps conceivable if it was soft.) Nor was there general agreement among members of the community that dredging was desirable. Those who had reclaimed parts of the lake had no desire to lose their fields; there were more northerly reservoirs that were in some respects more conveniently placed (though Chern does not note that they lacked the height above the fields, and hence the head of water, that Mirror Lake had possessed); and the sea-wall offered a barrier against the sea-water.

Chern suggests that one of the reasons for the accelerating deposition of alluvium in Mirror Lake was upstream deforestation.³² This had begun to become noticeable after

31 That is, the Qiarntarng on its old southern course, the Puuyarng (before it was largely re-routed as described below), and the Caor'er.

32 In a recent conversation with the authors in Harngzhou (December, 1994), Professor Chern indicated that he now attaches less importance to this factor.

the Jin 晉 government had moved south in the + fourth century. The theme of deforestation is examined more systematically in the second and third articles.

There were three main phases:

1. The Shaohxing forests were of the tropical mixed type, with a substantial proportion of conifers. The first source of pressure on them was the rise of the kingdom of Yueh 越 in the middle of the – first millennium. Timber was needed for buildings and boats, and to fuel the metallurgical, ceramics, and salt industries. The consequences were not severe. Even in Hahn times coffins were being made here out of whole logs, rather than planks.
2. After the + fourth century the use of timber probably began to exceed the capacity of the forests for self-renewal. Chern notes the appearance of merchants who cut and sold wood and bamboos. After the last part of the Tarn dynasty some of the forested hills were partly cleared for tea-gardens, but tea only grows well on sheltered sunny slopes, and it was still essentially a luxury at this time. The effect is unlikely to have been great.

By the Sohng dynasty, however, Zhuang Jihyuh 庄季裕 could observe of the area around Yuehzhou 越州 (Shaohxing) that “there are hills but not trees.” Peasants began to move up into the hills in Southern Sohng times where they grew a cereal called *jih* 稭 of which it was said that “its sprouts resemble millet but its awns those of rice,” as well as other dry-land crops like ordinary millet, buckwheat, and beans. This process presumably led to a permanent stripping of much of the forest.

3. Disaster struck in the eighteenth century when maize (which probably arrived in the area around the middle of the sixteenth century) and sweet potatoes (which came in perhaps half a century later) were grown on an ever-expanding scale in the hill country. Chern quotes the ‘Jixiang-zhih’ 機祥志 [Monograph on auspicious events] from the *Mirngshu* 明书 [History of the Mirng] to the effect that “for the first time people burnt land clear in the mountains of Zhehjiang, and the grasses and trees on both sides were swept away.” By the later part of the Qing dynasty Guihji was without significant forest cover. The extraction of salt from brine had to move from a process of boiling to solar evaporation because of the shortage of fuel.³³

This provides an provisional chronological framework within which to consider both the possibility of increased run-off caused by the loss of vegetation cover (in an area with a mean modern annual precipitation that is close to 1200 mm, but varied over the centuries) and of increased loads of sediment in the rivers, at least for a time.

The fourth article, in which Chern is joined by two co-authors, argues that the lakes of the coastal plain along the southern shore of the bay were vestigial depressions left behind by the retreat of the sea from the foot of the coastal mountains at about 4000 BP, and points out that they have the shallow profiles, with gently sloping sides, that are characteristic of such lakes. There were more than 200 of them initially in the Nirngbo Shaohxing plain. They were mostly saline at first, but were converted to fresh-water lakes by the installation of locks and sea-walls. Towards the end of the + first millennium they had either begun to silt up or be encroached upon by farmers wanting extra land, or both. Today there are only about 28 of them left. Modern reservoirs, in

33 This had already happened earlier in Furjiahn province. See M. Elvin, “Skills and Resources in Late Traditional China”, in D.H. Perkins, ed., *China’s Modern Economy in Historical Perspective* (Stanford: Stanford University Press, 1975), p. 100.

contrast, are mostly up in the hills and hold only about 40% of the water in total that is estimated to have been held in the lakes of the plain at their maximum extent.

In the fifth article, Chern suggests — to some extent in contradiction of his previous work — that the earlier lower course of the Puuyarng River was in fact also to the west into the Qiarntarng River, but in an indirect fashion through two broads³⁴ that have by now long since silted up, namely the Lirn Broad 监浦 and the Yur (or Fisherman's) Broad 渔浦. This may well have been the case for at least part of the river's water, and that there was an old curvilinear western course, *before* the shift to a northern and northeastern exit, is supported by the passage from Maa Yaohxiang quoted in section 3 on 'Hydrology and Hydraulic Engineering' below. Chern suggests that some sort of engineered overflow channel for flood waters may have existed here long before the Mirng, and that the shift of the main channel to this cutting through the hill may have been a complex process. While this is indeed likely, it is our view that he overemphasizes the unsatisfactory nature of the documentary evidence³⁵ for the establishment of the main channel through the Qiryahnshan 磧堰山 (or Qixiahnshan 七贤山) in the Mirng period, and that some of the material he cites can as well be taken as supporting the view that the main course before some time in the fifteenth century was indeed to the north. For example, the 'Monograph on Rivers and Channels' in the *Mirng History* 明史 states that:³⁶

In 1435, the Ministry Bureau Secretary Sheen Zhong 藩中 said that the Small West River in Shanyin 山阴 communicated upstream with Quhzhou 衢州 and Jinhuar 金华, and *downstream with the sea-mouth of the Three Rivers* 三江海口

... It had recently silted up, and it was necessary to *build* (*zhur* 筑) the Qih Dam 戚堰 at Lirnpuu, to *block* the water from *the lakes*, so that they flowed *as before* out the Small River (p. 70, emphasis added).

The italicized words indicate that the Puuyarng and the Small West River were, at this time, the same watercourse, that the Qih (= Qir) Dam to stop water going west was not yet in existence, and that immediately prior to this time the water from 'the lakes', which fairly certainly refers to the famous 72 lakes of the middle Puuyarng,³⁷ had flowed out along a northerly course. At the same time it suggest that there was at least an overflow through the Qiryahnshan, once a blockage had occurred. Personal inspec-

34 We use the old Norfolk word for these coastal salt-water lakes called *puu* 浦 in the Chinese sources (though aware that many of the Norfolk broads were not saline).

35 See, for example, Pirng Herng 平衡, *comp.*, *Sanjiangzhar-wuh quarnshu xuhkeh* 三江闸务全书续刻 [Supplement to the *Complete Documents relating to the Affairs of the Lock at The Rivers' Mouth*] (N.p.: 1854), j. 1, p. 14a: "In the Tianshuhn reign of the Mirng [1457-1464] His Honour the Prefect Perng Yih cut through Qiryahn Mountain in order to draw the water from the upper reaches [of the Puuyarng] into the Qiarntarng River via Fisherman's Broad." We are grateful to Professor Shiba Yoshinobu for a photocopy of this work.

36 See also the *Mirng Yingzong shirluh* 明英宗实录 [Veritable records of the Emperor Yingzong of the Mirng] (Tairbeci: Academia Sinica, Institute of History and Languages, 1966) 9: 5b, p. 0176.

37 See Morita Akira, "Water Control in Zhehdong during the Late Mirng", trans. M. Elvin and K. Tamura, *East Asian History* 2 (Dec. 1991), pp. 35-8. A late — sixteenth-century picture-map of the cut through Qiryahnshan is on p.33.

tion (December, 1994) suggests there is probably a fault-line in the rocks here, facilitating outflow, and this needs systematic examination. Similarly, in 1482, the Prefect of Shaohxing, Daih Huu 戴琥, wrote that:

The Zhujih River 積暨江 [i.e., the Puuyarng] used to have the Qir Dam 磧堰, so that it joined together with the Small West River to enter the sea. Only since the dam has disappeared has it *for the first time* divided into two (p. 70 emphasis added).

Professor Chern notes that the name 'Qir Dam' goes back to at least the twelfth century (p.73), which conflicts with Sheen Zhong's account cited above, and we agree with him that the issue is a complex one that will benefit from re-examination.

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The numerous studies of the rise and fall of lake-based irrigation in the Shaohxing region are tangential to the concerns of the present article, but the following may be mentioned briefly. Nishioka Hiroaki 西冈弘晃, "Sôdai Kanko no suiri mondai" 宋代鑑湖の水利問題 [The question of the hydraulics of Mirror Lake in Song times]³⁸ is a pioneering account of the specific social forces that pressed for the conversion of lakes to arable land. Honda Osamu, "Sô-Gen jidai no Kagaiko suiri ni tsuite" 宋元時代の夏盖湖水利について [On the water control of Xiahgaih Lake in Song and Yuan times]³⁹ has a brief account of the sea-wall that protected this lake just east of the Caor'er River. One source that he cites suggests that the maintenance of this wall, which weighed heavily on the local inhabitants in the form of contributions of rice to pay the labourers working on it, may also have begun to strain forest resources. Thus in 1362 the sea-wall was rebuilt using "useless paling timbers *zhahmuh* 柵木" from the Shangshee hills 上舍岭.

Recent Chinese hydrological literature specifically on Harngzhou Bay originated in two articles: Qiarn Nirng 钱宁, Xieh Hahnxiarng 谢汉祥, Zhou Zhihder 周志德, and Lii Guangbiing 李光炳, "Qiarntarng-jiang herkoou shakaan de jihndaih guohcherng" 钱塘江河口沙坎的近代过程 [Fluvial processes in recent times of the sandbar at the mouth of the Qiantang River]⁴⁰ and Chern Jiryur 陈吉余, Luoh Zuuder 罗祖德, Chern Derchahng 陈德昌, Xur Haaigen 徐海根, and Qiaor Perngniarn 乔彭年, "Qiarntarng-jiang herkoou shakaan de xirngcherng jir qir lihshii yaanbiahn" 钱塘江河口沙坎的形成及其历史演变 [The formation of and the historical changes in the sandbar at the mouth of the Qiarntarng River].⁴¹ There is also a useful entry in the historical section of the *Zhongguor ziharn dihlii* 中国自然地理 [Natural geography of China].⁴² Subsequent work has been substantial. We would draw attention to articles in volumes edited by Yarn Qirn-

38 (*Shigaku kenkyû* 史学研究 117, 1972).

39 (1981). In *Chûgoku suiri-shi kenkyûkai* 中国水利史研究会, ed., *Chûgoku suiri-shi ronshû* 中国水利史论集 (Tokyo: Kokushokan).

40 (1964). *Dihlii xuerbaoh* 30.2 (June).

41 (1964). *Dihlii xuerbaoh* 30.2 (June).

42 (Beijing: Kerxuer chubaanshe, 1982), pp. 238-42.

shahng 严钦尚 and Xuu Shihyuaan 许世远, and by Chern Jiryur, Warng Baaocahn 王宝灿, and Yur Zhihying 志英, note that remote-sensing analysis of the bay was pioneered by Shi Jihqing 施纪青 and Yarn Weihyurn 严蔚云, and the team under their direction.⁴³

Before summarizing the essential points, it is useful to make some general observations. Estuarine hydrology is complex, depending on the oscillatory motion of the tidal flow and the discharge of water from one or more rivers. The pattern of the tide in turn depends on, and shapes, the geometry of the coastline, which creates effects of reflection and refraction. In some cases the Coriolis pseudo-force may have some effect.⁴⁴ In the case of Harngzhou Bay, the tides come in from the Pacific along a southeast-to-northwest alignment between the southern end of Kyûshû and the northern end of Taiwan, entering through the multiple straits of the Zhoushan archipelago.⁴⁵ The Coriolis force, in so far as it affects them, would thus tend to deflect their path towards the northern shore of the bay. This force would likewise cause the current of the Yarngzii to be deflected towards the south after entering the sea, and this combination explains why some of its load of sediment is carried in the direction of Harngzhou Bay.⁴⁶

In this context it should be borne in mind that the period from approximately 1194 to 1853 was unusual in that the Yellow River exited only 300 kilometers north of the Yarngzii during this time (though it should be noted that from 1194 to 1289 it had both a northern and southern mouth, and that before the late-sixteenth century the lower course usually had multiple channels).⁴⁷ In the sixteenth century the southern mouth was blocked with silt to the extent that extensive flooding was caused inland and the idea of trying to dredge clear its path to the sea was officially discussed, only to be rejected as impracticable.⁴⁸ It is thus probable that the silt load in the Yellow Sea was

43 Yarn Qingshahng and Xuu Shihyuaan, eds., *Charnghiang sanjiaozhou xiahndaih chernji yanjuiuh* 长江三角洲现代沉积研究 [Research on present-day deposits in the Yarngzii delta] (Shahngahaai: East China Normal University, 1987); Chern Jiryur, Warng Baaocahn, and Yur Zhihying, eds., *Zhongguo haaian fayuh guohcherng her yaanbiahn guilüh* 中国海岸发育过程和演变规律 [The laws governing the process of development and evolution of China's coasts] (Shahngahaai: Shahngahaai kehxuer jishuh chubaansheh, 1989); Shi Jihqing and Yarn Weihyurn, "Yaorgan turxiahng zaih Harngzhou-wan tantur diahchar-zhong-de yihngyohng" 遥感图像在杭州湾滩涂调查中的应用 [The application of remote sensing to research on the mud-flats of Harngzhou Bay], in Guorjia haaiyarng kehjih si, *Yaorgan jihshuh zaih haaiyarng huarnjihng yuu ziyuarn diaohchar-zhong-de kaifa yanjuiuh* 遥感技术在海洋环境与资源调查中的开发研究 [Research on the development of remote-sensing technology in the investigation of the marine environment and resources] (N.p.: 1987).

44 Newton's first law of motion makes it appear that bodies constrained to move on the surface of a rotating sphere (except exactly along the equator) turn towards the right in the northern hemisphere in the case of a right-handed rotation (as of the Earth), and to the left in the southern.

45 See Sun Xiangpirng 孙湘平, et al., *Zhongguor yarn'ahn haaiyarng shuuiwern qihxiahng gaihkuahng* 中国沿岸海洋水文气象概况 [An outline of the hydrological patterns and weather of China's coastal seas] (Beijing: Kehxuer chubaansheh, 1981), pp. 15–6.

46 Professor John Chappell, personal communication.

47 C. Blunden and M. Elvin, *Cultural Atlas of China* (Oxford: Phaidon Press, 1983), map on p. 15.

48 Tani Mitsutaka 谷光隆, *Mindai Kokô-shi kenkyû* 明代河工史研究 [Studies on the history of hydraulic works on the Yellow River in the Ming dynasty] (Kyôto: Dôhôsha, 1991), pp. 64, 71.

being carried southward down the coast, and in part in the direction of Harnghzhou Bay, and was denser than it is today.⁴⁹

Sediment is also usually being cycled from one part of an estuary to another. As Dyer notes, "in many circumstances it is difficult to tell whether there are any long term trends because the larger variations mask them, and it may take only a small variation of sea-level to destroy a local equilibrium." Since most sediment discharge occurs at occasional extreme events, and erosive power rises more than linearly with discharge, "this intermittency causes considerable problems for sampling as well as in estimating the effect of riverine sediments on estuarine and coastal sediment budgets."⁵⁰ The composition of the bed can also determine how particles move. Thus surface ionic charges on clays increase the adhesion between particles, but these are absent from sands. So can biological activities. Some bacteria, for example, secrete mucus that can stabilize beds. Finally, human intervention on upstream river systems may have downstream hydrological consequences. L.B. Leopold has noted that "the reduction of floods by storage decreases...the competence [carrying power] of the transporting stream," and hence "the reduction of the floods reduces the ability of the stream to rework the tributary debris".⁵¹

The changes in the shape of Harnghzhou Bay in historical times have been extensive, and it therefore seems likely that the patterns of tidal flow have also changed. The *Natural Geography* points out that the Warnghparn mountains 王盡山 (mentioned in the summary above), rocky islands now about 20 km out to sea off Zhahpuu 乍浦 on the north shore (northeast of the northeast corner of the satellite image in Figure 1), were joined to the mainland in Jin 晉 times. According to the Song-dynasty writer Charng Tarnng 常棠:

The Huarngparn Mountains [i.e. Warnghparn] are far out in the sea, but the pillars of the bridge are still standing. In 1241 one could still find such things as old wells, small stone bridges, and the stumps of large trees along the shoreline in the tide. If one looked at the characters inscribed on the bricks of these wells, one could learn that a military colony had been stationed here in Eastern Jin times.

The *Natural Geography* also states that extension on the Yuryaor section of the southern shore proceeded at 60 m per year in the fourteenth and fifteenth centuries, and at half that speed from the sixteenth to the eighteenth centuries.⁵² It is evident

49 See Elvin and Su (forthcoming) for a quantitative estimate.

50 K.R. Dyer, *Coastal and Estuarine Sediment Dynamics* (Chichester: Wiley, 1986), especially pp. 3–10 and 256–8.

51 L.B. Leopold, M.G. Wolman, and J.P. Miller, *Fluvial Processes in Geomorphology* (New York: Freeman, 1964), pp. 455–6.

52 It may be worth pointing out that it cannot be assumed that the ratio of these rates corresponds to the relative volumetric rates of deposition during these two periods since, for an approximately semicircular salient, and an increasing depth offshore, the volume of sediment needed for a unit linear extension will increase at a rate proportionate to the square of the radius of the semi-circle, assuming a number of obvious simplifications, such as a constant sediment density, a linear slope, and so on. For a constant depth the rate of volume increase will be proportionate to the radius.

that the shape of the bay 1500 years ago was markedly different from that which it has today.

The short-term instability of the system was also known to contemporaries. The *Natural Geography* cites a passage from the Guangxuh reign period gazetteer for Shahngyur county that says: "In 1678 sands and silts rose up in the midst of the flow, for over 100 *lii* 里 in length and breadth",⁵³ and that this temporary bar then disappeared later.

Turning now to a review of some of the modern literature, we may note that Qiarn Nirng and his colleagues have described the hydrodynamics of inner Harngzhou Bay (about 30 years ago), in terms of the rapidly varying structure of a huge and mostly subsurface bar of finely sorted particles, with diameters predominantly within the range 0.005 mm to 0.1 mm, that lies between Gaanpuu 澉浦 and Wernjiayahn 闻家堰 (on the eastern bank of the river some distance upstream from Harngzhou city). They state that it runs for 130 km (along a line measured at an equal distance from both banks on a map of the appropriate date). The fine-grained particles are free of marine vegetation and so are easily entrained by the motion of the water. Chern Jiryur and his colleagues have estimated the mean thickness of the bar as 20 m, and its volume as about $4.3 \times 10^3 \text{ m}^3$.

The thalweg, or central line of flow, over the bar shifts seasonally with variations in river discharge, and also from year to year. In extreme cases, these movements have covered 200 m in 24 hours, and they have shown a range of about 10 km south of Haainirng.⁵⁴ The depth of the bar also varies with time. As Qiarn *et al.* note, "sometimes large quantities of sediment enter the river-mouth sector from Harngzhou Bay and are deposited there. At other times, large quantities of sediment are scoured from the river-mouth sector and transported outside. The range of the change in the mean height of the riverbed occasioned by the inward and outward movements of sediment can be in excess of 4 m upstream of Haainirng, and has reached 9 m. The range for the thalweg is over 6 m, with a maximum of over 15 m having been reached."

Compared with that of a river like the Yarngzii, the load of sediment carried by the Qiarntarng is light. The annual mean load is about 5.4×10^6 tonnes, and except at times of peak discharge amounts to less than 0.1 kg/m^3 . This is two orders of magnitude less than that often found in incoming tides at Gaanpuu. The greater part of the sediment in the bar derives from the Yarngzii, which empties into the sea rather more than 100 km to the north, with a significant contribution also scoured from the abandoned delta of the old south-course Yellow River in northern Jiangu.

Approximate overall equilibrium requires that the discharge from the river should scour away any residual quantity representing the difference between what is brought in by the rising tide and what is predominantly taken out by the slightly less rapidly moving ebb. (Otherwise the estuary would fill up and vanish, or the bar would be displaced offshore.) Evidence collected since 1915 indicates that when the riverine flow

53 The late-imperial *lii* may be taken as roughly two-thirds of a kilometer, or more precisely, as 644 m.

54 Presumably at a time when the channel here was wider than the 3 km that it is today.

Table 1. Riverine and Tidal flows, with related sediment transport, in the Qiarntarng River measured at Qibaa Station

River Discharge*		Direction of Tide	Velocity of Tide M/Sec	Volume of Tide 10 ⁶ M ³	Sediment Transported 10 ³ Tonnes	Sediment Density KG/M ³
Low	232	In	+0.80	106	+582	5.49
		Out	-0.63	105	-203	1.93
High	6030	In	+0.49	24.7	+47.1	1.95
		Out	-1.11	259	-719	2.78

* Annual Mean: 988 M³/Sec.

Source: Qiarn Nirng *et al.*, "Processes in Recent Times Affecting the Sandbar" (1964), p. 139. Last Column Calculated by Present Authors.

is below 2000 m³/sec tide-driven deposition dominates, and that when it is greater than 8000 m³/sec river-driven scouring of the channel prevails, with an unstable equilibrium at intermediate values. The reason that the flow of the river is crucial, even with its lower volume, is because, under appropriate conditions, it can reverse the difference between the normally greater competence of the incoming tide as compared with that of the more slowly moving ebb.

Since the period of heaviest rainfall is between May and August, discharge reaches its maximum in July and August, and falls to its minimum in November and December.⁵⁵ At Haainirng characteristic values for sediment brought in and sediment removed in one semi-diurnal cycle of the tide (season not specified) have been measured as, respectively, 1.8×10^6 tonnes and 0.85×10^6 tonnes. The sensitivity of the balance of forces between the river and the tide is apparent from Table I, which shows the values for Qibaa Station 七堡站, which is about 39 km upriver from Haainirng (measured along the centre of the line of flow). The width of the river here in the 1980s was just under 2 km but was greater in the late-1950s. The data for sediment transport appear to be measurements, not estimates, but the method used is not stated. In years of low rainfall the bar builds up, while it decreases in height during years of heavy precipitation. Thus, after increasing, during the dry period of 1951 and 1952, and the only moderate rains of 1952, it had reached a maximum at Zharkoou 闸口 in 1953 of 26 m. The scouring due to the heavy rains of 1954 reduced its maximum height in the year by almost 2 m. For the historical period, Chern Jiaqir 陈家其 has shown that in the Lake Taih area rainfall was relatively low in the periods 1504–59 and 1636–1723, and relatively high in the periods 1288–1378 and 1449–1518.⁵⁶

55 Sun Xiangpirng, *et al.*, *Coastal Hydrology*, p. 13.

56 Chern Jiaqir, "Narn Sohng yiilkair Taihhur liuryuh dah laoh-dahhahn jir jihngqir qushih gujih" 南宋以来太湖流域大涝大旱及近期趋势估计 [Major floods and droughts in the Lake Tiah basin since the Southern Sohng, and an estimation of the trend in the near future], in *Dihlii yarnjiuh 1987 (Mar.)*, 6.1.

It seems reasonable to hypothesize from these findings that anthropogenic alteration of the river flow around the bay in historic times is likely to have had some significant effect on the pattern of sediment deposition. The article by Chern Jiryur and his colleagues provides an example: the alteration of the course of the Puuyarng River between 1457 and 1464, so that most of it emptied into the Qiarntarng upstream of Harngzhou, is said to have incised the scour below Wernjiayahn and thus made the upper end of the bar retreat seawards.

Chern's article also present two maps showing reconstructions of the outer and inner bays from the + fourth century to the present. The coastline suggested for the earliest date for the inner bay remains, in our view, still uncertain. The lines for the inner bay at other dates coincide broadly with our own conclusions.

There is also useful incidental information. The authors note, for example, that in Eastern Hahn times the philosopher Warnng Choong 王充 reported that not only the Qiarntarng but also "the small rivers of Shahngyur and of Shanyin [i.e. Shaohxing]," on the south coast of the Bay, had tidal bores, which Warnng terms *taor* 壽, or in other words "large waves".⁵⁷

Both the comments of the authors and the materials they present suggest that the lower Qiarntarng was a less stable system a thousand years ago than it has since become. For example, the poet Su Shih 苏轼 (Dongpo 东坡), who served for a time in the eleventh century as the sub-prefect of Harngzhou, wrote:

The tide comes in from the east of the sea-gate (*haaimern* 海门) with the force of a thunderstorm, but there are shifting hills (*furshan* 浮山)⁵⁸ rising up in the midst of the river and facing the hills of Fisherman's Inlet (Yurpuu 渔浦 — south of Xiaoshan and approximately opposite Harngzhou), and interlocking like dog's teeth. So it is that one sees the water of the tide swirling in eddies there, and striking against them with redoubled fury. The silt shoals shift around, assuming the forms of demons and spirits, often surging forth from the deep pools to form mounds that run fore more than 100 *lii* and then vanish again between sunrise and sunset. Even the captains of boats and fishermen are unable to be certain where the deeps and the shallows are.⁵⁹

In similar fashion, Qiarn Weirshan 钱惟山, who was a native of Harngzhou, wrote in the middle of the + fourteenth century that:

A hilly eyot ⁶⁰ (*shanyuu* 山屿) shifts about (*fur* 浮) in the river, appearing to be a stable rock. When the incoming tide leaves the sea-gate behind,⁶¹ it divides in the middle into two branch-streams, the eastern one of which goes along the shores of Yue [that is, Shaohxing] towards the Furchurn 富春 [that is, the Qiarntarng River above Harngzhou], and the western one of

57 Warnng Choong, *Luhn Herng jiaohshih* 论衡校释 [*Discourses Weighed in the Balance*, with corrections and explanations], ed. Huarng Hui 黄暉 (Tairbee: Tairwan, Shangwuh yinshuguaan, 1964), p. 173, and cp. p. 175.

58 There was a Mount Fur (Furshan 浮山) in the Qiarntarng, but term seems to be generic here.

59 Su Shih, *Su Dongporjir* 苏东坡 [Collected works of Su Dongpo] (Shahnghaai: Shangwuh yinshuguaan, 1939), *che* 5, *j.* 9, p. 53.

60 An islet in a river or lake.

61 At this date between Mount Kan and Mount Zhee, not the present debouchment.

which strikes straight against this eyot with furious onslaught, and then withdraws. It is called the 'tide that turns its head aroud' (*huirtour-chaor* 回头潮).⁶²

This feature is not mentioned at later dates. It seems, then, that there may have been pressure at this time against the northern bank of the river, which then ran from Harngzhou city along the southern boundary of Rernher county to Mount Zhee, but across which the river now flows on its way to the bay. There is a crude map of this now-vanished coast in the 1579 gazetteer for Harngzhou, showing eleven landing-places (*buh* 埠) in an east-west line from Mount Zhee to the northern bank of the Qiarntarng opposite Xixing.⁶³

Lastly, it is useful to place the historical picture in the longer-term perspective of geomorphology. Yarn Qirnshahng 严钦尚 and Huarng Shan 黄山 have shown⁶⁴ that at the time of the maximal oceanic withdrawal, about 15000BP, a drop of from 150 m to 160 m below the present shoreline, there was a depressed trough running south from Lake Taih 太湖 and lying from 15 m to 25 m below the modern sea-level. This trough carried a major tributary into the palaeo-Qiarntarng River just north of the site of the future Harngzhou city. As the climate warmed up in the post-glacial era, the ocean rose to a maximum slightly above the present level between 7000BP and 6500BP. This created a northern estuary emptying into the bay, up the line of the former tributary channel. The lowest-lying parts of the platform between Harngzhou Bay and Lake Taih were covered with a shallow sea. The remainder became tidal flats with interspersed zones of low-salinity marchland on the higher ground. Deposition of sediment helped to raise the plain to its present-day height of from 2 m to 4 m above mean sea-level. By 2500BP the northern estuary, having first contracted, became filled in to the point at which direct contact with Lake Taih was broken, and this allowed the lake to begin to move towards a fresh-water regime. We may perhaps speculate that this process, whereby tidal deposition blocked off the northern estuary, was made possible by a flow of water south from the lake, and from the Tianmuh hills 天目山 on the estuary's southern flank, that was insufficient to provide a counterbalancing scour. As the sea-level fell further, these deposits would have blocked a northern exit by the Qiarntarng River. For the moment, this is speculation.

The geomorphological perspective needs to be joined with the hydrology and hydraulics of the historical period, which is not always easy. Two cases that might repay exploration are the following:

(1) Kitada has shown, in the article cited above, that Lake Taih extended further south in the + fourth and + fifth centuries than it does today, probably reaching some point east of modern Derqing 德清. Its drainage was becoming a difficult matter, and Kitada cites a memorial on this subject written by Liur Juhn 柳濬 around 445:

62 Cited in Chern Jiryur, *et al.*, "Fluvial processes", p. 121.

63 *Harngzhou fuuzhih* 杭州府志 [Harngzhou prefectual gazetteer] (Huar-zhong. Tairbei: Cherngwern, 1579. Reprinted 1983, #524), pp. 72-3.

64 In their "Harng-Jia-Hur pirngyuarn quarxinshih chernji huarnjihng de yaanbiahn" 杭嘉湖平原全新世沉积环境的演变 [The evolution of the holocene sedimentary environment in the Harngzhou-Jiaxing-Hurzhou plain], *Dihlii xuerbaoh* 42.1 (Mar. 1987).

The commandery of Wurxing 吴兴郡 (i.e., Hurzhou) over which I rule is cloaked and girthed with range after range of hills, but much of the land is low-lying and marshy. Streams from the springs flow together here, and [the channels] that have been cleared have slowly become blocked up [again]. Even before the seasonal rains [of late spring and early summer] have passed over, the region is already awash. Sometimes ploughing stops at the beginning of the spring, or the harvest drowns at the onset of the autumn. The farmers' families will have toiled in vain, and have no means of taking preventative measures.

In the hinterland of this region, the land is fertile, and the people numerous. In any year there is a good harvest, their prosperity equals that of the Capital. If, at times, there are floods, then several commanderies will suffer disaster.

In recent years scarcity has been frequent, abundance rare... Yaor Jiaoh 姚嶠, a commoner of this prefecture who understands, through comparison, what is advantageous, takes the view that because four prefectures all empty their waters into Lake Taih — namely Wurxing, Wurjuhn 吴郡, Jinlirng 晋陵 [modern Chongzhou], and Yihxing 义兴 [宜兴] — and the [eastward-flowing] song River 松江 and the Huh Ditch 滬渚 are choked up and so of no use, the result has been that floods surge everywhere, and the encroachment of the waters is turning into a disaster. He would like to open a channel from the Zhuh Stream 紵溪 in Wuokang 武康 (Derqing) to Lake Guu 谷湖 [possibly near the present-day city of Jiaying,⁶⁵ but more plausibly near modern Haaiyarn]⁶⁶ and thence straight to the sea along over 100 *lii*. By passing down this channel the water would not become blocked up.

Though it received imperial approval, this channel was in fact never cut. It would appear, then, that the draining of Lake Taih, which was to remain an administrative problem for more than a millennium, was first becoming a serious concern around this time, and it has to be asked if Kitada's explanation in terms of the unintended interference with outflow caused by dyke-building is sufficient, and whether it should not perhaps also be set in the context of the closing of the outlets by natural processes.

(2) Some time before the eleventh century the trend of sedimentary deposition on the north shore of the bay was reversed, and the low-lying coastal land (which was then many kilometers south of the present north shore) began to be washed away. There is a general description of this, from a late-Ming-dynasty perspective, in Guh Yarnwuu's *Commanderies and Principates*.⁶⁷

The [northern] sea-wall is 100 *lii* distant from the prefectural city [of Jiaying]. It runs all the way through the territories of Pirnghur 平湖 and Haaiyarn, a length of 170 *lii*. To the south it looks across [the bay] to Guihji [Shaohxing] and to Sihmirng 四明 [Nirngbo]. The old gazetteer records that when the First Emperor of Qirn was here, he wished to build a bridge across the sea. There are still stones sticking up out of the sea even now, which people point to as be-

65 See Guh Yarnwuu 顾炎武, *Tianxiah juhnguor lihbihng shu* 天下郡国利病书 [Documents on the Advantageous and Disadvantageous Aspects of the Commanderies and Principates of the Empire] (Shahngghaai: Shanghwuh yinshu-guaan, Sihkuh shahnbeen congshu edition, Compiled 1639–62. Reprinted 1936), *ceh* 22, Zhehjiang *xiah*, p. 2a.

66 On the assumption that the 'Guu Stream' 谷水 shown near Gaanpuu on 'the map of old boundaries' in the county gazetteer for Haainirng (*Haainirng xiahnzhih* 海宁县志. Reprinted 1984. Tairbee: Cherrngwern. Huarzhong #516), p. 51, is identical with or close to the lake.

67 Guh Yarnwuu, *Commanderies and Principates*, *ceh* 22, Zhehjiang *xiah*, pp. 3b–4a.

ing the columns of this bridge.

The Sohng-dynasty gazetteer notes that 50 *lii* to the south-east of Haaiyarn there used to be the Water-Storage Barrage (*zhuhshuui bei* 貯水陂), and 3 *lii* south of this the Indigo Field Inlet (*larntiarn puu* 藍田浦), and 3 *lii* further east the Transverse Inlet (*herng puu* 橫浦), linking in an easterly direction with Guhyih [颯邑 — unidentified]. When one went southward towards the sea there were also the Thirty-Six Sands, the Nine Mudflats, and the Eighteen Mounds, as well as the Seven Peaks of Huarngparn 黃盤 spread out across the seaside waste-land.

Today the county capital [of Haaiyarn] is only half a *lii* away from the sea, which has entirely drowned the last traces of the former barrage and reservoir. The tides flow back in a rotating fashion (*huirliur* 洄流) from the sandbar (*dan* 潭) [that has accumulated] on Mount Zhee and Mount Kan,⁶⁸ and strike against the borders of Haainirng and Huarngwan. When they reach the White Tower Rocks (*bairtaa* 白塔),⁶⁹ where the Qirn once had a guard station, they are in a condition of redoubled agitation in which rogue waves (*yourtaor* 游濤) are carried along by the wind, destroying people's houses and damaging their crops.

There have been constant proposals for dykes. In the Kaiyuarn reign-period [713 to 741] the Taihpirng Sea-wall was built. In the Sahohxing reign-period [1131 to 1162] the county magistrate constructed twenty *lii* of dykes, while in the Xianpirng reign-period [993 to 1004] Transport Commissioner Charng Maoh 常標 built a new dyke that was 36,250 feet in length. In the *jiaachern* year of the Zhihzheng reign-period [1364] the county magistrate ... built 48,000 feet of sea-defence dyke, but once it had grown old, being an earth dyke, it was easily destroyed. After this the land gradually turned into sea.

With the rise of the Mirng, ever more detailed proposals were made for improvements in the control of the sea, but the sea-wall repeatedly collapsed.

This long litany of effort underpins our later argument that there was a serious degree of technological 'lock-in' once local society had become committed to its hydraulic system. The question remains, though, as to why first the outer northern coast (around Haaiyarn), and then the inner northern coast (around Haainirng), were now being attacked.

2. *The shifting landscape: Harngzhou Bay from + 500 to + 1800*

*...ut iactetur aquae fluctu quoque terra vacillans,
ut vas interdum non quit constare, nisi umor
destitit in dubio fluctu iacterier intus.*

[...as the unsteady land, too, may be tossed about by the wash of the water,
just as a bowl at times cannot stand still unless the water within it
ceases to be tossed about in waves of an indeterminate pattern.]

Lucretius, *De rerum natura*, vi.554-6.

The only constant features in a continually altering landscape of alluvial plains, tidal flats and shallow sea were the mountains. Figure 1b, based on the satellite image reproduced in Figure 1a, shows the main mountains in the bay and along its coasts, in

68 *Huir* 洄 has two senses, namely of a movement *against* the current, and of a *rotating* liquid motion. *Dan* 潭 is a deposit of silt or sand emerging from water.

69 Now about 2 kilometers offshore just southwest of 30°30' N and 121°E. They have a height above mean sea-level of 47 meters. Admiralty chart #1199.

schematic fashion, in order to make it simpler to follow the topographies reconstructed in this section.

We begin with a survey of historical maps, moving backwards in time from the more to the less certain. The general pattern once established, we shall consider the details provided by the documentary record.

Figure 2 is based on the 1938 Japanese 1:50000 map of the inner bay. It is clear that while the river above Harngzhou and the north coast of the estuary immediately to the west and east of Haainirng have remained stable, the course of the Qiarntarng below Harngzhou but above the northern extremity of the Narnsha peninsula, has both narrowed and moved eastwards. This shift has been associated with the erosion of the west bank of the peninsula, which is now stabilized with seawalls and massive groins, and with the deposition/reclamation of two new promontories, one on the south bank to the north of the capital of Xiaoshan county, and one on the north bank descending almost as far south as Mount Zhee on the opposite shore. The former tidal flats on the east coast of the Narnsha peninsula have been dyked and reclaimed, and the spit on the north bank of the Caor'er, where it enters Three Rivers' Mouth, has been extended westwards.

Figure 3 reproduces a combination of oblique aerial view and map, orientated towards the south, from the 'Haaitarng tur' 海塘图 (Maps of the Seawall) in the Harngzhou Prefectural Gazetteer, showing the mouth of the Qiarntarng around the end of the eighteenth century.

This late — eighteenth-century topography may have related to the modern topography approximately as follows: the twentieth-century acute-angled bend in the Qiarntarng upstream of Harngzhou is not in evidence. Level with this city, the river turns towards the north and is constricted in a short reach with a north-north-east orientation just downstream of a line drawn between the city and Xixing. A recently reclaimed area projects into the river at this point from the left bank, protected by the Fahngong Dyke (inside of which runs the Old Earth Dyke) and the Tiaoshui Dyke, the latter apparently further safeguarded by groins. Downstream of this point of constriction, the river turns somewhat eastwards again in an almost straight line to a point just north of Mount Shuu, broadening as it does so. There are extensive undyked foreshores along the right bank, while the northern shoreline to Haainirng is guarded by a stone dyke (crosshatched double line) and, for most of its length, an inner earthen dyke. The stone dyke from Harngzhou to Haainirng is lined with 33 watch-stations (*baao* 堡). From Haainirng to the foot of the Mount Xiaojian the north shore is protected partly by a stone dyke (perhaps as far as the eighth watch-station) and partly by the Brushwood (or 'Fascines') Dyke (*chairtarng* 柴塘), with a further 17 watch-stations, and the inner earthen dyke. There is a stone cross-dyke running from the mainland to Mount Taa, also a sandy foreshore, now so reduced as to hardly exist, running from between the fourth and fifth Haainirng watch-stations along the northern coast and out to this headland. Within the Narnsha peninsula, the earlier river mouths through the Southern Major Cleft and the Central Minor Cleft have silted up. On the eastern shore there are what appear to be two successive layers of 'old sands' and one of 'soft sands' that together reach as far as Mount Pirngtour. This last-men-

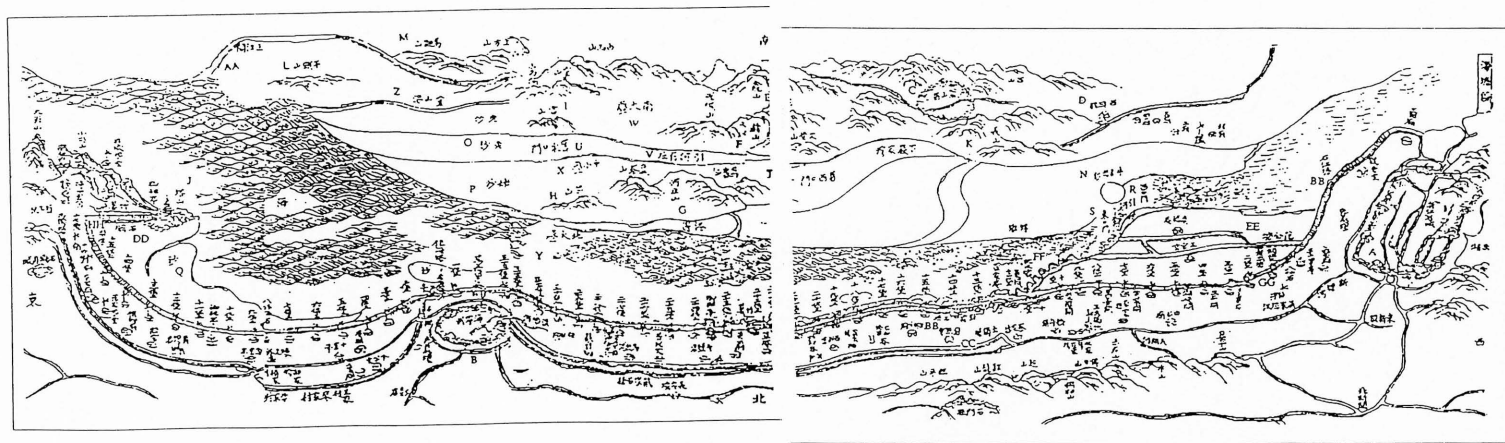


Fig. 3. The Mouths of the Qiantang River at the end of the 18th Century.

CITIES AND TOWNS

A: Hargzhou 杭州 B: Haainingr 海宁 C: Xiaoshan 萧山 D: Xixing customs station 西兴关

HILLS

E: Mount Kan 龕山 F: Mount Zhee 赭山 G: Mount Herzhuang 河庄山 H: Mount Shuu 蜀山 I: Mount Leir 雷山 J: Mount Taa 塔山 K: Mount Charng 长山 L: Mount Pirngtour 平头山 M: Mount Maa'an 马鞍山

SANDBANKS

N: Ox-tongue Sands 牛舌头沙 O: 'Old Sands' 老沙 P: 'Soft Sands' 嫩沙 Q: 'Sands' 沙

MOUTHS AND CHANNELS

R: West mouth 西口门 S: East mouth 東口门 T: Old West mouth 旧西口门 U: Old east mouth 旧东口门 V: Old site of induction channel 引河旧址 W: Southern major cleft 南大壑 X: Central minor cleft 中小壑 Y: Northern major cleft 北大壑 Z: Daangshan inlet 党山港 AA: Three rivers' lock 三江闸

SEAWALLS AND DYKES

BB: Stone riverbank dyke 石江塘 CC: Earthen reserave dyke 土备塘 DD: Stone sea crossdyke 石坝 EE: Fahngong dyke 範公坝 FF: Tiaoshuui dyke 挑水坝 GG: Old earth dyke 老土塘 HH: Brushwood (fascines) dyke 柴塘



Fig. 4. The mouths of the Qiantang River circa 1733.

SANBANKS

ii: Central high sands 中高沙

MOUTHS AND CHANNELS

jj: Newly opened induction channel 新开引河 kk: Newly opened Southern Channel 新开南港 ll: Qii channel 圪港 mm: Daangia Inlet 党家港

SEAWALLS AND DYKES

nn: Earthen reserve dyke 土备塘 oo: Brushwood (fascines) dyke 柴塘

tioned, apparently well north of Mount Maa'an and the old south-shore seawall, cannot at present be identified either on the 1:50000 map or the satellite image.

Figure 4 shows the mouths of the Qiantang River as they were perhaps around 1733, when the first attempt at reopening the central minor cleft by means of an 'induction channel' was undertaken, but before the third and more long-lived effort in 1747, since it is evident from the map itself that the situation represented dates from before the greater part of the Brushwood Dyke had been converted to stone (a process that began in 1732),⁷⁰ and likewise from before the final stage of building of the cross-dyke to Mount Taa in 1740. Only the earthen dykes and the Brushwood Dyke are shown.

Figure 5 is a composite cartographical/topographical scene, looking southwards from Mount Fehnghuang 凤凰山 (just south of Harngzhou) across the Qiantang River. We have assembled it from two separate pages of the Zhejiang prefectural

70 Dir junliarn 翟均廉, ed., *Haaitarng-luh* 海塘录 [A Record of the Seawall], in *Qirndihng sihkuh quarn-shu* 钦定四库全书, Shii-buh 史部, *ceh* 册 583 (Tairbee: Tairwan shangwuh yinshu-guaan, Wernyuan-ger ed, Reprinted 1986), p. 369.

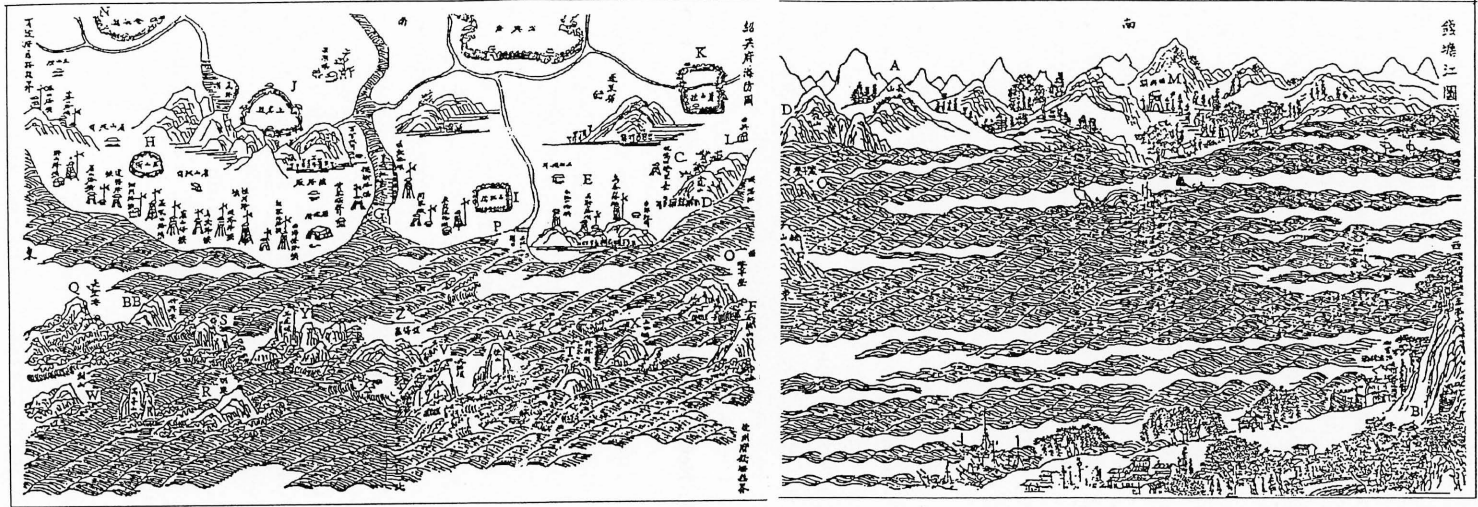


Fig. 5. The three mouths of the Qiantang River in the early 17th century.

(A cartographic/pictographic composite)

MOUNTAINS, WATCH-TOWERS AND BEACONS

A: Chong shan 长山 B: Fehnguarng shan 凤凰山 C: Kengwu shan Watch-tower 坑坞山了望台 D: Kan shan 龛山 E: Maa'an shan beacon 马鞍山烽堆
F: Zhee shan 赭山

RIVERS

G: Caor'er 曹娥江

CITIES AND MILITARY STATIONS

H: Lirshan Guard 盐山卫 I: Sanjiang suo 三江所 J: Shahngyur county 上虞县 K: Xiaoshan county 萧山县 L: Xixing 西兴 M: Xixing customs station 西兴关 N: Yuryaor county 虞姚县

CHANNELS

O: Biezi mern 鳖子壑

LOCK

P: Sanjiang zharkoou 三江闸口

ISLANDS AND REEFS

Q: Chongtur inlet 长涂港 R: Chour inlet 稠港 S: Daih shan 岱山 T: Duihzhentour 对针头 U: Gaotirng shan 高亭山 V: Huooyahntour 火焰头 W: Jiaan shan 剑山 X: Shahngxiah banks 上下勘 Y: Wuuhuu reefs 五虎礁 Z: Yarnchaang bank 盐场鼻 AA: Yur shan 渔山 BB: Zhurxing inlet 竹兴港

gazetteer that seem to illuminate each other when taken together, in spite of differences in conceptualization (such as the mapping of the background in the left half as against the pictorial treatment in the right half), minor stylistic differences (like the visual conventions used to show the waves), and different subject matter (the inclusion of coastal defence stations in the two left-hand panels, and of ships in the right-hand ones).⁷¹ The date of the scene is best taken as some time in the early–seventeenth century, since the Mirng system of Guards (*weih* 卫) and military stations (*suoo* 所) is shown, but it is probably unwise to try to be more precise. Its value is that it shows all three mouths of the river functioning, including the old south exit between Mount Kan and Mount Zhee, which is labelled the Turtle Hatchlings' Cleft (*biezii mern* 鳖子壘) after the midstream group of low hills that divides it into two channels. Three Rivers' Mouth Lock is visible in the second panel from the left. The most surprising features are the numerous reefs and small islands east of Mount Zhee and north of the mouth of the Caor'er River, none of which can be found on modern maps and which may therefore have been transients. The midbay peninsula is almost entirely missing.

Figure 6 has a northern orientation and shows the southern shore of the bay in the late – sixteenth century, with the focus on coastal defences.⁷² There are some obvious errors, such as the westward displacement of the Turtle Hatchlings' Gate 鳖子门 (which should be approximately level north/south with Mount Kan), that indicate caution is required in accepting its other features at face value. These features are, however, striking. The Narnsha 南沙 peninsula does not exist, and three rivers, whose mouths are marked 'A', 'B', and 'C', empty into the Qiarntarng River where the peninsula now is: 'A' to the east of Mount Charng 长山 and west of Mount Kan 龕山; and 'B' and 'C' to the west and east respectively of one of the groups of small hills (either the Taihershans 太和高 which lies on a line between Mount Kan and the northern extremity of Mount Maa'an 马鞍山, or the Shahngfangshan 上方山 and the Nanpirngshan 南屏山) that are located west of Mount Maa'an. The topography shows that the 'Mount Maa'an Beacon' (labelled 'H') is not placed on the summit of Mount Maa'an but on one of these small hills. These rivers, like the Small West River that enters the bay east of Mount Maa'an and is closed by the Three Rivers' Lock (labelled 'J'), all appear to be isolated from the sea by locks (double lines). The only seawall specifically indicated is that around the eastward bend of the Qiarntarng northwest of Xiaoshan (single line), which (seemingly) continues down to the lock on river 'A' east of Mount Charng. It would appear that the mouth of the Caor'er River is more open than it has been in the twentieth century, widening markedly at Clam Inlet Harbour (Chengpuu gang 鯉浦港, labelled 'K') facing Three Rivers' Harbour 三江港, that the coastal snadbars so evident there in modern times have not yet built up, and that the lower section of the Caor'er River has not yet formed the meanders so evident in Figure 1. This pattern fits better with that of the 'new' map reproduced in the *Three Rivers' Lock*, rather than

71 *Zhejiang tongzhih* 浙江通志 [Comprehensive gazetteer for Zhejiang province] (Shahngghaai: Shangwuh, 1934), j.1, pp. 200–1 and 172–3.

72 Guh Yarnwu, *Commanderies and Principates, ceh* 32, *Zhejiang shahng*, pp. 11a–12b.

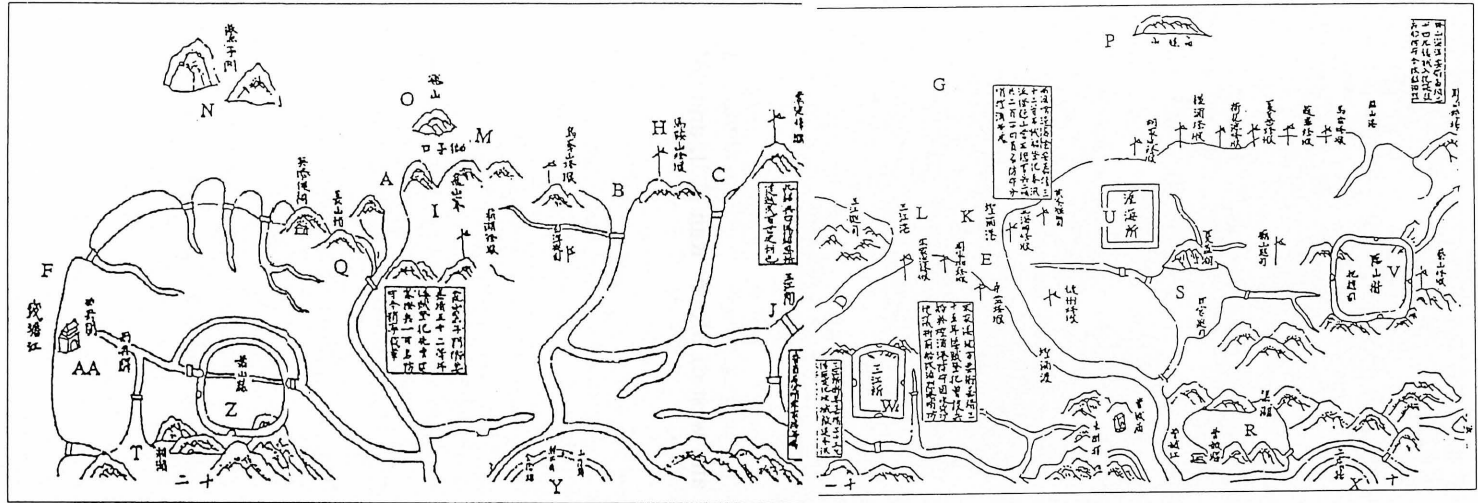


Fig. 6. The south shore of Harngzhou Bay in the later 16th century.

RIVERS

A: Unnamed, but possibly one of the mouths of the Puuyang 浦阳江 B: Unnamed, but possibly one of the mouths of the Qianqing River 钱清江 C: Unnamed, but possibly one of the mouths of the Qianqing River D: Probably the Xixiao jiang 西小江 (also part of the Qianqing system) E: Caor'er river 曹娥江 F: Qianrtarng river 钱塘江 G: Harngzhou Bay, also called the Houh Sea 后海

MOUNTAIN MILITARY CAMPS AND BEACONS

H: Mount Maa'an beacon 马鞍山烽堆 I: Mount Kan camp 龛山寨 (Founded in 1553 to defend against 'Japanese' pirates, but 'now' discontinued.)

LOCK

J: Three Rivers'lock 三江闸

INLETS AND HARBOURS

K: Chengpuo gang [Clam inlet harbour] 螳浦港 (Warships stationed here in the 1550s.) L: Sanjiang gang [Three Rivers' harbour] 三江港 M: Shizii kouo [The lion's mouth] 狮子口 N: Biezii kouo [Turtle hatchlings' gate] 鳖子门

ISLANDS

O: Qiur shan 嵇山 P: Bianjiao shan 扁礁山

MOUNTAIN

Q: End of Mount Charng 长山头

LAKES

R: Liarng lake 梁湖 S: Xiahgaih lake 夏盖湖 T: Xiang lake 湘湖

PREFECTURES, COUNTIES, GUARDS, AND MILITARY STATIONS

U: Lihhaai military station 瀝海所 V: Lirnshan guaro 监山卫 W: Sanjiang station 三江所 X: Shahngyur county 上虞县 Y: Shaohxing prefecture 绍兴府 Z: Xiaoshan county 萧山县 AA: Xixing customs station 西兴关

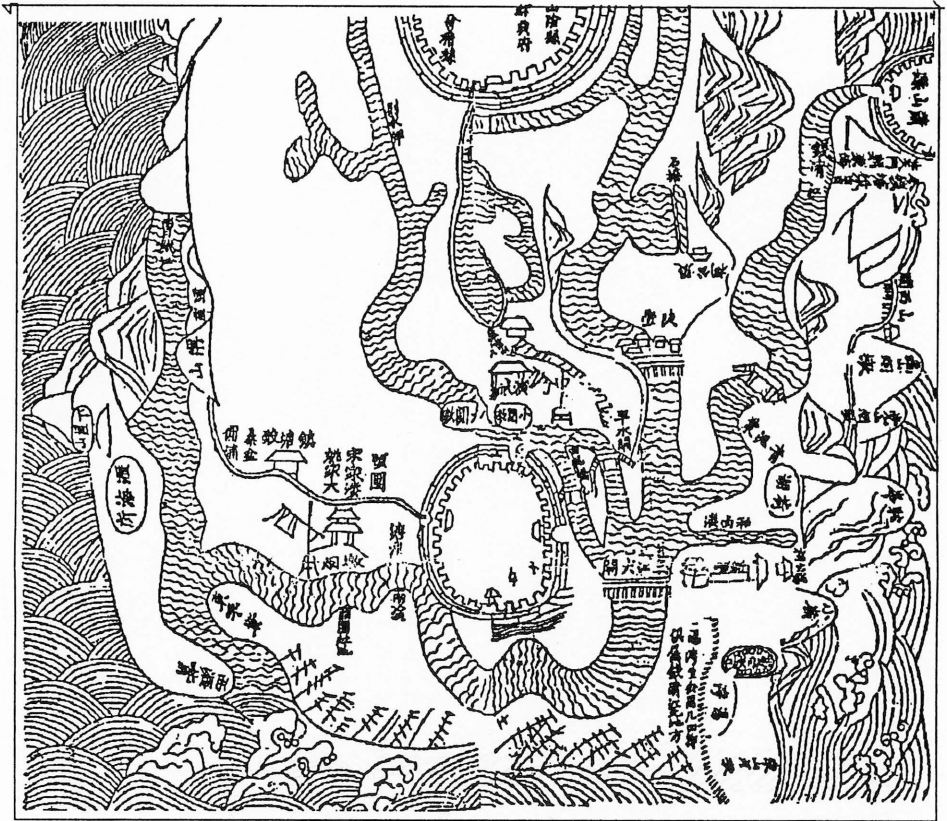


Fig. 7. The 'Old Map' of the Three Rivers' Lock, sixteenth century.

(The orientation is towards the south. The projection may be approximately described as a mapping onto the inside of a U-shaped basin. Part of Shaoxing city wall is visible at the top. The lock is the larger (and lower) of the two comb-like structures visible near the centre of the map. (The smaller one is a 'sluice' (*doumern* 陡壘).) The walled town to the east (left) of the lock is Three Rivers' Guard (*Sanjiang-suoo* 三江所). The double line running east from the town wall is a sea-wall. The Caor'er River enters the sea 'vertically' between the lefthand spit of land (where Lihhaai station 滙海所 stands) and the sea running along the lefthand margin. Note the graphic convention differentiating river water (parallel undulating lines) from sea-water (fan-like segments of concentric circles). The south shore of the bay runs along the bottom of the map. The city at the upper righthand corner is Xiaoshan, and the text below it notes that "today the waters of the Qiarntang River exit through the Major North Gate.")

the 'old' one. (See Fig. 7 and 8).⁷³

Figure 9 shows the northern coast at about the same period as Figure 6 (the cartouche on the upper left referring to 'Japanese' pirates in 1549 as "first" attacking).⁷⁴

73 Cherg Mirngjiuu, *Three Rivers' Lock*, *shahng, shahng j.*, 1a-4b.

74 Fahn Lair 範深, comp., *Liaang-Zheh haafang leihkako xuhbian* 两浙海防类考续编 [Continuation of the investigation according to categories into the Maritime defences of the Two Zheh provinces] (Huar-zhong. Tairbei: Chergwern, 1602. Reprinted 1983. #482), pp. 102-5.

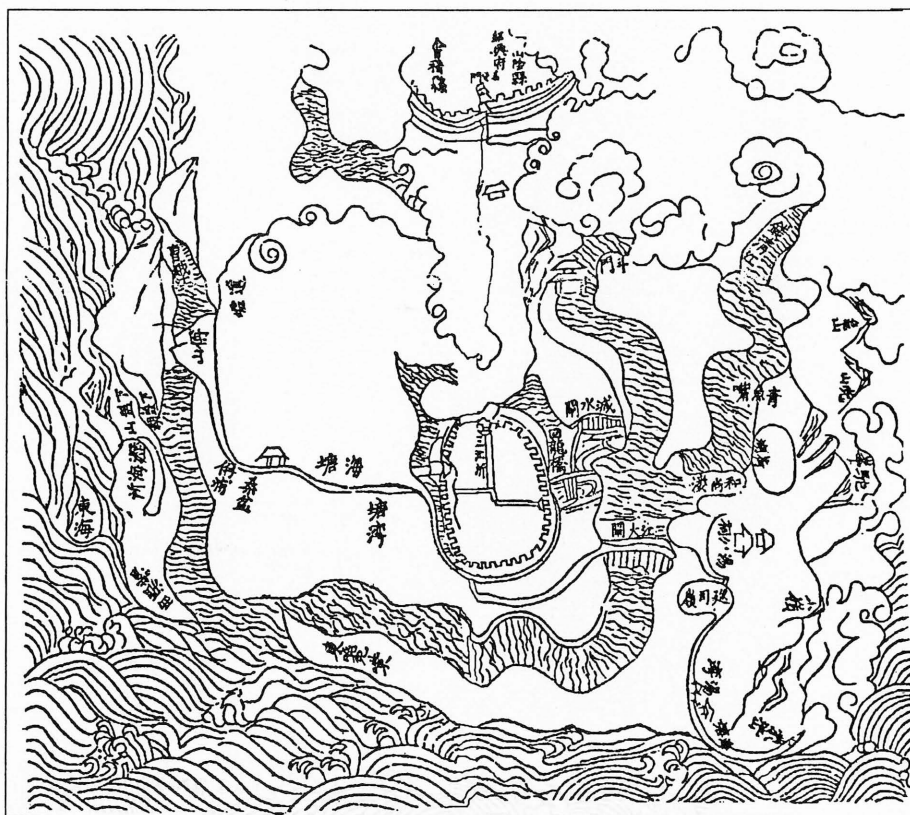


Fig. 8. The 'New' Map of the Three Rivers' Lock, perhaps early 17th century.

(Note how the sandbars near the mouth have been eroded, and how the coastal vegetation has disappeared. The arrangement of locks immediately upstream of the Three Rivers' Lock has also changed, though some of the details are hidden by what appear to be clouds.)

It is orientated towards the south, and shows the peninsula (markedly foreshortened) now stretching south from Shirdun 石墩, with its military encampment and headquarters, and Haainirng, to hills now on the southeastern edge of the present Narnsha, such as Mount Yarn 岩 (also 巖 or 岳) 山 and Mount Zhee 赭山, with their military beacons. The straight-line distance from Shirdun to the south end of Mount Zhee is approximately 36 kilometers, and the line runs directly across the present mouth of the Qiarntarng. Haainirng is separated from the sea by a substantial expanse of sands solid enough to support 8 military beacons (*fengdui* 烽堆), indicated by a Ω symbol. The isolated drainage pattern of the eastern half of these sands (left-hand panels) suggests the régime typical of a free-standing bank (such as the depositional island in the modern channel shown in Figure 1). The absence of any visible southern shore in the right-hand panel should probably be taken as a cartographic convention rather than an indication of the great width of the river. Finally, the mountains on the coastline west (that is, to the right) of Mount Zhee are unidentified and puzzling.

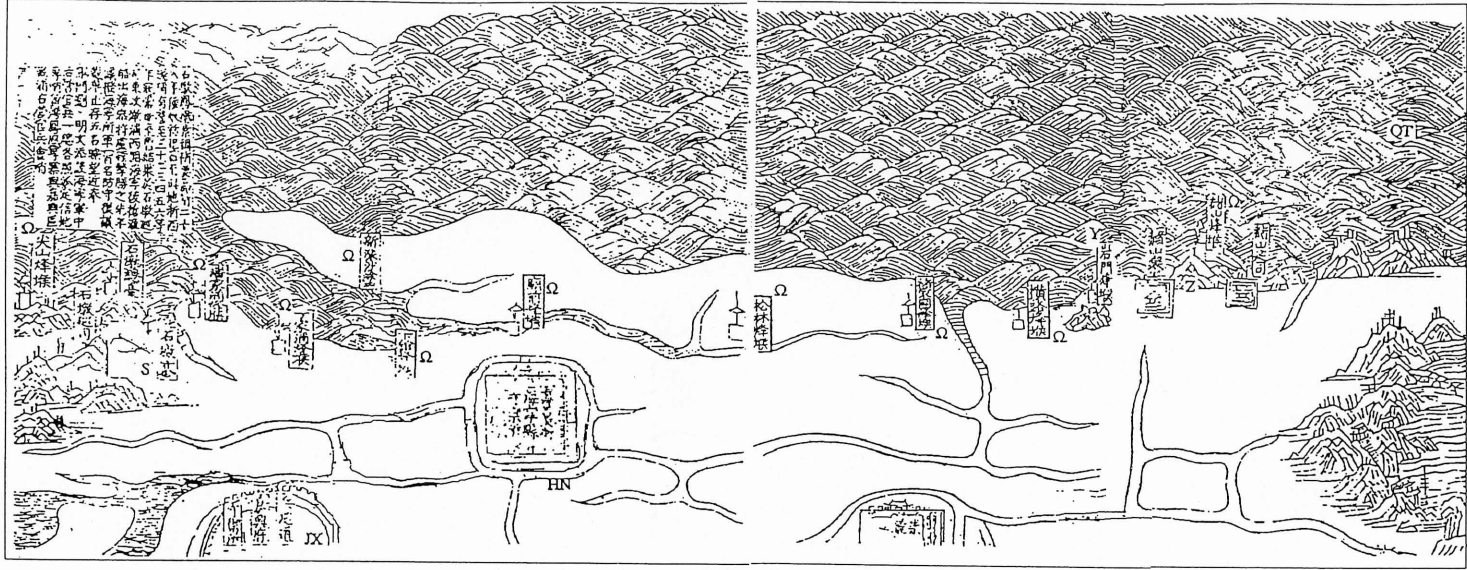


Fig. 9. The northern shore of Hanzhou Bay in the later 16th century.

MILITARY BEACONS ARE ALL MARKED WITH A Ω

S: Shirdun 石墩 military complex Y: Mount Yarn beacon 岩山烽堆 Z: Mount Zhee 赭山 military complex JX: Independent battalion 守御所 under the Military Intendant 兵巡道 of Jiaying prefecture 嘉兴府 HN: Haianing county 海宁县 QT: Qiantang river 钱塘江

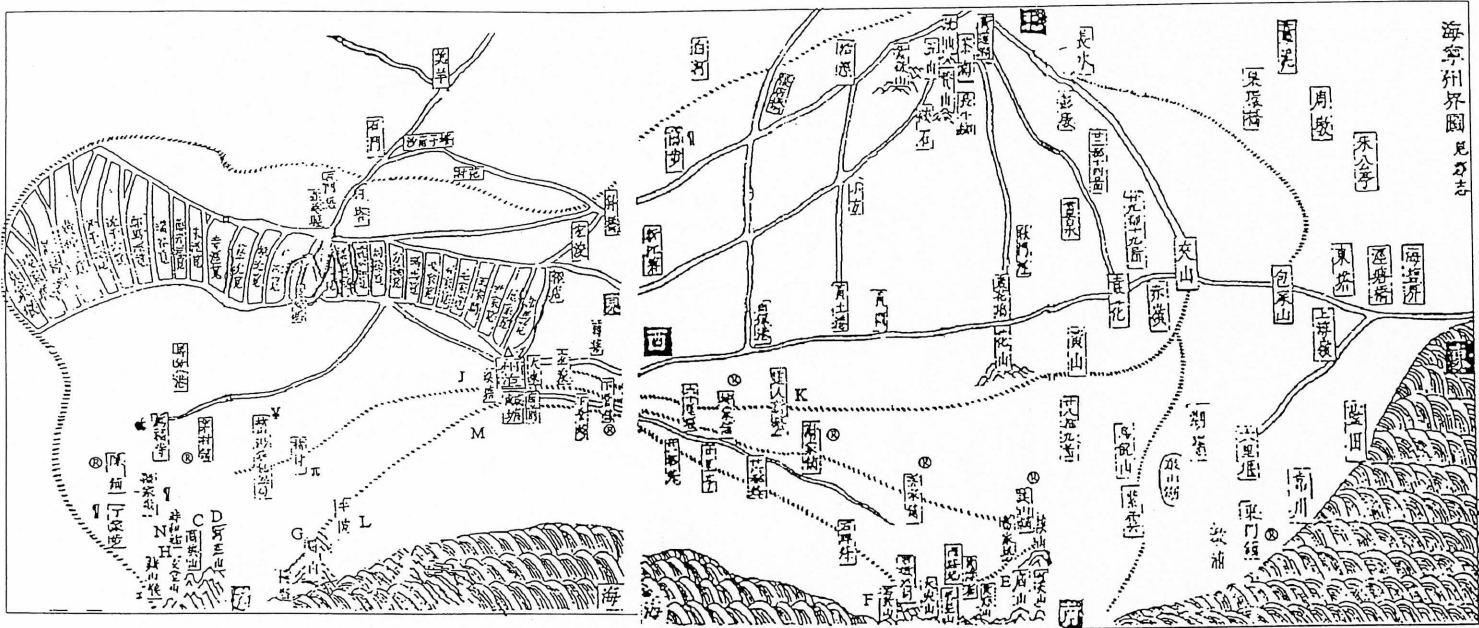


Fig. 10. The northern shore of inner Hargzhou Bay in Yuan times.

MOUNTAINS

A: Mount Dahjian 大尖山 B: Mount Fehnguarng 凤凰山 (not to be confused with its more famous namesake in Hargzhou) C: Mount Ger'ao 葛垸山
 D: Mount Herzhuang 河庄山 E: Mount Miaoh 庙山 F: Mount Shirdun 石墩山 G: Mount Shuu 蜀山 H: Mount Werntarg 文堂山 I: Mount Zhee
 beacon 赭山峰

DYKES

J: Dahn dyke 淡塘 K: Daohern new dyke 道人新塘 L: Ox barrage 牛陂 M: Xiarn dyke 咸塘

SETTLEMENTS

Landing places 步: ¶ Postal relay stations 舖: ® Village 村: π Department capital 州治: Δ Customs station 税课局: ¥ Temple 寺: N: Shirher rural
 district 时和乡

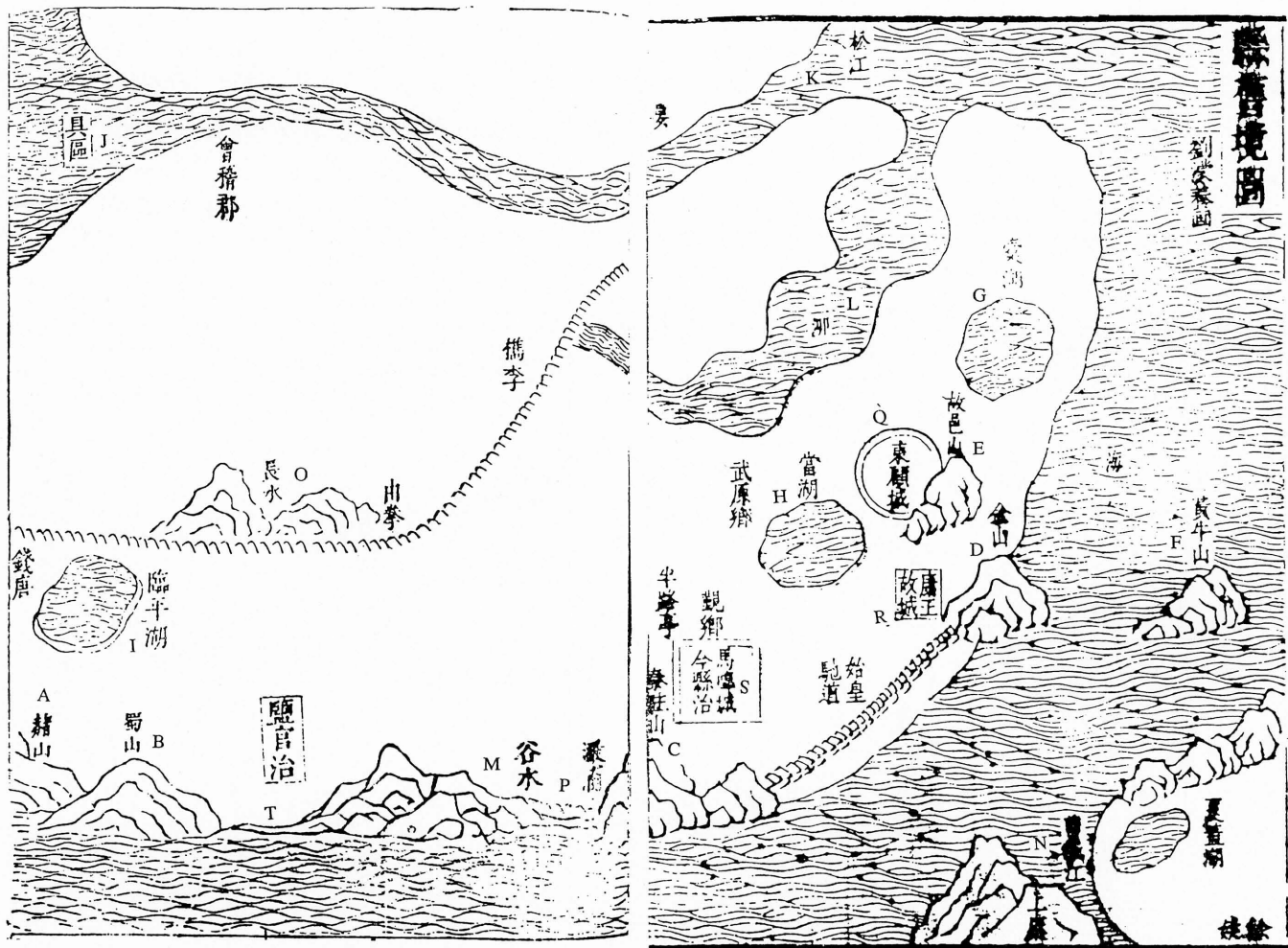


Fig. 11.

Figure 10 takes us as far as the detailed map record goes.⁷⁵ It shows Haainirng in Yuarn times (as may be seen from its designation as a *zhou* 州 ‘department’ rather than a ‘county’), in a northward-facing orientation. The most striking feature is the wide, gently concave, arc of continuous shoreline running west-to-east from north of Mount Shuu to Mount Shirdun and Mount Dahjian, separating the department capital from the sea by perhaps 6 kilometers (seeing that the distance from Mount Shuu to Haainirng (Yarnguan) today is about 12 kilometers). The whole coast is protected by two dykes (shown by vertically scored lines, which should not be confused with the almost identical lines for the department boundaries), both of them well inland. The outer of these is the Salt-Water Dyke (*Xiarntarng* 咸塘), which incorporates the Ox Barrage (*Niurbei* 牛陂), and the inner the Fresh-Water Dyke (*Dahntarng* 淡塘). The eastern half of the coast is also guarded by a third dyke, still further inland, the New Daohrern Dyke 道⁷⁶人新塘. There is evidence of settlement in the area later covered by the Major North Cleft, such as Chuu Village 楮村, and various postal relay stations (*pu* 舖), and ‘landing places’ (*buh* 步 = *buh* 埠). In Sohng times there were also two salterns in this area, one at Mount Shuu and one at Mount Yarn.⁷⁷ There is an array of closely aligned irrigation canals (*jiaan* 笕, more properly ‘bamboo flumes’, but this seems an unlikely sense in context), and cross-dykes (*yahn* 堰), to the northwest of the Haainirng, but this feature seems to have left no discernible trace today.

Figure 11 is a sketchy outline of the entrance to the bay from Qirn/Hahn times, about 2000BP, included in the gazetteers for Haaiyarn county and Haainirng department.⁷⁸ Mount Zhee and Mount Shuu are shown on the northern coast. Lake Taih appears under its pre-imperial name of Juhqu 具区, and is drained by the Song River 松江 which is much wider than it is today. There are probably two dykes, though

75 *Haainirng zhou zhih* 海宁州志 [Gazetteer of Haainirng Department] #591 in *Zhongguo fangzhi congshu*, Huar-zhong (Tairbee: Chergwern, 1983), j. 1, pp. 56-7.

76 The transcription of this character is uncertain.

77 *Gazetteer of Haainirng Department*, map, p. 15.

78 *Haaiyarn xiahu turjing* 海盐县图经 [Maps of Haaiyarn County] #589 in *Zhongguo fangzhi congshu*, Huar-zhong (Tairbee: Chergwern, 1983), pp. 20-1, and *Gazetteer of Haainirng Department*, pp. 50-1.

Fig. 11. The north coast of inner Harngzhou Bay in Qirn/Hahn times.

MOUNTAINS

A: Zhee shan 赭山 B: Shuu shan 蜀山 C: Qirnzuh shan 秦驻山 D: Jin shan 金山 E: Guhyih shan 故邑山 F: Huarngniur shan 黄牛山

LAKES

G: Zheh hur 柘湖 (supplied from the Haaiyarn map, shown here as Tuoh hur 橐湖) H: Dang hur 当湖 I: Lirnpuu hur 监浦湖 J: Juhqu 具区 (= Taih hur)

RIVERS, ETC

K: Song jiang 松江 L: San Maor 三泖 M: Guu shuui 谷水 N: Caor'er jiang 曹娥江 O: Charng shuui 长水 P: Gaanpuu 澈浦

SETTLEMENTS

Q: Dong Guh cherng 东顾城 R: Kang Warng guh cherng 康王故城 S: Maahaor cherng 马嗒城 (now site of Haaiyarn 海盐) T: Haaiguan 海官

this is speculative: one is what seems to be a seawall south of Mount Jin 金山, but labelled “Imperial Way of the First Emperor” (*Shiihuarng chirdaoh* 始皇驰道), and the other a long inland barrier that runs from Qiarntarng (钱唐 [only altered to 塘 in Tarnng times to avoid the use of the dynasty’s name]) to cut off the San Maor 三泖 inlet. Early in the + first century the capital city of Haaiyarn was drowned by the Dang Lake 当湖 (some sources say the Zher Lake 柘湖) and had to be re-established nearby. The Guu River 谷水 appears only as a name, west of Gaanpuu 澱浦, but on a map for Haaiyarn for a slightly earlier date⁷⁹ the course is shown flowing down from a lake into the bay at the same point. The general impression of the north coast is thus of a lowlying area full of lakes, open to the tides and hence somewhat saline.

We turn now from the cartographic record to the documentary record.

In the + first millennium, and probably for some considerable period of time before this, it seems that the Qiarntarng River debouched through the sea-gate between Mount Kan and Mount Zhee (subject to the caveat expressed in the section on the geographical context above). This was known in Qing times as the Major Southern Cleft (*narn dah mern* 南大壘). In the course of the first half of the + second millennium, it became silted up and after 1620 the river debouched through the Minor Central Cleft (*zhong xiaao mern* 中小壘). The history of the Narngaang 南港 is unclear, but it was said, in 1734, to have “long ago been intermittently used by ships carrying firewood or salt.”⁸⁰ Between the early 1690s and the middle of the – eighteenth century the river shifted again, this time to the Major Northern Cleft (*beeí dah mern* 北大壘). It seems that in the late – eighteenth century this channel ran immediately west and north of Mount Herzhuang 河庄山 as now,⁸¹ rather than some way away from it as in the earlier part of this century.

A summary of this history was given in a report made to the emperor in 1733 by Haaiwahng 海望 and his colleagues:⁸²

The surplus vital energy (*qih* 气) in the roots of the mountains would seem to resemble the drawn-out fibres of silk floss, so that when the tides pass the sediment accumulates. It may happen at times that there is a passage through, but it will subsequently become blocked again.

Thus, if the water does not go south, it goes north. If it goes south there are, however, Mount Kan and Mount Charng (常山, presumably for 长山) to defend against it. If it goes north, there is only the line of sea-walls, and it is easy in the extreme for the water to break in and flood.

At the present time, *the Major Southern Cleft has already silted up* [emphasis added] and become level land. Some tens of years ago [that is, *circa* 1700], some water was still passing in and out of the Minor Central Cleft. The water has gradually shifted to the north since then. The mulberry fields and cottages of the Major Northern Cleft have already become an expanse of open sea. We fear that should it be desired to block off the wild waves of the open ocean, to cause it to return to the central channel, it is beyond human power to do so.

79 *Maps of Haaiyarn County*, pp. 24–5.

80 *Haainirng xiahnzhih* 海宁县志 [County gazetteer for Haainirng] (Huar-zhong. Tairbeeí: Cheringwern, 1765. Reprinted 1983. #XXX), p. 500.

81 *A record of the sea-wall*, pp. 361 and 365.

82 *Haainirng county gazetteer*, p. 491.

With this as an introduction we now turn to descriptions of specific periods. Guh Zuuyuh's 顾祖禹 geographical handbook, compiled in the seventeenth century but for readers of the histories, and evidently referring to an earlier period, says of Mount Kan:

It looks down on the Qiarntarng River, and rises up to face Mount Zhee in Haainirng on the other side. There are small hills along its flank, called the Turtle Hatchlings' Hills (*biehzi shan* 鱉子山). The river flows out between them. Therefore this is known as the Turtle Hatchlings' Gate, or the Seagate. It is the lock and key of the Qiarntarng.⁸³

Elsewhere he notes of the river near Xiaoshan that

In times past it was 30 *lii* broad [that is, about 19 kilometers]. In recent years tide-borne sediment has gradually accumulated, and it is less than 20 *lii* across [less than 13 kilometers]. The broadest part of the mouth on the seaward side is almost 70 *lii*.⁸⁴

In Guh Yarnwu's anthology of documents, assembled about the same time, he cites an earlier source that has the elders of Haainirng saying:

Mount Zhee is in the south of the county, and is the gateway actually used by the river. To the east lies Huarng Bay (Huarng Wan 黄湾), a harbour with access to the sea. These two end-points are 140 *lii* apart [90 kilometers], but there is no intermediary city wall that can be defended. When the 'Japanese' made raids in earlier years, they would first speed to Mounts Kan and Zhee, then take possession of Mount Shirdun 石墩山.⁸⁵

This suggests that, at the time to which this refers (since the pirates were active in two main waves either the early-fifteenth or the mid-eighteenth century), the coastline ran unbroken from Mount Zhee (now halfway down the west shore of the Narnsha peninsula on the southern side of the bay) to Mount Shirdun, part of the Jianshan group on what is today the northern shore.

The documentary record is thus broadly in agreement with the maps considered above. It also amplifies it. Thus, with respect to Figure 11, the Saltwater Dyke (*xiarntarng* 咸塘), set back slightly from the coast, and its western sector running from just south of Haainirng city to the western slopes of Mount Shuu, then south to the east of Mount Herzhuang, is said to have collapsed some time before 1299 but to have been rebuilt in 1327,⁸⁶ or 1329/30.⁸⁷ The *Geographical Digest* states that this dyke, and the adjacent Freshwater Dyke (*dahntarng* 淡塘) replaced the Tarng-dynasty dyke that had

83 Guh Zuuyuh 顾祖禹 *Durshii fangyuh jihyaoh* 读史方輿纪要 [Geographical Digest for Readers of the Histories] (1667. Reprinted, Beijing: Zhonghua shujur, 1957), p. 3836.

84 Guh Zuuyuh, *Geographical Digest*, p. 3837.

85 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *shahng*, p. 2a. Many of the so-called 'Japanese pirates' (*wokouh* 倭寇) were in fact Chinese, especially in the 16th century. See Ishihara Michihiro 石原道博, *Wakô* 倭寇 [The 'Japanese' Pirates] (Tokyo: Yoshikawa Kôbunkan, 1964), who also has a chronological appendix. There were, for example, attacks on Haainirng and Zhahpuu in 1443 and 1446, then later on Shaohxing in 1523, Zhahpuu in 1524, Harngzhou in 1542, Zhahpuu in 1545, Shahngyur in 1551, Qiarntarng, Zhahpuu, Haainirng, Yuryaor, Gaanpuu in 1553 and following years.

86 *Haainirng county gazetteer*, p. 464.

87 Guh Zuuyuh, *Geographical Digest*, p. 3767.

been mostly destroyed in the tidal disasters of the early–eleventh century. When the Saltwater Dyke was rebuilt “the sea sands once again rose up rapidly [outside it], so any collapse could be avoided. For this reason the name of the department was changed to ‘Sea Peace’ [Haainirng].”⁸⁸

The northern bank of the Qiarntarng River immediately inside the Major Southern Cleft is inadequately covered by the maps available (apart from the sketch in the 1579 prefectural gazetteer for Harngzhou), and reconstructing it from documentary sources has to be provisional. The section on land routes in the 1529 gazetteer for Rernher county 仁和县 (one of the two prefectural counties of Harngzhou) says that “to the southeast [of Harngzhou city] one goes to Stone Bridge at Mount Zhee, reaching the border of Yarnguan [Haainirng] after 66 *lii*.”⁸⁹ (There was also a water-route along the Tangcun Dyke 汤村塘). This suggests a continuous shoreline from Harngzhou city to Mount Zhee. The same source also indicates that Rernher county contained cantons (*lii* 里) called ‘Mount Zhee’ (in Charngleh rural district 长乐乡) and ‘Seagate’ (in Lirnjiang rural district 监江乡).⁹⁰

This bank was under attack from at least the early–twelfth century. According to an official writing in 1116, “in recent years the hydrological circumstances have changed somewhat. From passing out to the sea by Mount Zhee, the water has turned and gathered at Yarmern 巖/岳/岩門 and Bairshir 白石 in the area along the northern bank. The damage done to the commoners’ farmland and to the salterns extends 30 *lii* from east to west and more than 20 *lii* from south to north.” In 1117 the prefect of Harngzhou observed that “the town of Tangcun, and Yarmern, and Bairshir lie alongside the Qiarntarng River as it makes its way out to the great sea. Day and night the two tides have little by little gnawed them away and encroached inland.”⁹¹ This situation worsened after the end of the fourteenth century:

Charngleh district is close to the Qiarntarng River on its southern side, and from the closing years of the Horngwu reign-period [about 1390] until 1409 in the Yoongleh reign-period it was smitten by the river and the tides. The dyked banks were broken down...In the fifth lunar month of 1414 Heaven-Nature unloosed torrential rains and merciless winds. The lightning-swift river and the tides overwhelmed the level land, the deep water reaching more than 10 *lii* from south to north and over 50 *lii* from east to west...Many of the inhabitants were drowned. There were countless deaths, and the survivors fled. Dwellings were swept away without trace, and the farmland was totally submerged.⁹²

Thus the Minor Central Cleft and the approach to the Major Northern Cleft were being opened from the landward side at this time.

On the seaward side the low-lying flast along the north coast of the outer bay were the first to be stripped away. Thus a Sohng-dynasty gazetteer records an extensive loss of land

88 Guh Zuuyuh, *Geographical Digest*, p. 3767.

89 *Rernher xiahnzhih* 仁和县志 [Rernher county gazetteer], #179 in *Zhonghwar fangzhih congshu*, Huarzhong (Reprinted, 1975. Tairbee: Cherngwern.), p. 55.

90 *Rernher county gazetteer*, p. 53.

91 Guh Zuuyuh, *Geographical Digest*, p. 3760.

92 *Rernher county gazetteer*, p. 390.

southeast of Haaiyarn, including irrigation systems, “now all submerged in the sea.”⁹³ This may have removed the outer defences of the northern coast of the inner bay. A benchmark for the inner bay is provided by the record that when the sea-wall for Yarnguan (Haainirng) was rebuilt in 721 it was at that time 30 *lii* south of the city (which is today on the sea-coast), and the sea was a further 10 *lii* south of the wall.⁹⁴ Some erosion was noticed in 1122,⁹⁵ but the real assault began early in the thirteenth century:

In 1219 the sea at Yarnguan forsook its ancient course, and the tides rushed in across more than 20 *lii* of level land, reaching in their incursions as far in as the county capital. The creek at Lurzhougaang 芦洲渴, and a number of salterns...were all destroyed. Mount Shuu was engulfed in [‘surrounded by’?] the sea. Almost half of the dwellings and farmlands were lost. The salt water reached four prefectures. The prefects of that time reported that, “...Last year the waters of the sea rose suddenly, and rushed in across the sandy shores, each breakthrough carrying it in a few tens of feet further, for day after day...The might of the tides presses in on the inhabitants. If the spring tides should irrupt with angrily bubbling waves, and a typhoon to back them, inspiring a convulsion of nature, it is all but inevitable that for 100 *lii* the common folk will be buried in the guts of the fishes.”⁹⁶

In 1222, when the tides broke in again, Liur Houh 刘屋, the intendant of Zhehxi, told the emperor that the threat was to the whole area to the east and south of Lake Taih, which might be rendered uncultivable by salination if nothing were done.⁹⁷

The overall pattern during the Mirng and the Yuarn can be summarized by quoting Chern Shahn’s 陈善 *Discussion of Sea-Walls*, written early in the seventeenth century:

The county capital of Haainirng borders the sea on its southern side...The sea-wall is only a hundred paces away from the city wall. Eastwards it goes as far as Haaiyarn, and westwards to the Qiarntarng River, stretching north to south for 100 *lii*. To the southwest of this sea-wall is Mount Zhee, which faces Mount Kan to the south. These mountains enclose the sea-gate between them, where the tides enter the river’s mouth.

Theorists aver that the sea is clear out in the vastness of the ocean,⁹⁸ but that when it arrives here it is constricted so that it cannot do as it will. It forthwith turns back eastwards in anger, reversing its direction of circulation. There is also Mount Shirdun to obstruct it, so that it becomes still more enraged and thereupon strikes in unstable fashion both east and west. The damage that this does is concentrated on Haainirng.

I would observe that, according to the old gazetteer, there were more than 20 *lii* of sand-fields outside the sea-wall, and that on the landward side of these sand-fields there were more than 160 or 170 *qing* 顷⁹⁹ of farmland, pastures, and orchards of mulberries, silk-thorns and

93 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, pp. 3b–4a.

94 *Haainirng county gazetteer*, pp. 461, 463.

95 *Haainirng county gazetteer*, p. 1663.

96 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, pp. 42ab. Compare *Haainirng county gazetteer*, p. 463: “The 40 *lii* south of the county capital have turned entirely into sea.”

97 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, pp. 42b–43a. Compare *Haainirng county gazetteer*, p. 463.

98 The discoloration of the coastal water due to its load of sediment is strikingly visible from satellite photographs.

99 1 *qing* = 100 *moou* 亩 = approximately 7 hectares.

jujubes. {So long as there was this external protection for the sea-wall, the tides could not impact on it and wash it away, and there was every assurance that what was on the landward side of the stone sea-wall could endure.

Today, the sand-fields and pastures have been entirely swept away by the sea. The protecting sands have totally disappeared. Life depends solely upon this girdle of newly constructed sea-wall.

I shall not record the constructions and destructions of the sea-wall since Sohng and Yuarn times,¹⁰⁰ but from the Horngwu reign-period [1368–99] to the Wahnlih reign-period [1573–1619], the sea has changed on five occasions, and the wall has been rebuilt five times.¹⁰¹

One source suggests that the mouths of the Qiarntarng were becoming blocked as early as the beginning of the fifteenth century. In 1420 an official from the Memorials Office reported that, “in the past there were seaways at Mount Zhee and Mount Yarnmern, but today both are closed by sediment, and so the behaviour of the tides has become still fiercer.”¹⁰² In spite of this, it does not seem likely that the Northern Major Cleft was already being used by this time. Evidence that it was not is provided by a letter written some time in the seventeenth century by Zhang Cihzhong 帳次仲, who was a native of Haainirng:

The sea at our county of Haainirng is no more than an arm of the great ocean, but, when the tides strike and the sands are gnawed away, one at once sees people’s fields and their houses being submerged...To the west, Mounts Kan and Zhee face each other south and north, enclosing the sea-gate between them, the mouth where the sea enters the river. To the east are Mount Shirdun and Mounts Dahjian and Xiaojian rising up unexpectedly in a corner of the sea, and forming the entranceway through which the sea comes into Haainirng. The tide rises in the east and passes Zhahpuu and Gaanpuu, being confined within the ‘Eight Mountains of the Nearby Sea’ (*jihnyarng ba shan* 近洋八山 [probably the *xia ba shan* 下八山 off Zhahpuu]).

The Qiarntarng River drains out to the west of [its confluence with] the Puuyarng River.¹⁰³ It passes the Yarn Foreshores (*yarntan* 严滩)¹⁰⁴ and so exits [into the sea]. The Yarn Cleft (*yarn mern* 巖壘) is constricted between the space of the sea-gate between Mount Kan and Mount Zhee. The entrance is exceedingly narrow, and of such a nature as to compel [the waves] to strike against each other. Since [the waves] have come from far away, they inevitably grow tumultuous and angry. For this reason they strike about in swirling fashion, with a dashing noise, and there is the menace of their bursting through [the sea-wall]...

The county capital is bounded by a sea-wall a hundred paces to its south...The section of several tens of *lii* near the city is locked by the [two] Mounts Jian at the east, and secured by Mount Zhee at the west, making an embracing arc [whose ends] protrude out [into the sea]. The county capital is to the north of these two mountains, the three of them constituting a three-sided *diing* 鼎 vessel that is struck at an oblique angle by the water. The area outside the city wall has become a headland-enclosed bay (*aoh⁴wei* 澳隈) for the sea.

When the tide rushes into the Yarn Cleft it is held fast by the outflow of the river, which it

100 The passage within braces only appears in the *Haainirng county gazetteer*, p. 471.

101 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, pp. 47ab.

102 Guh Yarnwu, *Commanderies and Principates*, Zehhhiang *xiah*, p. 46b.

103 At this period in the southwest corner of Xiaoshan county.

104 Probably at the Lower Yarn Family Bay (*xiah Yarnjia wan* 下严家湾) on the right bank obliquely opposite Mount Werntarng 文堂山. See *Harngh-zhou prefectural gazetteer* (1898), map, p. 256.

strikes against and then returns north. These several tens of *lii* are attacked from three sides, and so it is that we constantly see the sea-wall being broken down here.¹⁰⁵

The *Three Rivers' Lock*, quoted above in the section on the geographical context, puts the date of the change at 1692–5.

There was a period of about 50 years in the middle of the seventeenth century during which the pressure on the northern sea-wall is reported as having been eased. According to the county gazetteer for Haainirng:

After the sea-wall of Haainirng county was rebuilt in 1664, the area outside it was covered with protective sands that piled up for several tens of *lii*. The local people built shacks on it, to the extent of several hundreds of families. This settlement was called 'The Village Without A Name.' Near to the dyke the sand gradually became less saline and cotton was cultivated. On the new sands along the sea-shore they reduced brine by evaporation and boiled it to make salt. People garnered these profits without any longer being aware of the menace presented by the sea. In this year [1715] the wind-driven tides suddenly irrupted, and the sea-wall was smashed through.

There followed a period of instability:

From 1720 to 1721 the protective sands were demolished each day by a hundred feet or more, even by several hundreds...After [1724] the tides struck northwards every day. The protective sands were swept away without a remnant left. The dyke was repeatedly rebuilt and repeatedly broken.¹⁰⁶

In 1720 the governor of Zhehjiang, Zhu Shin 朱軾, reported to the emperor that, "recently, on account of the blockage caused by the deposition of silt, the river water and the tides have been made to move entirely to the northern bank."¹⁰⁷ This sounds like a decisive shift, but in fact there followed two decades of strenuous efforts to redirect both river and tides back to the Minor Central Cleft, especially by dredging. In 1733, for example, some time after an earlier effort at clearing the central channel started by Zhu Shih had been abandoned, the Yongzhehng emperor observed that:

If we dredge an induction channel (*yiinher* 引河) in the Minor Central Cleft in addition to [other measures proposed] and thus divide the flow of the Qiarntarng River into the sea, so as to reduce the force of the water, it would seem that this would also offer advantages.¹⁰⁸

His successor, the Qianlorng emperor, wrote in 1762 that "in recent years the pattern imposed by the tides has been gradually pressing into the Major Northern Cleft,"¹⁰⁹ and it is clear during the middle of the century there was a period during which the flows moved about considerably. Later in the same year the emperor wrote a summary history of these changes, much of it based on his own personal observations:

105 *A Record of the Sea-Wall*, p. 667.

106 *Haainirng county gazetteer*, pp. 474–5.

107 *Haainirng county gazetteer*, p. 477.

108 *A Record of the Sea-Wall*, pp. 323–4.

109 *A Record of the Sea-Wall*, p. 331.

After 1745, and prior to 1757, the sea went through the Central Cleft. The people of Zhejiang remarked that this was most fortunate and something exceedingly hard to obtain. I made visits on two occasions in 1757 to observe it, and to offer my congratulations on this good fortune [to the God of the Sea]. I did not dare to be certain, however, that this situation would last. Not long afterwards, in the autumn of 1758, there were scars in the sediment¹¹⁰ piled up on the northern headland of Mount Leir 雷山;¹¹¹ and in the spring of 1759 [the tides] pressed exclusively through the Northern Major Cleft. The protective sands along the northern shore were little by little scoured away. These had been the defence for the sea-wall of wooden billets and the stone sea-wall. At this moment it was no longer possible to delay the conversion of the section of the wall that was made of wooden billets to stone.¹¹²

The main channel seems to have oscillated between north and south up to 1765, but by 1780 or thereabouts it had settled into essentially the modern pattern.¹¹³

The present-day course of the lower Qiantang River is thus only a little more than 200 years old.

3. *Hydrology and Hydraulic Engineering*

*Est quoque uti possit magnus congestus harenae
fluctibus adversis oppilare ostia contra,
cum mare permotum ventis ruit intus harenam.*

[It is also possible that a vast conglomeration of sand blocks up the mouths of the river, flowing in a direction opposite to it, when the sea, agitated by the winds, casts up the sand shorewards.]

Lucretius, *De rerum natura*, vi.724-6.

The most important forms of human intervention probably affecting the evolution of the bay were (1) the stabilization of parts of the coastline with sea-walls, and (2) the reduction of the peak discharge of some of the rivers emptying into it. This statement is based on the hypothesis that the relative strengths of the forces tending to make for the deposition, or removal of, sediment in the various parts of the inner bay, were often close enough, to equilibrium for the relatively small effects of man-made structures to be sufficient, in some cases, to alter a trend or arrest it. This hypothesis seems reasonable as regards (1), though a number of seawalls succumbed to the attacks of the sea. As regards (2) it should be treated as speculative, though there is historical evidence to support it.

An example of the causal mechanism that we are suggesting was important is given in the Wahnliu reign-period gazetteer for Shaohxing prefecture:

In 1457 the prefect Perng Yih 彭谊 had the White Horse Mountain Lock (*bairmaa-shan zhar*

110 Such scars were thought to indicate the imminent removal of the sediment in which they appeared.

111 Located east of Mount Charnji 禅儿山 and on the northeast extremity of the south bank of the Central Cleft. See *Haainirng county gazetteer*, pp. 70-1.

112 *A Record of the Sea-Wall*, p. 342, and compare p. 351.

113 *A Record of the Sea-Wall*, p. 353.

白马山(闸) built in order to block off the tides at Three Rivers' Mouth.¹¹⁴ Eastwards of the lock [the seaward side] it all silted up and became farmland. After this the river's water was no longer in direct contact with the sea.¹¹⁵

White Horse Mountain Lock did not last long, however, being derelict by the sixteenth century.¹¹⁶

The entire south shore of the bay was enclosed by a sea-wall about 500 *lii* (i.e., over 322 kilometers) long, running from its western terminus at Mount Charng to Dihngghai 定海 (modern Zhehnghai) at its eastern end. For the period that concerns us, a section of some 61,600 feet protecting the area that is now Shaohxing prefecture, and sometimes called the Houh-Sea Sea-Wall (*houhghai-tarng* 後海塘), was built 40 *lii* north of the prefectural capital in the early-thirteenth century (replacing the earlier Tarng wall). It was said that, being "on the shore of the great sea," "if it is not repaired in good time, the fields and cottages will be drowned." By Mirng times about one third of it was faced with stone.¹¹⁷ The purpose of the wall was mainly "to keep the [fresh] water in and to irrigate the fields."¹¹⁸

A passage that may refer to the effects of installing locks or sluices on the rivers emptying into the sea-gate off the mountains of the south side is quoted in the Haainirng county gazetteer as a note to an entry dated 1500:

For many long years there have been counter-currents and unmoving accumulations of water (*suhhuir tirngxuh* 淤涸停滯). The streams¹¹⁹ have all thrown out sand-bars like obstructing walls. Thus the river-mouth has become constricted and the tides constrained so that they strike when reflected (*faanji* 反击) against the concave shore (*wei'an* 隈岸) of Yarn'guan [Haainirng].¹²⁰

We provisionally take this as pointing to the reduction in the competence of the streams discharging into the southern sea-gate channel, perhaps because of sluice and lock construction.

The sea-wall was only the final control mechanism in the irrigation system created for the Shaohxing plain, which had advanced slowly northwards from the alluvial

114 The quotation from Maa Yaohxiang below describes this lock as lying to "the north". Cherng Mirngjiuu's *Three Rivers' Lock* (*xiah, xiah j.*, p. 34a [in sequence, the given pagination being faulty here]) says that it is 45 *lii* northwest of Shanyin county capital (i.e. Shaohxing) at the foot of Bairmaa Mountain.

115 *Shaohxing fuuzhizh* 绍兴府志 [Shaohxing prefectural gazetteer] #520, Huar-zhong. (Tairbee: Cheringwern, 1597. Reprinted 1983), p. 591.

116 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, p. 48a.

117 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, 50a. The term taken (tentatively) to indicate facing is *zouh/zhouh* 甃 which means "a well", and "to repair a well".

118 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, p. 41b. There are similar comments in the Guh Zuuyuh, *Geographical Digest*, pp. 3833-4.

119 The character in the text is unclear. *Zhu qi* 诸溪 ("all the streams") may be *Zhee qi* 赭溪 ("[Mount] Zhee's streams"), but Mount Zhee is too small to have any major stream, so we adopt the reading given.

120 *Haainirng county gazetteer*, p. 469.

fans at the foot of the mountains for more than a millennium as the tidal wetlands were reclaimed for farming. A historical overview of this process is given by Maa Yaohxiang 马尧相, writing at an unknown date but before the middle of the seventeenth century:

The water sources of Guihji [Shaohxing] flow from the southwest to the northeast. In ancient times they were in direct communication with the sea. The inrush and the drainage were not regulated, which harmed the common folk. After [Later] Hahn times, when Maa Zhehn 马臻 had built Mirror Lake to receive the water off the mountains, sluice-gates were installed along the dykes, being opened and shut at the appropriate seasons. When water was in short supply they drained the lake to irrigate the fields. When water was plentiful they closed the lake and drained water from the fields into the sea...

Later they also built the sea-wall and opened Yuhshan Sluice [the principal control-point for water from the south entering the Qianqing River, about 33 *li* north of Shaohxing city and Mirror Lake]. After this the embankments of the lake slowly fell into disrepair. Though there were proposals in the Sohng dynasty to restore the lake, it had by this time become unnecessary. The reason for this was that the waters flowing into Guihji by diverse channels were several tens in number...

...One may say that those fields that lie along the feet of the mountains are watered by their springs, while those that border the sea are supplied by the streams that branch from the former. These latter, having obtained what the former has accumulated for them, are also spared the disasters [i.e., spate flooding] that afflict the former, both of these benefits depending on the sea-wall along the Houh Sea (*houhhaai* 后海 [i.e., Harnghzhou Bay]), which both stores the water and discharges it.

For this reason, when previously, under the Hahn, there was no sea-wall, it was essential to build Mirror Lake [as a reservoir for fresh water]. In these later times when, since the Sohng, there has been no Mirror Lake, keeping the sea-wall in good repair has been essential.¹²¹

But the loss of Mirror Lake, through the deposition of sediment and the reclamation of its area as fields by the more powerful of the local farmers, led to increased flooding in the plain below. This was intensified by changes in the pattern of flow of the Puuyarng River (which was also known as the Waan 浣江 in its upper course, and as both the Qianqing 钱清江 and the Xixiaao 西小江, or 'West Small River', in its lower course), which now came north and then, turning northeast, flowed across the lower plain at this time in an approximately west-to-east alignment. Maa Yaohxiang describes what had happened when the lower Puuyarng had shifted to this course from an earlier one apparently not greatly different from the northwestern route that it follows, again, today (though it would have had at this time to have circumvented the Qiryahn/Qirxiahn mountain):

There was a further cause for anxiety. All the water of the lakes of the counties of Puuyarng 浦阳 [present-day Puuijiang] and Jihyarng 暨阳 [present-day Zhujih] used to flow into the Jihyarng River 暨阳江 [presumably the Puuyarng], then turn north *west* and enter the Zheh River 浙江 [the Qiarntarng]. Its configuration was *curvilinear* and it could not go straight to

121 Guh Yarnwuu, *Commanderies and Principates*, Zhehjiang *xiah*, pp. 43a-44b.

its destination.¹²² Later it passed through Fisherman's Inlet and entered the Qiarng River [i.e. going north and then east]. To the north it went out of Bairmaa [shan] and other locks, and so entered the sea.

Today, however, these locks have also silted up. The water has no through passage. Once there are floods, it has to flow eastwards and make Guiji [Shaohxing] its sinkhole. Although there is the Yuhshan Sluice, it is not adequate to discharge water moving west-to-east with such force. Every time this happens, people break open the dykes. Though some limited relief is thereby obtained from the emergency, they are obliged at once to repair the [dykes of these] inlets (*puu* 浦) so that they are ready to store water again. This, too, is work that is hard to accomplish. [Emphasis added.]

Here is an example of “technological lock-in”, though in this case the problem was eventually solved. Once a community is committed to a system of this sort, it has no easy option — barring some technological escape — but to allocate labour and resources to maintaining it, even if the costs start to rise.

The county gazetteer for Shanyin (the western part of Shaohxing) emphasized this problem, while indirectly indicating the extent to which the flow of the rivers had by now been separated from the sea:

After Mirror Lake had been done away with, and made into farmland, whenever the springs [in the hills above it] overflowed, there was nowhere for the water to be stored. It was joined by the water of the Waan River, which poured into the West [Small] River...Shanyin thus became a vast flood. Whenever there were heavy rains, the water was so placed that it spread far and wide. With only the single lock at Yuhshan, it was impossible to drain it all off.¹²³

The terrain was said to have had ‘the configuration of a water-jar’ (*wehngxirng* 甕形).

Between 1448 and 1511 at least 13 new locks were built to drain off the water of the West Small River both to the north and the south, and to drain two ‘new rivers’, one near Mount Kan and one simply attributed to Shanyin county, both presumably north into the Sea Gate area.¹²⁴ These measures were not adequate, and the temporary breaching of the dykes was still required in emergencies. According to one source: “The mouths of the two locks [at Biaantuo 扁 (匾) 拖 near Yuhshan] are narrow in the extreme. When the water arrives here it overflows several hundred [square] *lii*. When it reaches the sea-wall it has become a ferocious and turbulent commotion that is a great disaster for the farmland.”¹²⁵ The Shanyin county gazetteer also commented that “once the dykes had been broken and the wild torrents had foamed swiftly away, it was inevitable that the channels would rapidly run dry. The weary people were then

122 In the middle of the + 1st millennium, the Puuyarng River entered a lake, the Lirnpuu 监浦, north of where Lirnpuu town 监浦镇 stands today, but which has long since vanished, and then passed through a narrow channel into Fisherman's Inlet (*yurpuu* 渔浦), also now disappeared, which in turn emptied into the Qiarntarng some way upstream of Harngzhou city. See Chern Qiaoryih's fifth article (summarized above) and Shiba, *Jiarngnarn*, pp. 554–5, and 564.

123 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, 47a.

124 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, 47ab.

125 Cited in Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, 48b.

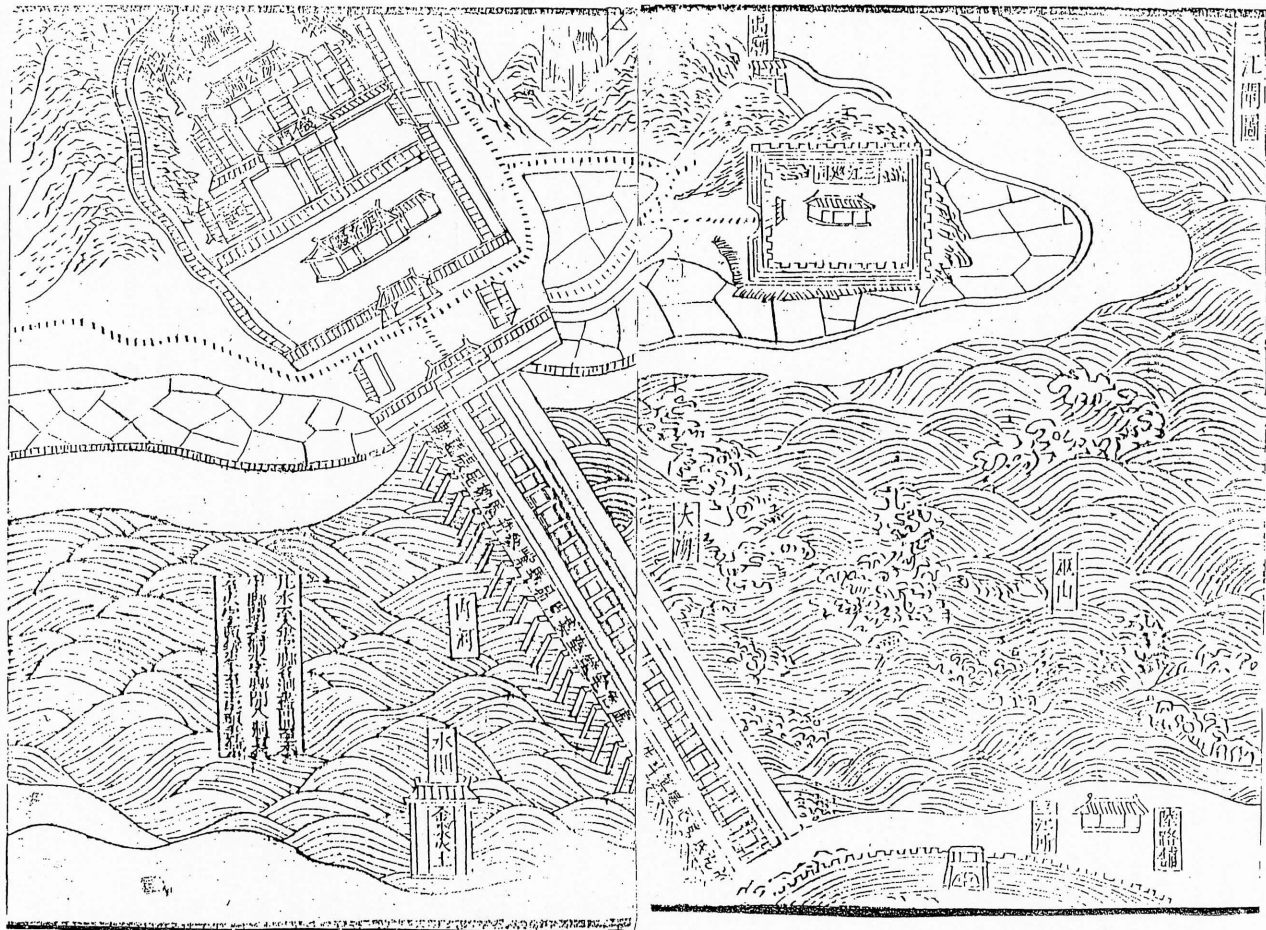


Fig. 12.

burdened by having to plug the breaches, yet before this work had been completed they would be suffering from a shortage of water.”¹²⁶

The solution lay partly in the re-routing of the Puuyarng River already referred to, the use of locks at and near the Mar Stream (Marqi 麻溪)¹²⁷ to stop too much water coming north, and the building of the Yihngxiuh Lock (*yihngxiuh zhar* 应宿闸), or Three Rivers' Lock (*sanjiang zhar* 三江闸), whose 28 sluices (*dohng* 洞) were each named for one of the 28 stellar mansions (*xiuh* 宿), across the mouth of the Puuyarng at Three Rivers' Mouth. It was constructed between two hills (the southern one of which was a small outlier) that were joined by a natural stone pavement into which the huge stones of the lock's foundation were 'mated' and caulked with a sort of paste made out of boiled millet stalks and lime or mortar (*hui* 灰).¹²⁸ It was flanked to the north by an earth wall that was 4,000 feet long and 400 feet broad, reinforced by iron and later bamboo in a fashion that the sources do not specify except to note that it was needed because the mud (*naoh* 淖) of which this barrier had been made proved "unpredictable at first". The flow of water was regulated by means of a double layer of wooden planking in each sluice. The construction is said to have been hurried: the threshold on which the lock stood was not perfectly level and tight; the wooden boards leaked and had to be repaired, and some of them replaced, every dry season. The initial outlay required in money was 6,000 ounces of silver for the lock and that for the earth dyke several times that amount, both raised by a levy on acreage in the three counties affected. The labour was mobilized by conscripting local commoners on a rotating basis. "With this, the water no longer behaved violently, and the sea-wall was no longer [deliberately] breached and repaired."

The massive lock (see Fig. 12) was completed in 1537. The engineered separation of the Shaohxing plain water system from the sea was now total except for the Caor'er River on the extreme eastern edge. The result (at least on the assumption of the unrigorous but plausible principle of *post hoc ergo propter hoc* was the immediate

126 Guh Yarnwuu, *Commanderies and Principates*, Zhehjiang *xiah*, 47b-48a.

127 Located a short way upstream of the point where the Puuyarng River had been re-routed.

128 Guh Yarnwuu, *Commanderies and Principates*, *ceh* 50, *fuhzhu* [appended notes], 60a, note 9. The stones of the piers were tapered (*yaan* 剡) where they met the impact of the water, "so that they did not fight with it."

Fig. 12. Three Rivers' [Mouth] Lock 三江闸 in late-Ming times.

The 28 sluice-gates are labelled with the 28 *xiuh* 宿 or 'stellar mansions'. The lock serves as the barrier between the 'inner river' (*neihher* 内河) and the 'great sea' (*dahhaai* 大海). A gauge measuring the height of the water (*shuuzier* 水则) may be seen at the bottom of the left-hand panel. On the bottom right of the right-hand panel is a land-route relay station (*luhtuh pu* 陆路舖). To its left is the Three Rivers' Military Station (Sanjiang-suoo 三江所). On the seaward end of the far bank may be seen the Three Rivers' Patrol Office (Sanjiang xurnsi 三江巡司) and, above, it a small temple to Yuh the Great, the tamer of floods. The complex of courts and buildings at the upper left contains, among other edifices, a shrine to Tang Shaoh'en 汤绍恩, the official responsible for the construction of the lock. (Source: *Shaohxing Prefectural Gazetteer* (1719), pp. 1624-5.)

build-up of sediment deposits off-shore:

The tides were blocked by the lock and the earthen dyke, and could no longer insinuate themselves upstream. This made it possible to farm more than 10,000 *moou* [within the sea-wall]. Outside the dyke, where hills formed flanking wings, the sediment (*yu* 淤) became soil (*raang* 壤) so that little by little [a further] several hundred *qing* of farmland could be obtained.¹²⁹ The marshy portions could be used for growing reeds. The brine could be drawn off to make salt. The swampy pools could be used for fishing. Mulberry trees could be grown along the edges of its fields, and merchants could travel on its paths.¹³⁰

Given this evidence of seaward-side land formation following the lock's building in 1537, and the overall chronological sequence of events, there is a case for suspecting that the filling in of the Major Southern Cleft and the ensuing shift in the debouchment of the Qiarntarng River in 1620 to the Minor Central Cleft, may have been in part the consequences of the preceding hydraulic closure of the coastal plain along the southern shore of the bay, in which the Three Rivers' Lock was the culminating installation. These processes in the inner bay were of course interconnected with a larger pattern of events in the outer bay — such as the separation of Huarngparnshan from the coast — that were outside, or almost outside, human influence.

It was said in the seventeenth century that the effect of the work of Tang Shaoh'en, the creator of the Three Rivers' Lock, was that “with regard to the high and low conditions of the water, he regulated them to proportional quantities (*fen shuh* 分数).”¹³¹ What this means is that the peak discharge (*jiershuui* 节水 = ‘seasonal flood’) was replaced by a managed régime. In the words of Cherng Mirngjiuu, in the later — seventeenth century:

In years past, both the sea and the river-channel were deep. Today the sediment accumulates easily, and makes use of the flowing [river-] water to scour it clear. The water of summer and autumn is, however, closely linked to farming operations. It is necessary to conserve it with a grudging parsimony. When winter has come, then there is no cause not to take the boards [in the lock-sluices] down and to desist from caulking [the fissures in them] with mud...Before the peak discharge is finished [in the early summer], the lock-gates are closed, but caulking is not necessary. Once the peak discharge is past, it is essential, once the gates have been shut, to caulk [the cracks]...[But] opening and shutting ought to follow the particular seasonal conditions. It is not right to adhere inflexibly to a set pattern.¹³²

The management of the lock had observable effects. As Cherng wrote:

It is now a hundred and some tens of years since His Honour Tang built the great lock, and renovation has been undertaken twice in the space of this time...Over these years the tides have caused difficulties, with sediment blocking it up, the problem being that there is no strategy for dredging it clear...

129 One *qing* = 100 *moou*, hence say another 20,000 to 30,000 *moou* in all.

130 Guh Yarnwu, *Commanderies and Principates*, Zhehjiang *xiah*, 49a.

131 Cherng Mirngjiuu, *Three Rivers' Lock*, *shahng*, ‘Tang-shern shirshin luh’, 12b.

132 Cherng Mirngjiuu, *Three Rivers' Lock*, *xiah*, *xiah j.*, p. 3a.

If the lowest boards of the deeper sluices are entirely removed, then the state of the water will be swiftly rushing along, and the ferocity of the current redoubled. *The sediment that comes in with the tide will, in the same fashion, be taken out by the tide.* [Emphasis added.] If it is not seen to that the lowest boards are removed, then inevitably the current cannot move swiftly right down at the bottom.

It is, however, entirely the responsibility of the lock-workers to remove or retain these lowermost boards at the times when the lock is vented. In the deep sluices, where opening and closing off are difficult, they either go only halfway, or do not remove the boards completely. For this reason the clear water floats over the top and the current does not reach to the bottom. The sediment accumulates here, and there are no means of expeditiously draining away. This is one reason why the river is silted up...¹³³

A lack of rain and a well-repaired lock could also trigger deposition. The ‘Summary of Current Concerns’ relating to the lock noted that

Harm caused by silt blockage began in 1671. After this time there were years of hot, dry weather. Although the situation was manageable upstream of the lock, it often happened that downstream the silt piled up as far as the East Charn Spit [at the mouth], and the water inside would often accumulate for a month or more without draining away. After the repairs done to the lock in 1682, there were not many fissures through which the water could leak out, and the current in the river [below the lock] repeatedly flowed in reverse direction (*lüü huir* 履洄), and under these conditions it was easy for the sediment to block it up.¹³⁴

The current was also slowed down by fishing-screens. Cherg recorded that

What is more, curved screens (*qu bor* 曲簿=箔) are used to trap fish. According to the old system, this would begin at mid-autumn and the screens would then all be withdrawn after the first full moon of the [lunar] new year. Today, the number of fishing-screens has incessantly increased, and there is no season at which they are withdrawn. Furthermore, multi-layer fishing-screens are set up everywhere, cutting off the current and making...pools in which the water-weeds start to grow after enough time has passed, and this is even more effective in bringing the flow to a stop.¹³⁵

The destruction of local vegetation cover also accelerated deposition in the channel:

In 1664 the main provincial army forces pastured their horses along the sea-coast [by the mouth of the river], and by so doing destroyed all the reeds. The salt-producing households took advantage of this opportunity to develop it all as being ‘unvegetated land’ (*bairdih* 白地).¹³⁶

133 Cherg Mirngjiuu, *Three Rivers’ Lock*, *xiah*, *xiah j.*, pp. 36ab.

134 Cherg Mirngjiuu, *Three Rivers’ Lock*, *xiah*, *xiah j.*, p. 38a.

135 Cherg Mirngjiuu, *Three Rivers’ Lock*, *xiah*, *xiah j.*, p. 39a. *Shahng*, *shahng j.*, p. 45b also speaks of removing fishing-screens “so that the current of the river would flow swiftly to the sea.”

136 This term seems originally to have referred in Sohng times to uncultivated official land sold off for farming. See Sutô Yoshiyuki 周藤吉之, *Chûgoku tochi-seido-shi kenkyû* 中国土地制度史研究 [Studies of Land Tenure Systems in China] (Tokyo: Tokyo University Press, 1954), p. 194, n. 11. Later it could simply mean ‘untaxed land’, with an implication of its being heavily saline soil. See Hoshi Ayao 星斌夫, comp., *Chûgoku shakai keizai shi go-izokuhen* 中国社会经济史語汇 [Supplement to A Glossary of Chinese Social and Economic Terminology] (Yamagata: Kôbundô, 1975), p. 132.

Since the turbid flows were no longer confronted by the reeds, whenever there was a fierce rainstorm, the mud floating on top of the bare land was swept into the river, where it accumulated...

Since the reeds were destroyed by this pasturing of horses, the sand-flats in several places have been eroding away for the last twenty years or so. Both upstream and downstream of the lock [the channel] has been constantly full of sediment. It is from the fact that this has been happening for the last twenty years or so that it is possible to be certain that it is because of the destruction of the reeds that the river is filling up, and, perhaps, that the land is eroding...

Although there is no unvarying pattern to erosion and deposition, it is deposition that dominates, and this is an omen that the land surface is in the course of extending. After a few more years the sea-mouth will be locked shut.¹³⁷

Behind this local story lay processes that worked on a larger scale further out in the bay. These may be glimpsed from a selection of passages given in the Kangxi reign-period gazetteer for Shaohxing prefecture (1719), most of them either dating or probably dating from some time considerably before the date of compilation in the later seventeenth century, and describing the sand-bar (*shadan* 沙潭):¹³⁸

Merchants who find the labour and expenses of the inland waterways burdensome sometimes go by sea [here] for the sake of speed. This is called 'mounting the sand bar' (*deng dan* 登潭). The sand-bar is the sand [accumulated] in the middle of the sea. ...

The schedule of the tide at Xiaoshan [at the western end of the south coast] is always behind that of Yuryaor [to the east]. The men of past times said that when there was high water at Yuryaor, the tide coming to Xiaoshan had to 'mount the sand-bar' before it arrived. *This is erroneous.* It is caused by a difference in topographical height...¹³⁹ [Emphasis added.]

If, today, one examines the mouth of the Zhen River, it starts at Zuaanfengtirng 纂凤亭 from where one can look across at the large hills of Jiaxing on the northern shore, and the water is more than 200 *li* across. It is for this reason that the ships of sea-going merchants who want to avoid sand-bar out of fear do not proceed up the main river but only sail as far as Yuryaor's little river, change vessels there, and navigate up the canal to Yuehzhou [Shaohxing] and Harnghzhou. The reason for this is that there is a sand-bar under [the water] stretching unbroken from north to south. It intercepts the waves as they flood in and puts an obstacle in the way of the forces of the tides...

As the waves pile up in decelerated motion, the water behind comes in in increasing quantity, so rising up to overtop the sand-bar...and becomes a great wave (*taor* 涛, that is, a tidal bore). This is not the consequence of a constriction produced by the mountains in the sea.

The *Mysteries of the Tides* by Zhu Zhong 朱中 of the Song dynasty says: "...Only after the water has made up the difference in height can it enter.¹⁴⁰ Before it has reached the sand-bar the Qiantang River is still completely empty. Once [the tide] has grown and confronted [the bar] head-on, it discharges from the sand-bar as though through a sluice. The sediment

137 Cherng Mirngjiuu, *Three Rivers' Lock*, *xiah*, *xiah j.*, pp. 39b-41a.

138 *Shaohxing fu zhih* 绍兴府志 [Gazetteer for Shaohxing prefecture]. Zhou Xurzaai 周徐彩 comp., and Yur Qing 俞卿 rev. #537, Huar-zhong. (Tairbee, Chernmgwern, 1719. Reprinted 1983), pp. 649, and 655-6.

139 The Chinese text says: 昔人谓:余姚平来,萧山者必登潭而后至也。非也。地势高下然耳。

140 The Chinese text says: 夫水盈科而后进。

that builds up in the river is sometimes found to the east and sometimes to the west, having no constant location. The tides are aligned [in their flow] by these banks of sediment...The general picture is that the sand-bar is high in the centre, and somewhat lower at its two ends. The high point is where it encounters the onrush of the Qiarntarng River. The slightly lower portion in the east faces the mouths of the two rivers, the Qiarngqing [Puuyarng] and Caor'er where they debouch. The sand-bar is at its lowest at the mouth of the Qiarngqing, and the tidal bore there is extremely small. The sand-bar off the mouth of the Caor'er River is slightly higher than that off the Qiarngqing, and therefore the tidal bore there is a little higher."

The *Illustrated Schedules for Tides in the Zheh River* by Jur Borxuan 聚伯宣 of the Yuarn dynasty says: "Mounts Kan and Zhee rise up side by side. Below them lies the sand-bar striding across the river for over 300 *li* like a hidden threshold. When the tide enters the Zheh River...it becomes confined, then obstructed by the sandbar, off which it is reflected, then refracted, after which it rushes between the two mountains."¹⁴¹

There is no such clearly defined step-like feature in this area in the modern bay in the areas indicated, and it seems likely that much of the material in the old bar described in the Sohng sources has been either moved further upstream to the Narnsha peninsula or, perhaps, moved south to be deposited on the Yuryaor salient.

*

In spite of the immensity of the forces at work, the conception of controlling the bay, at least to some extent, seems to have emerged in the eighteenth century. Thus in 1723 the Yongzhehng Emperor favoured dredging one of the blocked mouths of the Qiarntarng "so that there is a through-flow, causing the tides not to cause an obstruction by dropping their load of sediment" and thus safeguarding the Haainirng sea-wall.¹⁴² The clearest example of this interventionist approach was the plan put forward in 1732 to build a stone barrier across the neck of the sea separating the Lesser Mount Jian on the mainland east of Haainirng from Mount Taa 塔山 about half a kilometer off the coast:

It will divide and overcome the force of the water, so that the tides go south, and we may anticipate the renewed deposition of protective sands along the northern bank.¹⁴³

This barrier was to be 1,820 Chinese feet in length, and it was estimated that it would have to range from 40 to 130 feet in depth. When the final sector of 810 feet was completed in 1739, however, the greatest depths were reported to be only 18 to 19 feet because of the deposition of 'floating sand'. The disparity was commented on, but no further explanation given.

Groins of two sorts were also built to neutralize the impact of the waves on the sea-wall. One type was the 'chicken's-beak bar' (*jizuui-bah* 雞嘴坝), a narrow, pointed spit

141 The translation of this last sentence is somewhat speculative, partly because the reading of the character marked in brackets is problematic: 潮... [退] 碍沙潭, 回薄激射, 折而趋于两山之间.

142 *A Record of the Sea-Wall*, p. 319.

143 *A Record of the Sea-Wall*, p. 384.

whose purpose was to “deflect the return flow (*yii tiao huir-liuh* 以挑迴溜) so that the fury of the waves would find it hard to act in mutually reinforcing fashion.”¹⁴⁴ The other type was the semi-circular ‘grass platter’ (*caao parntour* 草盘头), which was described as “a barrier-dyke to deflect the water” (*tiaoshuui-bah* 挑水坝) sticking out into the sea, and could be 30 or 40 feet high. The rationale behind it was that, “in those places where the dyke is fundamentally stable, it may happen that when sands have piled up on the shore opposite, or sand-bars have accumulated out of sight under the sea, the pattern of force in the water will strike directly [against the dyke], which being thus assaulted will no longer be safe but in peril. For this reason ‘grass platters’ are built to deflect the currents (*tiao liuh* 挑溜).”¹⁴⁵ In practice it may have served as a sort of artificial headland refracting the waves around itself in such a way as to reduce the energy impacting on the unprotected stretches of shore.

A third protective measure was the ‘water-leveller’ (*taanshuui* 坦水), which was a kind of hydraulic *glacis* sloping downwards at the foot of the outer side of the sea-wall. It was constructed with rubble, topped with stone slabs secured between double rows of timber pilings. The idea, it may be surmised, though there is no explicit evidence for this suggestion, was to destroy the coherence of waves being reflected from the sea-wall and so lessen their capacity for undermining the wall’s foundations by interacting with the incoming waves. The *Record of the Sea-Wall* observed that:

To the east of Haainirng, however [in contrast to the firm ‘iron-board sands’ in Haaiyarn discussed immediately before this], in the district around the Jian mountains, there is also water from the river flowing down. The tide and the river strike against each other in conflict, and if the tidal bore (*chaortour* 潮头) then rises high, feeling out [the shore] at an oblique angle and gnawing at it sideways on, the resulting situation is impossible to resist. Furthermore, when the tide is ebbing, the river water, following the lie of the land, washes and scours [the mud] away (*shahnshua* 汕刷).¹⁴⁶ If the foot [of the sea-wall] is not solid, it is hard to be without anxieties. For this reason the sea-wall at Haainirng has been repeatedly re-built. After the main body of the sea-wall was doubled [in size] the hydraulic *glacis* at its base was also doubled, but since on all previous occasions rubble (*kuaihshir* 坎石) has been used, even though numerous slabs have been laid, from three to five layers of them, it has been easily scattered. Thus there have been frequent re-layings, and this is in no way a policy that provides a permanent solution.¹⁴⁷

When that part of the sea-wall that directly defended Haainirng city, some 5,052 Chinese feet, was being rebuilt in stone in the early-1730s, it was equipped with a *glacis* that, the *Record* implies, it was hoped would be massive enough to resist these processes of destruction. It was estimated that each section of this *glacis*, some 10 feet long and 12 feet across, contained 100,800 *jin* 觔 (of the general order of 50 tons by

144 *A Record of the Sea-Wall*, p. 384.

145 *A Record of the Sea-Wall*, pp. 381–2.

146 For the justification of this translation, see *shahnshuaun* 汕损 in E-tu Zen Sun, *Ch’ing Administrative Terms. A Translation of the Terminology of the Six Boards with Explanatory Notes* (Cambridge, Mass.: Harvard University Press, 1961), #2428, p. 354.

147 *A Record of the Sea-Wall*, p. 381.

modern conversion ratios but probably here a good deal less) of rubble, and perhaps¹⁴⁸ about 6 feet deep, which had a covering of stone slabs seven inches thick, and 12 feet by 1.2 feet in size. The immense size of the undertaking is evident, even if the weight of the rubble used is almost certainly substantially overestimated (by the use of a modern conversion ratio) at approximately 25 thousand tons.

Another example of the intention to manipulate the way in which the bay changed is the following account, unfortunately not always easy to translate accurately, of the efforts of Grand Secretary Ji Zengyurn 稽曾筠 to clear a central exit for the river in the mid-1730s:

Although the disasters to the sea-walls take place on the northern shore in Haainirng county, the causes of the trouble are on the south shore. This is because on the south there are always sandy foreshores (*shatan* 沙滩) rising up by deposition, and deflecting the current (*tiao liuh* 挑溜) so that it goes northward, and the sea-walls are in ever more danger...

Grand Secretary Ji Zengyurn created the method of 'making use of the water to attack the sand' (*jieh-shuui gong-sha zhi faa* 借水攻沙之法). He either used metal implements to excavate the sandy islands of the southern shore in a way that followed the lie [of the land] (*suir shih* 随势), or 'cut off the roots' in accordance with the flow of the current (*shuhn liuh jier gen* 顺溜截根),¹⁴⁹ or else dug channels to meet the incoming tide, so causing the water of the river and the tides of the sea to come and go day and night, themselves doing the scouring. The flow of the river moved towards the south shore day by day, while on the north shore the deposited sands grew daily higher. Thus was the great work accomplished.

In 1744, the governor, Charng'an 常安, contrived the means to dredge an induction channel through the Minor Central Cleft; and, in the area around Mount Shuu, he used as before the 'method of cutting the sand' (*qieh-sha zhi faa* 切沙之法). On the inside he dredged and scooped, while on the outside he extracted and cut (*tiaoqieh* 挑切). In the spring and summer of 1747 the tides little by little swung towards the south, and the deposited sands [on the north side?] appeared wider and wider each day. In 1747 the Minor Central Cleft was flowing through in full, and it is by no means certain that the method of cutting the sands was unconnected with this success.¹⁵⁰

At the same time as an exit channel was being cut south of Mount Shuu, the Qianlorng Emperor ordered that bamboo panniers (presumably with stones in them) should be placed along the northern shore of the bay "to deflect the current and suspend the silt (*tiao-liuh guah-yu* 挑溜掛淤)."¹⁵¹ There was thus a growing sense on the part of the authorities, even if only partly well-founded, that it was possible to some extent to manipulate the coastal sea.

148 This 'perhaps' owes its presence here to the absence in the source of quantified information about the slope of the *glacis*, so it is unclear where the height was taken.

149 Meaning unclear. Perhaps the 'roots' were obstructions?

150 *A Record of the Sea-Wall*, p. 383.

151 *A Record of the Sea-Wall*, p. 365.

4. *Technological Lock-In*

*Nam quod adest praesto, nisi quid novimus ante
suavius, in primis placet et pollere videtur,
posteriorque fere melior res illa reperta
perdit et immutat sensus ad pristina quae aue.*

[For it is what lies ready to our hands that is particularly pleasing to us, unless we have previously known something more delightful; and so it seems to hold the dominant position. Yet later on, when something better is found, more often than not it undermines this preeminence and alters our attitude towards everything from earlier times.]

Lucretius, *De rerum natura*, v.1412–5

Technological ‘lock-in’ is a concept commonly used in economic theory to describe certain exceptional cases when an established but inferior technology continues to dominate because of secondary advantages, that derive from the consequences of its prior establishment.¹⁵² These can typically include investment in the training of those using, servicing, and selling the existing system, and the availability of compatible accessories and interfaces. Examples from the present day are the VHS video system, the Fortran programming language, the lay-out of the standard typewriter keyboard, and English spelling. In this paper the idea has been used slightly differently to describe cases where the commitment of an economic and social system to a particular technology has proceeded to the point that (1) its abandonment would lead to immediate losses in production, and often of social stability and security, that are unacceptable under any ‘normal’ conditions, even where there are evident long-term benefits in prospect; and (2) a substantial proportion of the economy’s currently available resources (such as money, labour, materials, skills, and organizational capacity) are constantly required for the maintenance of the system. The effect is that a sizeable part of the future is, so to speak, ‘mortgaged’ indefinitely. The true cost of the system has therefore to include the loss of the opportunity to use this proportion of output in a different, and possibly ultimately more productive, fashion.

In the present paper we have considered a generally (though not universally) unstable system of hydraulic coastal defences, and, by implication, the (also generally unstable) hydraulic network inland that depended on it. Attention has been drawn at appropriate points to aspects of lock-in. Systematic documentation and analysis of this phenomenon for this area, so far as they are possible, will be presented in a later paper. There are significant difficulties in a meaningful historical cost-benefit analysis, however, that may be briefly mentioned here.

1. The determination of the appropriate spatial and financial unit of account is problematic, though to some extent operationally defined in terms of the areas on which

152 For a summary of the idea as used in modern economics, see W. Brian Arthur, “Positive Feedbacks in the Economy,” *Scientific American* 262.2 (Feb. 1990), especially pp. 84–5: “Increasing-returns mechanisms...can...cause economies...to become locked into inferior paths of development...Technological conventions...tend to become locked-in by positive feedback.”

surcharges in labour-services and money were levied to pay for construction and maintenance. Hydrological units (demarcated by watersheds and comparable natural features) tend not to coincide with hydraulic units (since a large proportion of farmland within a given watershed may not benefit from irrigation or flood-control), and interests external to the unit (such as the imperial government's concern to protect the Grand Canal to the north of Haainirng) may also be important.

2. A non-trivial component of coercion was usually involved, and even where payments were made (which was quite extensively done in Qing times) they did not necessarily reflect the market value of labour or materials.

3. The long periods of time involved (typically hundreds of years) make it hard to find a suitable means of comparing monetary values at widely separated dates. (The use of the very high real Chinese rates of interest for time-discounting leads to absurdities over such long spans of time.) This difficulty is compounded by the need for almost continual maintenance, and quite frequent reconstruction, if the flow of income from the original investment, and from many other dependent investments (such as the desalinization of fields, the construction of subsidiary water-systems, settlements, and the like), was not to vanish.

Because of these and other difficulties, we often find ourselves obliged to depend mainly on the perceptions of the officials and members of the gentry responsible for making decisions. Thus, when the government cut in half the funds for the maintenance of the Three Rivers' Lock in 1678, in order to make money available for military expenditures, the harvests in Shaohxing are said to have suffered for year after year in consequence.¹⁵³ Likewise, in 1682 it was said on a stele, inscribed in memory of His Honour Jiang 姜公, that if the dyke along the West Small River was breached "the fields of three counties had no harvest for two years."¹⁵⁴ The compilation of the documents relating to the Three Rivers' Lock, and a two-volume supplement in 1854,¹⁵⁵ was primarily motivated by a concern for continuity in the methods used by those undertaking maintenance and reconstruction. As one of the prefaces observed, "Alas! If there are founders of enterprises in this world, there must be continuators who come after them."¹⁵⁶

The scale of work needed for a major renovation may be seen from the report on that directed in 1578 by Prefect Xiao Liarnggahn 蕭良干, which cost about 60% of the original construction forty-one years earlier:

They first built cross-dykes (*yahn* 堰) upstream and downstream of the lock, in order to provide a barrier against floods and tides [while the work was in progress]. The method used for these was that of heaped earth faced with slabs of stone. They also emplaced small 'shuttle mounds' [*suodun* 梭墩, perhaps raised walkways on which the workmen could walk back and forth to access their work] in front of the lock. They used stones mated in interlocking

153 Cherg Mirngjiuu, *Three Rivers' Lock, shahng*, Luu preface, p. 2a.

154 Cherg Mirngjiuu, *Three Rivers' Lock, shahng, shahng j.*, p. 35b.

155 Pring Herg 平衡, *Three Rivers' Lock, Supplement*.

156 Cherg Mirngjiuu, *Three Rivers' Lock, shahng*, Luoh preface, p. 1b.

fashion, built upwards from below. Whenever they encountered fissures in these stones, they would consolidate them with [molten?] cast iron. On the top of the lock, from head to tail, they ensured that the covering stones were level; and they further added large stones on both sides [of each sluice] to serve as water-guides (*larn* 栏), so that each of the 28 sluices was separately fed by a sluice-way cut in these guides. In places where there were cracks or splits they would pour in [molten] tin to which the ash of glutinous millet (*huishur* 灰秫)¹⁵⁷ had been added. They also attended in comprehensive and scrupulous fashion to the baseboards (*dii-baan* 底板), the threshold stones (*kaanshir* 槛石), and the banks on both sides, wherever these needed repairing, replacing, or resetting in correct alignment, and wherever mortar (*hui* 灰) or iron were needed...

This work was managed by Sub-prefect Yarng Zhuang, helped by Assistant County Magistrate Zhehng Rihhui, and Battalion Commander Taor Bang...They spent several thousand ounces of silver, and employed several thousand workers. The project was completed in three months...

The shape of the lock was stronger and thicker. It was on this account really a second creation.¹⁵⁸

The nature of more routine maintenance work may be seen from the regulations left by Prefect Xiao, and the other officials who also rebuilt the lock over the following century. The following is a typical example:

Item: There are 1,113 lock-boards [*zharbaan* 闸板 | used to close off the sluices]. Each one is 8.3 inches across and 4.2 inches thick. The labour-cost is 0.3 ounces of silver. One each board is a pair of iron rings, weighing 12 ounces. The labour-cost is 0.06 ounces of silver. The selection and procurement of material for these boards shall be entrusted either to honest and capable officials or to the lock officials themselves. They shall be furnished with the money and go in person into the hills to purchase large pine-trees at standard prices, and hire artisans to split them into sections. The pieces used should have all four corners square, and be sturdy and without imperfections. Those with flimsy edges are to serve as roofing-boards...Old boards are to be replaced every other year, and the lock-workers are to send them as before to the area in front of the Zuooshehng temple for the quantity to be verified. If there is a shortfall, they are to be punished and obliged to make restitution, and the same will apply if there are cases of boards being carried off by the current when the lock has been being opened, or of having rotted when piled up together, or of having been stolen.¹⁵⁹

This was only a small part of a complex operation that was habitually seen as imposing a severe burden on local inhabitants.

In a stele dated 1630 and commemorating the dredging of the Qiarnqing River by the Prefect of Shaohxing, Liur Guangdoou, the burdens of water control are likened to the attacks made on China by the northern barbarians:

The disasters caused by water in the Southeast are like the troubles occasioned by the bar-

157 *Huishur* on its own was used, presumably as a mortar, to "stick stones together". See Cherng Mirngjiuu, *Three Rivers' Lock, shahng, shahng j.*, 16a.

158 Cherng Mirngjiuu, *Three Rivers' Lock, shahng, shahng j.*, pp. 14ab. Compare the account in *id.*, 16ab.

159 Cherng Mirngjiuu, *Three Rivers' Lock, shahng, shahng j.*, pp. 20b–21a.

barians under the late-Southern Song dynasty, who were a poison to our people they entered, and trampled upon our cities. Yet the affliction of water is worse than they were... Though the Yaan Brook 剡溪 rushes down vigorously into the southern parts [of Shaohxing], and the Zhe River and the sea have fierce tides that shake its north, disasters such as the present blocking up have not been heard of before. Among these are the approximately three thousand *moou* or more of newly emerged sands [stretching out] from Houhguo 后郭,¹⁶⁰ which have caused the nature of the water to become unruly, rushing northwards and then following a path southwards. The fertile soil in the places harmed has been engulfed and cannot pay its taxes. The thread-like length of sea-wall, struck at both straight on and at an angle, has had no means to resist it. When [the flood-water] broke in during the spring, there was no wheat harvest; and when it broke through in autumn there was no rice harvest... Though the county magistrates spent their treasure to buy masonry, and led the people to rebuild the sea-walls, yet time and again the wild waves flooded in, and the stones did not always adhere firmly together. This was indeed bestowing a fortune on the boundless floods, or like repeatedly sending our wealth each year to the barbarians at the time of the Southern Song, without being able to satisfy their desires... [Although Prefect Liur has had the river dredged,] the situation resembles that of the barbarians after 1126 [when the Northern Song capital fell], and the exhaustion of our people is like that following the constriction following the migration south at that time. But for Prefect Liur, though, those of our people who live here would now be fish and turtles.¹⁶¹

There was a commitment here that could not easily be escaped, unless by good luck the pattern of local natural forces changed, and the cost of doing so would have been perceived to have been high. The past held the present captive.

160 This is an unidentified place-name, possibly related to the alternative name for Harnghzhou Bay, namely Houhhaai 后海, and with a sense perhaps of 'the defensive perimeter of the Houh Sea.'

161 Pirng Heng, *Three Rivers' Lock, Supplement*, j.1, pp. 15a-16a.