The Yellow River

THE PROBLEM OF WATER IN MODERN CHINA

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2 *Management and Mismanagement in the Imperial Period*

IN ADDITION to the biophysical forces already explored, the ecology of the North China Plain during the imperial period was deeply transformed by human action. During this long sweep of history, mutually supporting values and institutions evolved within which the manipulation of water was embedded. This system of values and institutional patterns encountered internal and external pressures, including demographic growth, commercialization of the economy, and imperialism, which collectively contributed to a breakdown of the imperial system and hydraulic structures by the late nineteenth century. During the twentieth century, new political, social, and cultural forces from the West were grafted upon Chinese values and practices to forge a new equilibrium between the human-built and natural worlds. This process would command the attention of a variety of Chinese state systems across the political spectrum during the twentieth century and would ultimately generate environmental outcomes both familiar and unprecedented.

Water and the Rise of Chinese Civilization: The Formation of State Authority

As the geographer Vaclav Smil stated, "Few rivers had such a profound effect on a major civilization as the Huang Ho [Huanghe, or Yellow River] had on China."[1] Whether real or imagined, the river has been central to the historical memory of Chinese down to the present. The writing of history, which perpetuated this cultural

mythos, is part of a historiographical tradition unparalleled in human history. The lion's share of artifacts from ancient China has been unearthed in the Yellow River valley, giving this region preeminence in the reconstruction of Chinese history. Oracle bone etchings, bronze inscriptions, and writing on bamboo, wood, and finally paper have all been discovered in the Yellow River valley. "Consequently, throughout Chinese history the Yellow River valley . . . and the Wei River valley of Shaanxi, were regarded by historians and common people alike as the cradle of Chinese civilization."[2] This was the literary context in which the myth of Yü the Great (Da Yü) was created and disseminated to subsequent generations. The myth's narrative focus was the regulation of the waters of the North China Plain, but the moral lessons served to connect the ordering of water and good governance for political elites up to and including the present.

Lying "at the root of every educated Chinese person's idea of the beginning of Chinese history," the story of Yü the Great is one among a set of "creation myths" that collectively laid the historical basis for Chinese civilization.[3] The greatest collator and transmitter of the lives and heroics of the "sage-kings" of antiquity was Sima Qian (ca. 145–86 BCE), who wrote the *Records of the Grand Historian (Shi ji)*, which incorporated oral traditions and earlier records by Mencius (372–289 BCE) to recreate the story of the Five Emperors, which began with the legend of the Yellow Emperor (Huang Di; presumed reign: 2696–2598 BCE). Each of the Five Emperors is credited by Sima Qian with foundational feats: institutions of rulership, the development of writing, the formulation of calendars, the separation of Heaven and Earth, and the moral foundations of ruling authority. The last of the legendary kings was Yü, and his great accomplishment was to direct the excavations of nine discrete waterways to channel the swampy waters of the North China Plain to the sea. Yü is also credited with recognizing that the beds carrying Yellow River water were already being raised by sedimentation. Accordingly, Yü adopted a method of constructing dikes along the riverbank to contain floodwaters. Constricting the flow of rivers by dikes, the normative approach to managing the rivers on the North China Plain throughout Chinese history, thus received historical sanction through the transmitted myth of Yü.

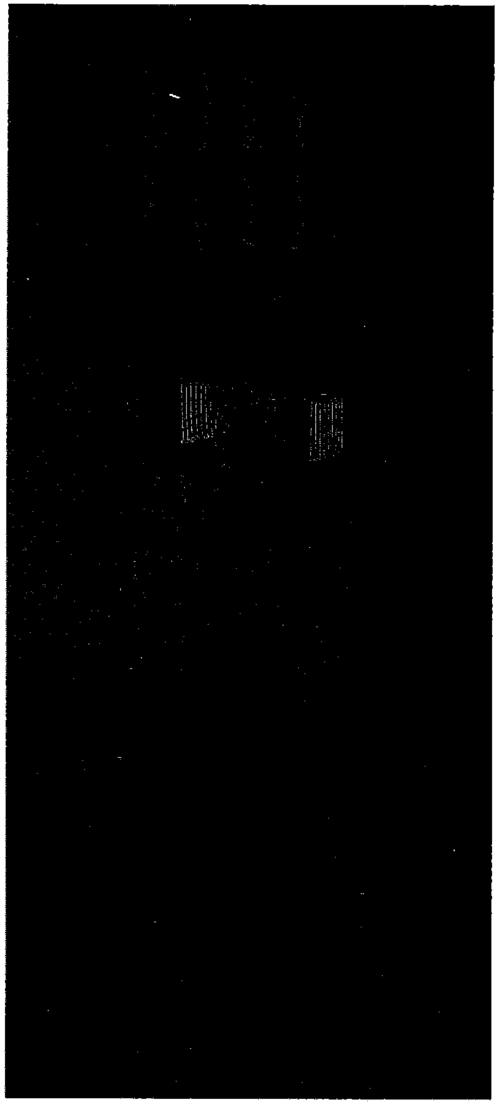
According to Chinese historiographical tradition, Yü's brilliance in controlling the floods and relieving his people established the ecological basis for agriculture. This accomplishment supplied the moral and material basis for Yü to establish China's first dynasty–the Xia (ca. 2070–1600 BCE).[4] At a number of levels, China's great flood myth and the epic narrative of reasserting social and ecological order are consistent with flood stories in a variety of cultures. Flood myths are often *re-creation* myths that are formulated *after* tales of human creation (the *original* creation myth). Such tales are sanctioned "for the existence of a particular body of practices that are central to the people who create the myth."[5] Two additional themes of these myths center on the flood as a form of punishment or repudiation of the immediate past and on water as the principal motif of the re-creation myths (i.e., as opposed to fire or other cataclysmic natural events). It is significant to note that, in these early myths, water is represented alternatively as a destructive or constructive force or as a symbol of chaos or order:

> Chinese flood myths exhibit all the features previously described in accounts of flood myths from other parts of the world. First, they were tales of the re-creation of the world that provided origin myths and thus justification for the major political institutions, particularly those associated with the role of the monarch or emperor and his servants. Second, they employed water as an image for the dissolution of all distinctions, and thus presented the taming of the flood as a process that recapitulated in the age of men, and, through human action, the creation of the world. Several versions of the myth also explicitly contrasted channeled water with the rampant waters of the flood that flowed properly and thus was beneficial. Third, those versions that touched on the origins of the flood attributed it to rebellion, and several versions identified the taming of the flood with the punishment of criminals.[6]

In the version that appears in the *Mencius*, the flood was a metaphor for the collapse of order during the Warring States period (475–221 BCE). In his telling, the flood represented the political and

social disorder that resulted from bad rule or criminality by rulers in the past (represented in the myths by Yü's predecessors, Gao and Gun). "The Chinese myths insist that the flood began through rebellion, or some other criminality, and was ended through the successful actions of the ruler and his servants. The manner in which the flood was conquered in the tales of Yü, the bringing of water back into channels where its course could be guided for the benefit of humankind, was directly adapted from one of the major roles of the government in the period."[7] In the subsequent historical narrative of Sima Qian, the ordering of the waters by Yü, or the "second creation" of the Chinese world, was a "fashioning of an ordered physical space" that represented correct rule and sanctioned a political and social system premised on an "ordered and hierarchically divided human realm with the central role played by the family as the social unit."[8] From his perspective in the Han dynasty, Sima Qian was seeking moral sanction for central authority based on the Qin dynasty's (221–207 BCE) reunification of China after the disorder of the Warring States period. The world "re-created after the flood is often marked by the imposition of some new regime or institutions, and the purpose of many flood myths is to explain or justify such institutions."[9] Thus, Sima Qian's refashioning of the flood myth was a reflection of the Chinese world that was emerging from the chaos of the Warring States period. This same myth would be adopted and refashioned in a subsequent creation authored by the CCP after 1949.

The sanctioning power of myths, adapted and retold to legitimize political authority, was expressed in a host of water management projects throughout Chinese history. This ethos of "directing the waters" penetrated all levels of society. In his synthetic study of the rise of "Oriental despotisms," the eminent sinologist Karl Wittfogel observed the sophistication of water management schemes in China and concluded that such accomplishments could have been managed only by a state that had the absolute power to organize material and human resources necessary to build and maintain these projects. However, subsequent research on local society during China's imperial period has proved Wittfogel wrong. Although the state sponsored large-scale hydraulic projects, village-based organizations initiated and organized myriad projects at the local level.



"Historical" Yü the Great. (Collection of the National Palace Museum, Taiwan)

But Wittfogel was not totally off base if we conclude that there were unmistakable cultural patterns that valorized the manipulation of water patterns that pervaded the spatial and temporal dimensions of imperial statecraft in China.[10]

Contemporary Yü the Great. Robin McNeal, photographer. From Robin McNeal, "Constructing Myth in Modern China," *Journal of Asian Studies*, Vol. 71, no. 3 (August 2012), pp. 679–704. Copyright © 2012 The Association for Asian Studies, Inc. Reprinted with the permission of Cambridge University Press.

The recurring commitment to engage in water management in China was engendered by military conflict, economic transformations, and demographic expansion. Large projects were pursued by early Chinese states as an adjunct to the creation and sustenance of centralized authority. Maintaining such authority depended on the systematic extraction of agricultural wealth from a stable agrarian base. Thus, the manipulation of existing waterways and the creation of artificial arteries were deemed necessary to expand agricultural production through irrigation and to enhance military mobility. Chinese states had an important stake in the planning and implementation of large-scale projects in early China. The "Chinese imperial state was a meddlesome one, carefully looking after its own interests and, in keeping with cultural traditions, actively seeking to develop resources and rearrange nature so as to maximize tangible and taxable wealth."[11] In early China, this orientation of the state was expressed in a variety of large projects that contributed to the cultural ethos of "ordering the waters." In this way, the myth of Yü the Great served to perpetuate this form of statecraft for centuries in China.

The adoption of levees for flood control was one of the first organized expressions of water management on the North China Plain. Ever-larger protective dikes were part of the strategic culture (along with the technological and organizational know-how) of managing large public works projects. This strategy was also manifest in the walled boundaries between early Chinese kingdoms and, beginning in the Qin dynasty, in the construction of the Great Wall. Levees could also be utilized for offensive purposes during times of conflict. During the Warring States period, rupturing dikes to inundate the territory of a neighboring enemy was a well-developed practice. This strategy of war would be repeated on multiple occasions in Chinese history, most recently in the late 1930s, when Chiang Kai-shek ordered the destruction of the Yellow River dike in Henan Province to defend against Japanese invasion from the north. Thus, on the eve of China's imperial period, well-developed water management practices were adopted by a variety of states.

Early imperial-era water projects focused on the construction of canals for transportation and irrigation. Sima Qian and other chroniclers emphasized the moral dimension of rule that made these projects possible and indeed vital to social and political stability. Among China's early canals, the most celebrated was the Zhengguo Canal constructed by the Qin in 246 BCE at the end of the Warring States period. The story of the canal is part of every primary school lesson chronicling the Qin's rise as China's first empire. As recounted by Sima Qian, during the Warring States period, the prince of Han devised a ruse to sap the financial strength of the rival Qin by dispatching a river engineer named Zheng Guo to the Qin court. Zheng's task was to persuade the king of Qin to create a large irrigation district by constructing a great canal linking the Jing and Luo Rivers. Before the canal was completed, the king of Qin discovered the trick but was nevertheless convinced by Zheng of the benefits of the project. Instead of decreasing the financial strength of the Qin, the irrigation project enriched its coffers. Tax receipts from increased agricultural production supported the creation of a Qin army to unite China. Although sediment eventually clogged the Qin canal, the telling and retelling of the tale by historical chroniclers provided potent reminders of the historical imperatives of "ordering of the waters" to agricultural wealth and centralized rule.[12]

Although constructed well south of the North China Plain in today's Sichuan Province, a second remarkable irrigation system has informed the historical memory of every generation of China's educated elites for centuries. The Dujiangyan irrigation system was also built by the Qin during the Warring States period (in 265 BCE) under the leadership of Li Bing. Continuously in operation for two millennia, the vast system today hydrates 1.7 million acres of the Chengdu Plain. The project, completed by Li Bing's son, Li Erlang, largely retains its original form and function today. "Dig the channels deep and keep the spillways low" (*shen tao tan, qian zuo yan*) was the operative management approach attributed to Li Bing, an approach that contrasted with the tradition in the north that emphasized the construction of protective dikes.[13] Providing water control functions for over 2,000 years, the project has become a symbol of Chinese water management ingenuity. Li Bing and his son hold an eminent place in the pantheon of "water heroes" (*shui gong*) in China. As observed by Needham: "The Chinese were never content to regard notable works of great benefit to the people from a purely utilitarian point of view. With their characteristic ability to raise the highest secular to the level of the numinous they built . . . a magnificent temple . . . to commemorate Li Bing's heroic victory; and further back, in a scarcely less beautiful site . . . another one to that of his son Li Erh-Lang [Li Erlang]."[14] Serving as a link to the historical power of controlling the water, a temple dedicated to Yü the Great stands nearby.

The Zhengguo Canal and the Dujiangyang irrigation system are celebrated as exemplars of the capacity of centralized states to organize the human and material resources to manage large water projects. The Zhengguo Canal was but one of a set of early Chinese irrigation and transport canals that served to integrate regional polities and economies. Many years later, the famed Grand Canal (Da Yunhe), completed during the Yüan dynasty (1271–1368), was explicitly intended to integrate the political center in North China with the economic core of the lower Yangtze River valley. The official histories of subsequent dynasties consistently esteemed the brilliance of the water heroes in conceiving and directing projects that strengthened agricultural society and, by extension, the state. Imperial states viewed the management of water as a means of promoting agricultural production, thereby increasing the ability of the state to appropriate agricultural surplus to expand and sustain the empire and the state. The expansion of agriculture was due to many factors, including the development of agricultural markets and of an ethical ruling system that valorized agricultural pursuits. This interlocking rationale, based on material and moral factors, provided the underpinnings of state projects to manipulate water.

Nature in Chinese Traditions

For the past several decades, a repeated refrain has emphasized traditional Chinese respect for nature, typically contrasted with the wanton disregard of the natural world exhibited by industrialized Western countries. The impulse for such comparisons, however, emanated from Western countries, not China, as connections were made between traditional Judeo-Christian attitudes toward the natural world and a continued human disregard for the natural environment that generated unsustainable environmental practices. An early articulation of this perspective was offered by the historian Lynn White Jr. in 1969. White argued that Judeo-Christian beliefs engendered a utilitarian attitude toward nature that promoted a thoroughgoing exploitation of the natural world. The destructive practices that such traditions promoted ultimately generated a scholarly and popular reaction in the West by the mid-twentieth century. One component of this reconsideration of Western ecological practices was the impulse by some to contrast traditions in

China that presumably reflected a moral and ethical system that venerated the natural world.[15] Yet fouled air, murky waters, and other ubiquitous images of environmental degradation in contemporary China seemingly run counter to these claims. Often these realties have been ascribed to an abandonment of traditional cultural attitudes as Chinese modernizers succumbed to the allure of post-Enlightenment notions of progress and twentieth-century modernist ideals of development.

The fact is that by the twentieth century the landscape in China had already been altered in a massive way. The "Chinese have . . . altered their environment, over three millennia, of close and intensive occupance, probably on a greater scale than has been the case in any other part of the world until the present century."[16] Deforestation, reengineering of watersheds, and manipulation of soils were all responses to China's demographic growth, empire building, and commercialization of the economy during the imperial era. The "Chinese agricultural landscape, and eventually almost every hectare of inner China, was thoroughly anthropogenic. People chose (sometimes unwittingly) which animals and plants lived. People governed (as best they could) the paths of waterways. Even the soil was a human construct."[17] In the realm of water, a "voluminous body of writing on the management of water systems indicates that the Chinese largely shared the Western attitude that nature should be managed for the benefit of humans."[18]

There are, however, strong ethical traditions in Chinese thought that have promoted the notion of harmony among Heaven, the natural world, and humans. But it is important to come to a nuanced view of what the "natural world" means in this context. This concept of nature did not stress a "wilderness ideal" that sought the maintenance of a pristine world devoid of human artifice. Even if we go back to the classic texts of Daoism, which seemingly prescribed human noninterference with nature, "there is no good reason to presuppose any necessary prehistoric balance with nature. The restraint preached by the environmental archaic wisdom found in certain Chinese classical texts is both familiar and in all likelihood commonly misunderstood; it was probably not a symptom of any ancient harmony, but, rather, of a rational reaction to an incipient but already visible ecological crisis."[19] Perhaps the ethos of human restraint did not reflect an impending "crisis" but, rather, an aspirational harmony with forces of nature that were in a delicate, if not precarious, balance in a landscape that had been thoroughly engineered to support human communities. In other words, the natural order envisaged here was one not untouched by humans but, rather, an order that included (perhaps even centered on) the stability of the landscape and the ability of the land to produce agricultural sustenance in the face of natural forces of climate and the marginal fertility of the soil. So, "it is not surprising that the society as a whole valued it [the land], or that the official belief in the rightness of the particular harmonious system of co-operation which had been worked out was confirmed. It was a demanding environment, especially in its water balance, from a farmer's point of view . . . it returned munificent rewards for the kind of sensitive attention which the Chinese lavished on it."[20]

Despite its rhetorical flourishes, the following account of a Westerner traveling on the North China Plain in the early twentieth century clearly illustrates the relationship between man and nature in China:

> The most significant element of the Chinese landscape is thus not the soil or vegetation or the climate, but the people. Everywhere there are human beings. In this old land one can scarcely find a spot unmodified by man and his activities. While life has been profoundly influenced by the environment, it is equally true that man has reshaped and modified nature and given it a human stamp. The Chinese landscape is a biophysical unity, knit together as intimately as a tree and the soil from which it grows. So deeply is man rooted in the earth that there is but one all-inclusive unity—not man and nature as separate phenomena but a single organic whole. The cheerful peasants at work in the fields are as much a part of nature as the very hills themselves. The Chinese landscape . . . is the product of long ages. Literally trillions of men and women have made their contribution to the contour of hill and valley and to the pattern of the fields. The very dust is alive with their heritage.[21]

Over the centuries, the received landscape, as originally manipulated by Yü the Great and further shaped by subsequent human action, was a challenge to maintain on the North China Plain. It is not surprising that an ethical canon developed that reflected these challenges. China's importation of development models from Japan and the West, beginning in the nineteenth century, introduced technologies and institutional arrangements that had profound environmental consequences. But twentieth-century high-modernist perspectives on nature, the state, national identity, and economic growth were not simply grafted onto an alien Chinese cultural and ecological landscape. Irrespective of their various ideological orientations, Chinese states of the twentieth century drew upon a long tradition of ecological intervention that could accommodate environmentally transformative structures like hydroelectric dams.

Patterns of Environmental Change in Imperial China

Throughout the imperial period, sustaining the agricultural basis of the state and society required managing water resources. Periodic structural changes in the economy, climate change, demographic growth, and external pressures from non-Chinese groups have led to acute ecological challenges for the inhabitants of the North China Plain, including a breakdown in the hydraulic system toward the end of the imperial period. But for much of this period, the state employed variations of hydraulic management techniques established in the pre-imperial and early imperial periods. Traditions continued of managing water to support an expanding empire and a strong state structure, as well as the moral imperative to "order the waters" to buttress state authority. Much of the institutional and cultural innovation that occurred in China's history has been grounded in these traditions.

The growth of agriculture to sustain an expanding empire and a complex administrative bureaucracy depended on converting forest to tillable land and on exploiting water resources. Timber was also used in cooking, heating, smelters, and kilns and for constructing houses, boats, bridges, and pilings. Over the span of the imperial period, the vast majority of China's forests were felled. The removal of this forest cover resulted in the loss of topsoil through erosion, which was particularly severe in the hilly and mountainous regions after the demographic pressures of East and Central China increased migration to hill regions. The carrying capacity of these highland regions, however ephemeral, was considerably augmented by the introduction of New World food crops beginning in the sixteenth century. Upland migrants cleared land for the cultivation of maize or sweet potatoes following the introduction of these crops. As a result, the soil was exhausted after several agricultural seasons. Farmland was abandoned, and soils washed away. Deforestation in the loess highlands of the Yellow River valley had particular consequences for the Yellow River valley and the North China Plain. One estimate suggests that over the course of four thousand years, forest cover on the Loess Plateau declined from 53 percent to 8 percent.[22] The destabilized loess soils easily washed away, creating gullies of varying size that ultimately led to the Yellow River. Sediment was carried downstream and deposited on the riverbed as the speed of flow decreased in downstream regions, precipitating the never-ending battle to maintain hydraulic stability on the North China Plain.

From the later imperial period to the present, large levees have been constructed along the banks of major waterways like the Yellow River to contain spring and summer torrents. There has been a similar commitment to maintaining the artificially constrained waterways of smaller streams and channels, some of which had been developed for irrigation. Persistent sediment deposits in all these waterways required the periodic raising of levees. But the capacity of human engineering to maintain the Yellow River within these levees was limited. The river periodically ruptured its levees, and its water poured out over the raised bed to forge a new course to the sea. This pattern would be repeated as levees were constructed or augmented to ever-increasing heights. This "hydrological instability required the constant maintenance of large-scale engineering structures to achieve ecological stability."[23] This type of technological and managerial lock-in has continued to define water management on the North China Plain to the present day.

In addition to a constant emphasis on water management practices, another critically important aspect of China's imperial statecraft practices, and one that affected China's environmental history, was China's "medieval economic revolution," which occurred between the ninth and twelfth centuries, roughly coinciding with the Song dynasty (960–1279). Two major developments of this period with important consequences for China's natural environment were demographic growth and commercialization, two trends that would again accelerate in the late imperial period (ca. 1500–1911). From the beginning of the Common Era to the eighth century, China's population remained at around 50 million. The expansion of rice cultivation in Central and South China contributed to a doubling of the population by 1100. Agricultural prosperity and higher population density, in turn, encouraged greater commercialization. The extension of rice cultivation to the lower Yangtze River valley and to areas farther south meant the additional clearing of forest resources and the need to develop water resources for irrigation. At the same time, growing commercialization presented farmers with opportunities for regional specialization, as the extension of a market system allowed for a "national" exchange of goods. One example of the environmental impact of the development of China's markets was the demand for additional timber resources in Central and South China. The development of an efficient market for timber significantly depleted forests in the middle and upper river valleys.

Political transitions were also reflections of ecological change in imperial China. To be sure, military activity and its accompanying social and economic disruption had an environmental impact. Perhaps more importantly, dynastic transitions were often markers of a changed dynamic in China's frontier regions that separated the agricultural practices of mainly sedentary Chinese farmers from the pastoral practices of herding societies. The waxing and waning of the relative influence of these agricultural and social systems had significant ecological impacts. The extension of imperial power typically brought traditional patterns of deforestation followed by intensive cultivation. During periods of waning imperial influence, these regions would revert to more diversified groundcover as pastoral practices expanded. Throughout the imperial period, the degree and extent of anthropogenic ecological change reflected a "start-stop character," and there were periods in which human-created ecological change was reversed and natural forces prevailed. A variety of factors conditioned the pace and extent of ecological change in imperial China: the demographic and economic dynamics of dynastic transitions, the waxing and waning of frontier areas between pastoral and sedentary societies, and climate change. All these factors were mutually conditioning.

Although the character of the Chinese state was not uniquely defined by the imperatives of effective water management, as was elegantly argued by historians several generations ago, the state was nevertheless clearly involved in managing the ecological affairs of the empire in a variety of ways. In the case of water management, research has revealed a variety of arrangements whereby local, regional, and central administrative units independently or jointly managed projects. But the central state clearly had a critical function in large projects, particularly on the North China Plain, where the mandates of managing the Yellow River transcended the boundaries of bureaucratic and administrative constituencies. Ken Pomeranz sees a Chinese state interest in regulating ecological outcomes as an expression of maintaining the agricultural basis for state and society.[24]

Throughout the imperial period, the hydraulic system that sustained the human communities and their agricultural pursuits rested on an unstable ecological construct that could be undone by neglect. Thus, this was a "highly labile" environment, which required constant maintenance through regular investment of labor and materials (like timber and stone), and, above all, of the financial resources of the state and local communities. The state locked itself into maintaining large dike systems on the Yellow River, which, if neglected, could be destroyed in a summer torrent, as sedimentation steadily raised the riverbed. Such disasters did happen on a number of occasions during the imperial period, when the state lapsed in its commitment to control the waters on the North China Plain. An indication of the challenges faced in maintaining the great water systems of the imperial period is suggested by the history of the Zhengguo Canal. The source for the canal, the Jing River, rapidly

bore down into the loess sediment below the irrigation intakes of the canal. Despite repeated lowering of the intakes, the system eventually collapsed by the late imperial period.[25]

Water Management in the Imperial Period

As early as the onset of the Common Era, the state began to develop an abiding interest in maintaining the hydraulic stability of the Yellow River. This interest centered on encouraging irrigation development in the middle valley while committing to large-scale flood control efforts in the lower valley. Many large projects were administered with a mixture of central and local institutions and executed with labor-intensive methods. Even in smaller projects carried out under the leadership of local elites, the imperial state still provided moral encouragement and occasional technical assistance to help manage local waterways in order to advance rural prosperity and stability.[26] As the historian John McNeill argues:

> In comparative perspective the Chinese state . . . appears remarkable for its ecological role. The Chinese imperial state was a meddlesome one, carefully looking after its own interests and, in keeping with cultural traditions, actively seeking to develop resources and rearrange nature so as to maximize tangible and taxable wealth. Here, more than elsewhere, the state served (often unsuccessfully) as the guarantor of ecological stability. The state took primary responsibility for building and maintaining many big waterworks for flood control. . . . Its bureaucrats were taught to see a link between natural events and imperial politics, and to propitiate, placate, manage, and manipulate nature in the state's interest.[27]

During most of the imperial period, a focus of state activity on the North China Plain was control of the Yellow River. Although state management practices strongly supported the efforts of local organizations to develop irrigation systems, the principal objective of the state was to control flooding in the lower Yellow River valley. Routine dike maintenance was a requisite to maintain the integrity of the system, but during flood crises, renewed debate about control strategy inevitably emerged. The parameters of these debates, however, were largely bounded by assumptions about the importance of fixing the river channel through a system of dikes. This broad approach would be modified, but not fundamentally altered, by the introduction of modern hydraulic engineering and technologies in the twentieth century. Throughout the imperial period and down to the present, a succession of water managers became cultural heroes for rectifying the integrity of the flood control system in the lower Yellow River valley. In similar terms, late imperial-era water experts who recreated hydraulic stability, and hence could ensure social and economic order on the North China Plain, could consciously lay claim to a position among the pantheon of water heroes as they sought solutions to hydraulic breakdown on the North China Plain.

Here, it is worth returning to the legend of Yü the Great as recounted in the *Mencius* and the classical histories. Two great water heroes were appointed to relieve the massive floods that occurred at the time of the legendary emperor Yao. The first, Kun, spent nine years constructing dikes to contain the waters. Unfortunately for Kun, and perhaps as a signal of the importance of his task, Kun was exiled, killed, and cut to pieces by Yao after the former's efforts to tame the waters proved unsuccessful. Subsequently, Kun's son, Yü the Great was appointed to regulate the waters. After passing the door of his own house for years without entering (a sign of his unstinting efforts), Yü succeeded in dredging waterways for nine rivers and in permanently channeling the waters that had inundated the North China Plain to run into the sea. The recounting of these legends suggests that significant debates existed on how best to manage the Yellow River well before the imperial period began. The debates centered on the desirability of constructing a single diked channel versus multiple channels. The disagreement was an expression of a larger moral argument about the degree to which nature should be manipulated by humans. The "Confucian school" emphasized the need to control natural forces by constructing high dikes to constrict the flow. The other school (which we might call the "Daoist school") supported using the forces of nature to control

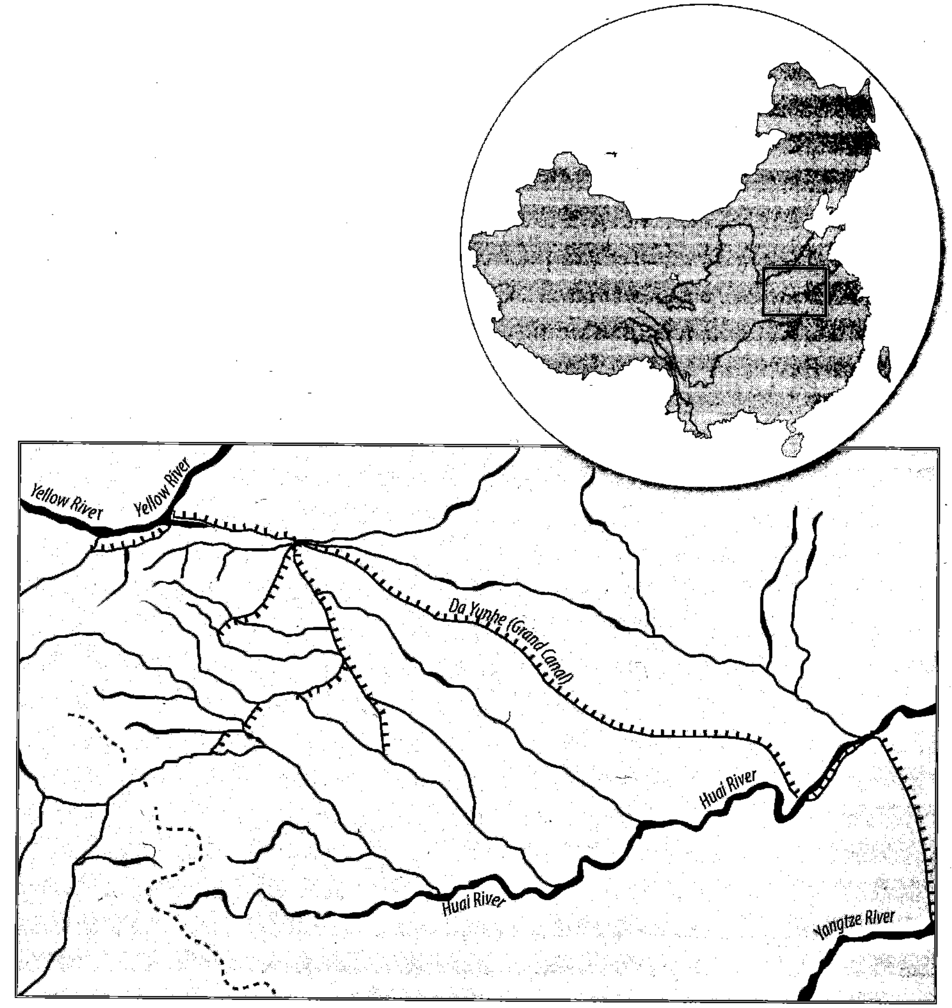
water flow, by constructing low dikes farther apart to allow the river greater freedom to deposit its silt and to find its own course. Needham expands on this idea by noting that Confucians reflected "the forceful repression of Nature by the erection of convex 'masculine' ridges along the rivers was a case of what the Taoists [Daoists] called *wei* as opposed to *wu wei* (no action contrary to nature). The deepening of river beds by excavation of 'feminine' concavities was, on the contrary, a going along with nature [supported by Daoists]."[28]

The retelling of the legends of Yü and Kun during the imperial era suggests that both dredging and diking became orthodox river management doctrine. Although subsequent projects would adopt neither principle to the exclusion of the other, the subtleties in emphasis revealed a set of debates about how best to control the river. Charles Greer, an American geographer, argues that both schools of water management were based on the pre-Confucian and pre-Daoist precepts of controlling the river according to natural forces and of utilizing the river to control the river and that both of these approaches were reflected in the heroic efforts of Yü the Great.[29] Subsequent claims of the benefits of different technical approaches were really different claims for how best to achieve these ancient principles. The lynchpin for flood control, irrigation, and transport was the system of levees along the great Yellow, Huai, and Hai Rivers. Maintaining the integrity of the levees was a constant battle against sedimentation. During the two thousand years of China's imperial period, the Yellow River dikes experienced five major ruptures and subsequent course changes. Each occasion provided the opportunity for China's leaders to legitimize their political authority by reorganizing and renewing river management efforts.

During the Han dynasty (206 BCE–220), the state established many institutional practices to address the periodic ruptures of Yellow River dikes and to establish dike-maintenance regimes. The scale of such water management projects during the Han was greater than in any previous era. In the lower course of Yellow River, river management was of paramount concern, while irrigation development continued apace in the middle reaches. The strong Han central government also established the precedent of state direction for large projects as well as the recruitment of corvée labor to build such projects. In 11 CE, a series of ruptures of the restraining dikes along the lower Yellow River effected a dramatic course change that inundated large tracts of land on the North China Plain. Memorials to the Han imperial court advocated a variety of strategies to reassert control of the river, from restoring the beds of the nine rivers of the time of Yü the Great to creating an entirely new river bed, and from carving multiple drainage channels to allowing the river to meander freely across the alluvial plain.[30] Amid this hydraulic breakdown, the first two imperial-era river engineers to establish themselves as water heroes were Jia Zhang and Wang Jing. Attempting to alleviate the widespread flooding that followed the rupture of the Yellow River dikes, Jia advocated a three-pronged approach in 69. Jia concluded that restoring the Yellow River to its former bed was impossible because of the height of the current channel. He recommended: (1) reducing the flow of the river by drawing off water for irrigation in the middle section; (2) diverting sediment-free water from tributaries into the lower Yellow River valley; and (3) strengthening Yellow River dikes.[31] Jia's approach is generally identified with the Daoist tradition, for he sought both to dissipate the power of the river flow and to construct dikes some distance apart to allow the river to meander. His approach proved ineffective, but Jia's engineering principles were carefully studied by subsequent water managers.

Unlike the case of Jia, there is little historical material available to evaluate the precise methods of Wang Jing, the second and most famous of the first-century Han dynasty water heroes. Wang is reputed to have paid particular attention to strengthening dikes, dredging major tributaries, and building sluice gates to regulate flow in the main river channel. His general approach would likely have included maintaining strong dikes and restricting the Yellow River to a single channel. The greatest testament to the success of his engineering methods (whatever they were) is that the river did not experience a major course change for the next thousand years.[32]

From the beginning of the imperial period through the Song dynasty, the drainage systems of the Yellow River and the Huai River were integrated by a series of canals that linked the two regions. Further canal construction extended this exchange to the increasingly prosperous Yangtze River region. The integration of the major

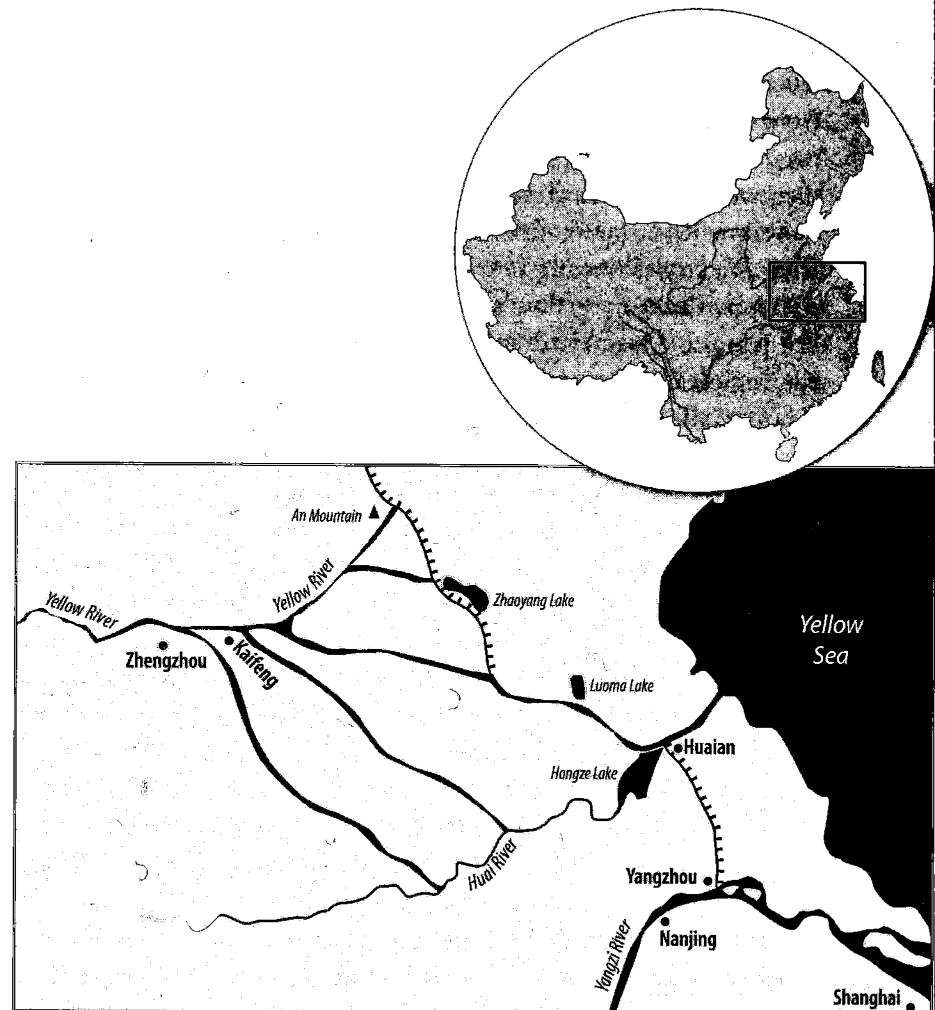


Canals linking Yellow and Huai River systems by 1000

drainage basins of the North China Plain generated long-term hydrologic transformations as silt from the Yellow River system clogged the canals and irrigation systems in the Huai valley. The full integration of the two river systems had reached its apogee when the whole system crumbled in the massive dike break of 1194. The rupture was the culmination of a series of breakages that were precipitated in part by direct human action.

During the politically fragmented and contentious Five Dynasties (907–960) and the later Song dynasty, control of waterways was a key strategic concern. During this period, water was viewed as one component of warfare—as it had been in the past and would be again in the future. For example, to resist the Jin army, which was advancing from the north, Song forces breached the Yellow River dikes. Later, the Jin army turned the tables by puncturing dikes near Kaifeng and sending Yellow River water southward to inundate Song forces. Deliberate destruction of the dikes meant that the waters inadvertently followed the Daoist ideal of a river "seeking its own course." The Yellow River drained through multiple channels, most leading to the Huai River. The continuing social and political commitment for the Chinese state to create and maintain stable hydraulic conditions on the North China Plain impelled the state to rectify this "ecological disorder." Attempts were made to regulate the drainage of the Yellow River, but between the twelfth and sixteenth centuries Yellow River waters followed a variety of courses both north and south of the Shandong highlands (on the Shandong Peninsula), although the majority of its waterflow during this period joined with the Huai River in what is now northern Jiangsu Province.[33]

To help defend the imperial system from nomadic and seminomadic peoples of the north, the imperial capital of the Yüan dynasty was located to the north in Beijing. It was during the Yüan that existing canals, between the Yangtze and Huai River valleys and between the Huai and Yellow River valleys, were augmented to form the Grand Canal. The Grand Canal sustained the capital and northern military garrisons with provisions from the Yangtze River valley. Thus, by the fourteenth century engineering projects had created a hydraulic system that fundamentally changed the drainage networks of the North China Plain. A new system of dikes on the Yellow River regulated all flow into the lower bed of the Huai River. At the same time, the monumental Grand Canal, running from south to north, bisected the drainage system of the entire region. The long-term struggle to maintain this new waterscape centered on silt. In short, the challenge was to engineer drainage of the Yellow and Huai Rivers in ways that did not threaten the integrity of the Grand Canal.



Yellow River drainage into the Huai River, ca. 1400

The increasingly complex task of managing the Yellow River–Huai River–Grand Canal matrix spawned the creation of centralized bureaucratic organizations. The water management strategies adopted during the Ming and Qing dynasties (1644–1911) were predicated on one goal: maintaining the transport of tribute grain to Beijing via the Grand Canal. This was precisely the responsibility that awaited Pan Jixun (1521–1595), later renowned as the greatest water hero in Chinese history, after he was appointed the Ming imperial commissioner of the Yellow River in 1565. The situation confronting Pan was formidable. Since the breakout of the Yellow River from its dikes in the late twelfth century, gradual progress had been made in building defensive bulwarks on the north bank of the former main stem of the Yellow River. This sent an increasing amount of Yellow River flow to the Huai River channel. By 1494 all Yellow River water was flowing into the Huai River through a dozen or so routes, with the main flow entering the Huai near Huaiyin in northern Jiangsu. Thus, Huaiyin was where the three main waterways of the region converged: the Yellow River, the Huai River, and the Grand Canal. Inexorably, silt did its thing. Silt gradually accumulated on the joint bed of the Yellow and Huai Rivers, ultimately preventing the Huai River from continuing in its original bed to the sea. As a result, Huai River water began to settle in depression areas west of Huaiyin, gradually forming a large retention basin that became known as Hongze Lake. Silt caused other problems. For example, at times of heavy Yellow River discharge, water would backflow into Hongze Lake, flooding massive tracts of agricultural land as well as the Ming Tombs west of the lake. Sediment deposits from the Yellow River heightened the bed of Hongze Lake during periods of Yellow River backflow, and eventually the Huai River could drain neither into Hongze Lake nor through its original bed. In addition to critical problems with Huai River drainage, the increased silting of the Grand Canal near Huaiyin raised the bed of the canal and resulted in frequent transportation blockages.[34]

Pan was ordered to solve this hydraulic mess. From the Ming government's point of view, there was no choice. For centuries, China's imperial states had staked the integrity of their empires, and their capacity to rule, on their ability to extract wealth from the lower Yangtze region. Pan understood what was at stake. The complexity of the task and the political pressure to maintain the hydraulic infrastructure resulted in Pan's being appointed to (and dismissed from) office on four different occasions between 1565 and 1592. Pan carefully studied past river control practices and concluded that the current approach (largely followed since the massive dike ruptures of 1194) was flawed. The method of "divert the Yel-

low, restore the Huai" *(fen Huang dao Huai)* focused on dredging multiple channels to channel Yellow River water into the Huai bed. The "divide the channel" strategy for the Yellow River was intended to alleviate dike breaks upstream from Huaiyin that could deprive the Grand Canal of the water necessary for a functioning transport system. Dissipating the power of the river (so that the river could not break its dikes) was one of the traditional approaches to river management. Pan opposed the "divide the channel" method, arguing that dividing and consequently slowing the flow only lessened the capacity of the waters to transport sediment. If engineers followed this scenario, the multiple channels carrying Yellow River waters would need constant dredging.[35] Based on his observations of the river's flow and its carrying capacity, Pan proposed building close-set dikes along the lower course of the Yellow River to restrict the spread of floodwater and to force the water to flow at an accelerated pace (which would flush silt out to sea).

The second important component to Pan's water management strategy centered on storing the clear waters of the Huai River in a catchment basin near the Huai's confluence with the Yellow River in northern Jiangsu. This basin, Hongze Lake, would release water into the Yellow/Huai channel to augment the silt-carrying capacity of the current, a strategy referred to as "storing the clear to scour the Yellow River" *(xu Qing shua Huang)*. Pan's empirical observations about river current and silt led him to devise a system that was more comprehensive than earlier approaches. He drew on engineering principles that included the use of reservoirs, which informed a set of hydraulic practices that in many ways represented the greatest expression of river control up to his time, constrained as it was by social and economic organization and premodern technology. Pan's approach was ultimately accepted as orthodoxy. His dual approach (of restricting the flow and storing water) would also be followed in the Qing dynasty and became a fundamental tenet of water management during the twentieth century. This enduring legacy made him, after Yü the Great, the greatest of China's water heroes.[36]

It took Pan all four terms in office to realize his strategy, in part because of the fractured nature of the water management bureaucracy in Ming China and in part because of the persistent power of alternative visions for Yellow River management. During the Ming, the imperial commissioner of the Yellow River, the imperial commissioner of the Grand Canal, the minister of public works, and the provincial officials responsible for supplying labor all had a bureaucratic investment in managing the waters of the North China Plain. Although the goal of Ming policy was to protect grain transport, there was no single path to this goal. Different institutions advocated different solutions. Although Pan gained more administrative authority when he was concurrently appointed vice-minister of public works, provincial and central officials continued to promote different schemes. For example, the governor of Zhili Province sought to dig a different channel for the Yellow River, but the commissioner of the Grand Canal wanted to dig separate channels for the Huai and Yellow Rivers. Pan was dismissed from his second tenure as imperial commissioner after the minister of public works blamed him for inadequate grain shipments via the Grand Canal. In short, Pan was in and out of office, depending on which bureaucratic constituency could claim sufficient bureaucratic clout to pursue competing plans. This "fragmented bureaucracy" was an early harbinger of patterns repeated during the Mao and post-Mao eras.[37]

The Qing achieved an unprecedented degree of central control over Yellow River management as it established the Yellow River Administration (YRA) headed by a director general and staffed by thirty centrally appointed officials. The YRA was charged with overseeing the hydraulic integrity of the lower Yellow River. The efficient transportation of grain tribute via the Grand Canal continued to be of prime importance to Qing rulers. Indeed, the YRA was effectively an administrative adjunct of the Grain Transport Administration. Near the beginning of the Qing, the Kangxi emperor (reign: 1661–1722) appointed Jin Fu (1633–1692) as director general of the YRA. Jin extended the strategies of Pan Jixun as he raised and constricted the apertures of the Yellow River dikes to increase the sediment-flushing velocity of the river's flow. Jin's approach was based primarily on the idea of "storing the clean waters of the Huai to combat the silt of the Yellow River." Like the efforts of his distinguished predecessor, Pan Jixun, Jin Fu's success in creating a new ecological balance on the North China Plain was short-lived. The effective management of silt remained an elusive dream.[38]

By the advent of China's late imperial period (ca. 1500), successive imperial governments had committed themselves to economic, social, and political institutions on the North China Plain that required "controlling the waters" through perpetual investment in maintenance. The mandate to protect the lifeline of the imperial system, the Grand Canal, "committed the Chinese state to a conflict with the [Yellow] River that it could not afford to lose, and could only momentarily win."[39] There were two basic alternatives regarding technological and managerial approaches available to the Chinese state: "dividing the flow of the Yellow River" and "utilizing a single flow to scour [the riverbed]." In the Ming dynasty, Pan Jixun proposed the construction of retention basins in upstream segments of the Yellow River in order to regulate flows. This would have been a significant innovation in river management, but for reasons that are not entirely clear, this plan did not materialize. The sort of administrative control that would have been necessary for such a project (both horizontal and vertical control) would not appear in China until after 1949, but the technological approach articulated by Pan Jixun was largely consistent with the tenets of Yü the Great as incorporated into the canon of imperial statecraft. The necessity for Chinese authorities to "order the waters" continued to be a straitjacket on the state down to the present day.

Beyond formulating general goals, adjudicating disputes, articulating an idealized local society, and providing the moral encouragement to manage water in service to that ideal, imperial governments were not directly involved in managing small-scale projects. Yet much of the anthropogenic landscape of the North China Plain was (and is) the aggregate of the outcomes of innumerable water projects, large and small. The ecological foundation of the economic and social commitments of the imperial system required the state to engage in a perpetual struggle with the hydraulic forces and climate of the North China Plain. The constant effort to engineer and reengineer the landscape was a symbiosis of the small and the large, of the central and the local. The massive water management projects that made heroes of Li Bing, Wang Jing, and Pan Jixun were "made possible by Chinese administrative virtuosity in planning, organizing, conscripting, taxing, and coercing. These reshaped the Chinese physical environment, and committed a large part of the Chinese economy to a paradoxical relationship with water that was startlingly productive yet relentlessly costly to maintain, protective yet intermittently terrifyingly hazardous, and above all, one from which it could not, and has not yet to date been able to, extricate itself."[40] By the late imperial period, it seemed that practitioners of water management had won the old debate over the best means of "controlling the waters." The authors of this late imperial water management orthodoxy, such as Pan Jixun and Jin Fu, appear to have taken an approach rather similar to that of modern engineers. These Ming and Qing dynasty water officials "believed that by using dikes and sluice gates, by dredging, and by digging diversion channels, planners could determine the flow of even the largest rivers of the empire. Although they did not use concrete, they devised plans that required massive amounts of timber, bamboo, earth, and human labor in order to reshape nature radically. The builders of the Three Gorges Dam and other giant dams of today have followed their example."[41]

Environmental Breakdown in Late Imperial China (1500–1911)

The challenges of maintaining the engineered landscape of the North China Plain were enormous. Throughout the imperial era, central states and local communities employed an array of strategies that, for significant spans of time, created a stasis between anthropogenic and natural forces. For example, local agricultural knowledge grew and local practices adapted to the vagaries of soil, hydrology, and climate. Villages also adopted organizational techniques based on collective responsibility that diffused the risks and burdens of managing scarce resources. To be sure, there was conflict inherent in this regime, as the interests of adjacent polities may have differed. Resource rights and allocations could be bitterly disputed. As a partner in promoting the health and stability of rural

society, the state sought to mediate these disputes through its bureaucratic representatives. But beyond this judicial function, local societies were supported in the broader project of "ordering the waters" by an imperial state that attempted to impose ecological order on natural forces that were beyond the capacity of local institutions to control. Managing the rivers was one such endeavor. Other elements of imperial statecraft served to buttress the mutually supporting system of state and local society. Promotion of alternative agricultural practices (what in modern parlance we might call "agricultural extension"), technical partnerships between representatives of the bureaucracy and local elites and a granary reserve system to smooth out price fluctuations during periods of famine were all attempts by the central government to assist local communities in adapting to environmental stress. The continued existential task was to adapt to and further manipulate this high-risk environment. It was a challenging cycle. Despite the success that local and central institutions achieved during the imperial period, periodic floods, famines, and droughts signaled ecological breakdown. Such crises required additional adjustments to reimpose hydraulic stability.

One of these periodic breakdowns in the ecological balance of the North China Plain took place in the nineteenth century and lasted throughout much of the twentieth century. Some of the forces impelling this breakdown were familiar to political elites who had absorbed traditional notions of cyclical political change in China. For example, a sclerotic imperial government, increased corruption, and deleterious climate change (probably understood by observers at the time as ominous natural events, such as floods and drought) were all well-worn markers of social and political instability. At the same time, the same observers of the late imperial period witnessed historical forces that could well have been considered novel (or seen as traditional forces that had reached a new intensity). These forces included unprecedented commercial development, unprecedented demographic growth, and unprecedented global forces, including trade and technology transfer. The combination of internal and external dynamics, Chinese traditions, and foreign novelty profoundly shaped virtually every element of China's late-imperial experience. Collectively, these forces generated a rupture of the ecological balance on the North China Plain. An important part of the mission of every Chinese state in the post-imperial period has been to address this breakdown. Would the reimposition of hydraulic stability be guided by traditions in water management? Or would the seeds of China's stability be found in one of the forces that impelled breakdown, namely, China's integration into an international system dominated by the West?

Forces of Ecological Change in Late Imperial China

During the late imperial period, a convergence of demographic, climatic, economic, and political factors led to unprecedented ecological transformations in China. By the beginning of the Qing dynasty in 1644, "China entered a new phase of definite and irreversible change," and over the next "two centuries the Chinese natural and economic environment had changed . . . beyond recognition."[42] During this period, China's population tripled. At the same time, food crops from the New World entered China, while foreign demand for tea and silk skyrocketed. Pressures to increase food production and commodity production combined to increase exploitation of China's forest, land, and water resources. To sustain an expanding empire and burgeoning population and to reproduce the material basis of social stability, China was walking an ecological tightrope. Consequences of these trends included denuded hills, flooded river valleys, and desertified border regions. Compared to other periods of profound change (e.g., China's so-called medieval economic revolution during approximately the eleventh to twelfth centuries), the pace and degree of ecological transformations in the late imperial period were unprecedented and surpassed only in the post-1949 era.

A critically important cause of these transformations was demographic growth. The population of China increased from roughly 100 million in 1500 to between 320 million and 350 million by 1800. There had been periods of population growth prior to the late imperial period, but checks such as epidemics and war had restrained growth rates.[43] Although the reasons for a sudden surge in population during the late imperial period are not entirely clear, the outcomes of this growth were. Cultivated land per person in China decreased from 1.4 hectares/person in the Han dynasty to 0.8 hectares per person in the late imperial period.[44] As a consequence, Chinese farmers began to exploit every parcel of land available. In addition, the empire doubled in size during the late imperial period, and much of this area was ecologically vulnerable. Internal migration to these ecologically fragile border regions relieved some of the demographic pressures on the North China Plain and lower and middle Yangtze River valley regions.

As China's population-to-land ratio declined during the eighteenth century, the Qing state was well aware of the mounting threat to its ability to promote the material basis of social and political stability. According to the historian Peter Perdue, "[The] emperor and his advisers grew increasingly concerned about the uncontrollable movements of millions of peasants, laborers, and refugees, but they recognized that it was impossible to force them back to the villages. In the pre-industrial empire, commerce could absorb only a fraction of the labor force. The clearance of new land had been the classic answer of previous dynasties, but expansion of the land area alone was insufficient. As the population to land ratio increased, the promotion of greater yields from existing lands became the primary means of providing for the people's livelihood."[45] Faced with these constraints, the state promoted a variety of measures to maximize yields from existing farmland:

> They [the rulers] focused most of their attention on the control of water and land. Absent inputs from new technologies, agriculturalists had to increase intensification of farming method—increasing output per acre . . . additional sources of fertilizer and development of new sources of irrigation were part of a suite of responses by local society and the state to address the worsening land-population calculus. The state and its clients embraced an ethic of agrarian developmentalism, dedicated to maximizing yields from China's limited supplied of arable land, increasing total land area as much as possible, and channeling water sources to supply the fields.[46]

Faced with an obvious potential for social instability, the Chinese state made a "sort of national priority" of increasing agricultural productivity in the eighteenth century.[47] Such statecraft explains the extraordinary success of the Qing dynasty to feed its people through the eighteenth century, but the environmental consequences of this success led to constraints as the land–population ratio continued to decline.

One of the outcomes of feeding a rapidly increasing population was deforestation and the directly related outcomes of erosion and sedimentation. Deforestation was particularly severe in hilly and mountainous regions where migrants opened up new land for cultivation. Often, upland areas were cleared, and then, as fertility was exhausted, they were abandoned after only a few agricultural seasons. In addition, New World food crops that were introduced to China in the sixteenth century, such as maize, peanuts, and sweet potatoes, could be grown on what had previously been considered marginal land. The introduction of such supplementary calorie sources increased the ability of China's land to support population increases, but the cultivation of these new crops hastened erosion. The increasing number of floods on the North China Plain in the late imperial period served as proxy for measuring the increasing rates of sedimentation coming from the loess region. Records indicate flooding every 1.89 years between 1645 and 1855.[48]

The increased commercial focus of China's rural economy was also a major driver of environmental stress during the late imperial period. This robust development of market relations in the imperial period has been a topic of considerable attention by historians of China. Commercialization led to a "radical simplification of the natural ecological order."[49] China's loss of ecological diversity in the late imperial period was a consequence of agricultural specialization, whereby large swaths of ground were given over to commodity production. During this period, other factors that led to specialized market production included an expanding population, a warmer climate in the eighteenth century, and integration into global silk and tea markets. Other studies, focused on the Yangtze River, have shown similar forces with familiar results: deforestation, erosion, monocropping, and heightened risk of flooding. This

research has shown that state policies, formed in reaction to the growing population–land dilemma, promoted intensified agriculture and land reclamation. Otherwise resistant to aggressive land development efforts by local landowners, the late imperial state was forced to cede significant autonomy to local elites.[50] Such trends compromised the utility of water control structures that had, to that point, mitigated flood threats from the Yangtze River and its tributaries. By the nineteenth century, floods had become endemic in the region. It is not entirely clear to what degree similar processes were at work on the North China Plain. Patterns of landownership and social organization differed between the two regions. Small-scale, locally managed irrigation facilities were largely absent from the North China Plain. Still, there was increasing commercialization of agriculture in North China that may have engendered similar patterns in response to the deterioration of the land–population ratio.[51]

Climate change was an important contextual element of environmental transitions on the North China Plain during the late imperial period. Over the past two decades, there has been considerable work on reconstructing temperature and precipitation data for the North China Plain. As global climate change has emerged as a regional and national issue, China has directed research funds to exploring historical climate change in China. A variety of studies suggest that much of China, and indeed most of East Asia, followed the general pattern of global climate change over the past two thousand years. For example, average annual mean temperatures from 1951 to 1980 were 0.17° C higher than from the beginning of the Common Era to 510. The Medieval Warm Period ensued in 510 and extended to the mid-fourteenth century. This was followed by the so-called Little Ice Age, which lasted from the mid-fourteenth century to the late nineteenth century (during which mean annual temperatures declined by 0.10° C). Within the Little Ice Age period, however, there was also a relatively mild period in the eighteenth century.[52]

The North China Plain has been characterized by distinctive temperature oscillations (rapid warm-cold and cold-warm transitions). For example, in a short span of ninety years between the late fifth and the sixth centuries, temperatures decreased by an average of 1.3° C. Similarly quick transitions occurred between the mid-thirteenth and mid-fourteenth centuries, when temperatures decreased by 1.4° C, and between the late nineteenth and early twentieth centuries, when temperatures increased by 1.0° C. Perhaps even more striking is the temperature increase of 1.5° that occurred between the mid-nineteenth and late twentieth centuries.[53]

Coupling precipitation patterns with temperature data, many studies have concluded that the climate of the North China Plain followed a warm-humid/cool-dry climate pattern over the past two millennia.[54] Consistent with these correlations of cold-dry periods, most of the Little Ice Age was relatively dry, with periods of acute aridness. Indeed, the most arid period in the past two thousand years, as recorded in stalagmite reconstructions, occurred during the first half of the seventeenth century. But China has also seen other periods of significant drought, for example, 850–940 and 1350–1380. In contrast, sustained wet intervals preceded the Little Ice Age (during the periods 190–300, 920–1010, and 1090–1140), and similar conditions prevailed in the early twentieth century.[55]

There has been a temptation to rely on climate change to explain the rise and fall of polities in China; but regardless of the historical veracity of such views, there seems to be little question that fluctuations of temperature and precipitation have had profound effects on local and regional conditions. First, historical climate dynamics have coincided with shifting control of China's border areas between sedentary and pastoral communities of North and Northwest China. Generally speaking, during relatively cool and dry eras, nomadic herders moved southward, looking for better conditions to sustain their animals and their livelihoods. However, during warmer and wetter periods, Han Chinese farmers reestablished settlements to the north. This linkage has led some scholars to posit a connection between climate change and political transitions over the long run of Chinese history. The geographer David Zhang has perhaps argued most forcefully for the determinative power of climate change on the course of Chinese dynastic history. He contends that the frequency of warfare in eastern China correlates with Northern Hemisphere temperature oscillations and that virtually all peak periods

of warfare and dynastic change have occurred during a cooling phase. "The reduction of thermal energy during cooling phases significantly shrank agricultural production. Such ecological stress interacted with population pressure and China's unique historic and geographic setting to bring about the high frequencies of warfare over the last millennium."[56] Indeed, a juxtaposition of data for temperature, precipitation, and political turbulence in China over the past millennia suggests that such correlations are not easily dismissed.[57]

As we have seen, by the late imperial period a variety of forces were working to upset China's ecological balance. The "biological old regime" had been stretched to its limit by population growth and by structural changes to China's agricultural economy. The brilliant success of China's agricultural practices, namely, high returns from high labor inputs, had come at a price. As pressures grew to feed China's growing population, agricultural capacity was maximized by the clearance of virtually all hilly and mountainous terrain. Double- and triple-cropping spread, and New World food crops filled marginal farmland. These areas were particularly vulnerable to floods and drought, but there was also a limit to further development of available water resources, given the available hydrological technology.[58]

Beyond this, intensification of agriculture fostered the growth of economic and social forces that threatened the stability of water control structures (if such structures were not carefully tended by local political organizations or the imperial bureaucracy). The situation at the end of the imperial period is consistent with the notion of the "hydraulic cycle," which described successive eras in the imperial period when robust state sponsorship of water control was followed by neglect and ultimately by a breakdown in water management.[59] Implicit in such a "cyclical" interpretation of hydraulic breakdown is the idea of "technological lock-in." The stability of China's late-imperial economy and society was dependent on the success of a particular hydraulic technological complex, which had been replicated throughout the late imperial period. The "hydrological instability of man-made water systems made the burden of maintenance perpetual."[60] During this period, China still lacked technological innovations that would be the focus of twentieth-century water management, and any disruptions in the heavy investment of material and labor that were necessary to maintain the viability of the water system inevitably led to deterioration. With the weakening of the Qing dynasty and the withdrawal of state patronage for Yellow River management in the nineteenth century, water management systems atrophied and ecologies deteriorated on the North China Plain.

Did China exceed its carrying capacity by the nineteenth century? Did it encounter a Malthusian crisis that ultimately led to China's modern environmental crisis? Political scientists, historians, anthropologists, demographers, and economists have all weighed in on the debates surrounding China's modern political transitions. For example, Esther Boserup has argued against the notion that Malthusian "positive checks" exist as a consequence of population's exceeding resources. On the contrary, she claims that population growth has been an inducement to increased agricultural output. Other paradigms, informed by Marxism, by liberal economics, or by agrarian studies, have advanced their respective arguments. However, to all such analytical and methodological frameworks for understanding China's late imperial crisis we must now add an ecological perspective. The dynamics of this approach are shaped by considerations of demographic growth, commercial development, and climate change.[61]

The causative factors employed by the theoretical models outlined above (which explain political, social, and economic crisis in one region of the world, e.g., Europe) may be quite inadequate to explore realities in China. Nevertheless, there were synchronistic social reactions to global environmental phenomenon in regions with differing cultural, social, political, and religious systems. Violence was one adaptive response to resource scarcity conditioned by climate change. Precipitating such responses were the pressures of a growing population upon the limited carrying capacity of land. The agricultural output of this land was, in turn, conditioned by climate. Climate oscillations impacted the length of the growing season (e.g., whether there would be two crops or one in any given year) and also governed the availability of water for irrigation. Of course, the flip side of the climate equation, namely warm-wet periods, could induce excessive precipitation and could lead to widespread inundation.

The role of the state has also been a central theme in analyses of environmental change in a variety of national and regional contexts. Similarly, maintaining social and political order in China's ecologically fragile regions was a continuing challenge to China's political elites during the imperial period. It was simply not possible for China to abandon the ecological status quo and, at the same time, to maintain the social, economic, and political structures upon which the imperial system rested. Imperial rulers were acutely aware of these challenges and strove to bolster the resilience of agriculturalists on the North China Plain. In effect, the state sought to manage risk to these agriculturalists (and, by extension, its own risk) by sponsoring hydraulic engineering schemes that provided favorable conditions for irrigation and transportation, as well as by establishing a social safety net in the form of a state granary system that served to smooth price fluctuations in times of agricultural privation. As long as the state maintained the capacity to effectively administer these functions, and as long as it maintained its own legitimacy, China's central government achieved what can only be considered extraordinary success in ensuring social and political order over much of the imperial period.

An influential and persuasive neo-Marxist interpretation of Chinese history links ecological destruction to the development of capitalist modes of production, particularly in the agricultural sector, where agribusiness practices supplanted subsistence production patterns.[62] Although they recognize that similar outcomes occurred in regions of China that experienced the impact of capitalist modes of production, scholars of China's late imperial environmental transformations rightly emphasize the presence and impact of the imperial state in the rural economy. The active role of the state was reflected in its propagation of new agricultural techniques and its provision of infrastructure to help increase agricultural production. Indeed, from a broader perspective, state policies toward the agricultural sector were long aimed at guaranteeing subsistence for farmers and generating a surplus to sustain the imperial structure. Will argues that "increasing agricultural productivity in the face of a population that was rapidly growing upon a severely limited land base had become a sort of national [Qing] priority."[63] That the state successfully utilized these policies to promote sufficient agricultural productivity to feed virtually every Chinese speaks to the strength of the imperial state. Thus, in considering the collection of variables that impacted the management of water, we must always include state capacity. In addition, at the end of the imperial period, along with population growth, diminishing returns on agricultural labor, and climate change, we should remember that the deterioration of state administrative capacity had a profound impact on the waterscape of the North China Plain.

The 1855 Yellow River Course Change

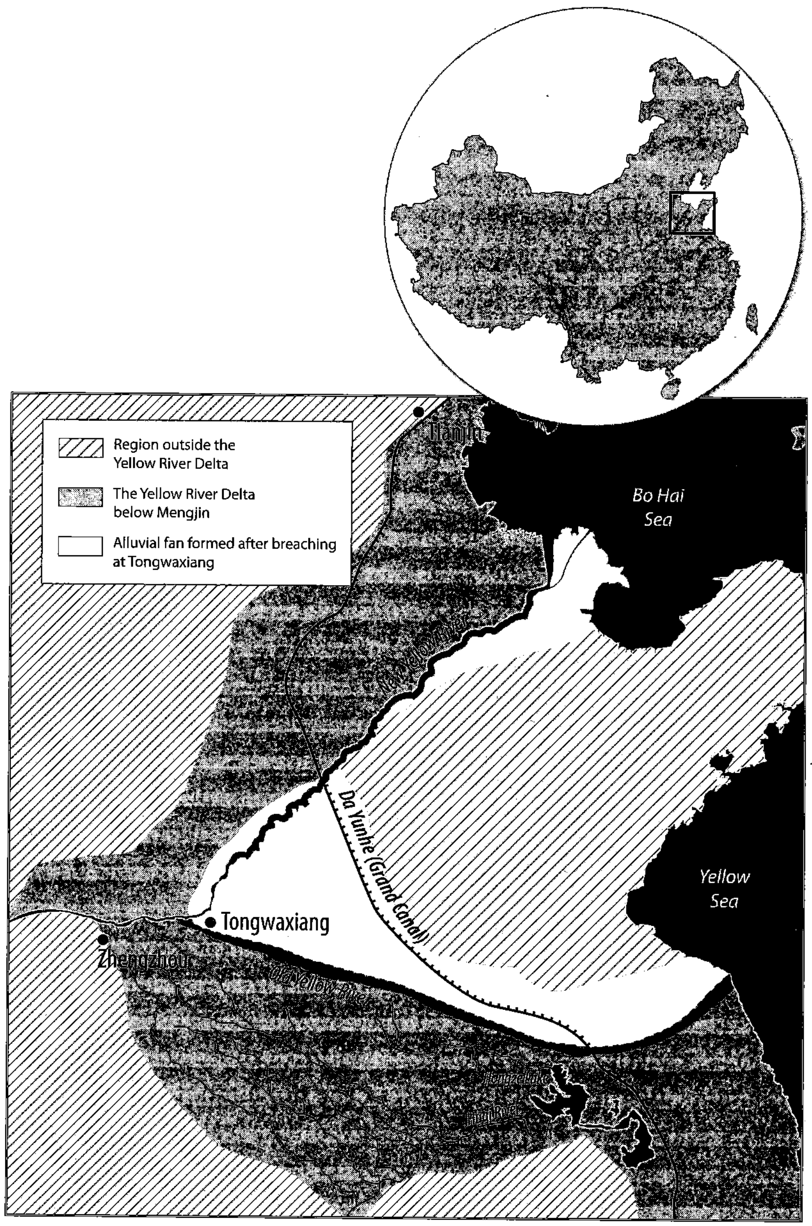
Water management practices on the lower Yellow River reached their zenith in the early eighteenth century, during Jin Fu's tenure as general director of the Yellow River Administration. Given the imperial mandate to protect grain shipments from the south via the Grand Canal, Jin faced the fundamental problem that had been confronted by all Yellow River managers since the completion of the Grand Canal: how to prevent the Yellow River from overflowing its dikes and inundating the canal. Jin renewed Pan Jixun's strategy of constricting the flow to combat silt *(shu shui gong sha)*, and he ordered the building of higher dikes along the Yellow River, along the Grand Canal, and around Hongze Lake. Over the next 250 years, this control system underwent a further process of articulation, driven primarily by the hydrologic peculiarities of the Yellow River. The result was a hydraulic system that could be maintained successfully only at the cost of an ever-greater share of the state's fiscal and administrative resources.[64]

Following the success of large-scale hydrological engineering projects in the early Qing, Jin created a permanent paid workforce to maintain these installations. The burgeoning YRA workforce was an early manifestation of the financial burden that the Qing assumed as it shouldered imperial commitments to maintain the delicate water matrix on the North China Plain. Indeed, by the early nineteenth century, the YRA bureaucracy was burning through Qing financial resources at a moment when imperial coffers were

weakening. A century earlier, the Qing treasury had had an ample surplus, but by 1800 it was struggling with insolvency. Furthermore, the cost of sending 3 million to 4 million piculs (1.8 million to 2.4 million kilograms [kg], or 1,984 to 2,646 short tons) of rice to Beijing from the lower Yangtze River region via the Grand Canal was becoming absurdly expensive. One picul (60 kg) of tribute rice was estimated to cost four to five times the market price. Official appropriations for the YRA by the early nineteenth century were 4.5 million taels (1 tael = 37 grams) of silver per year. This amount, however, did not include dike repair. Regular expenditures on the YRA alone constituted more that 10 percent of Qing revenue. Faced with increasing financial demands on many fronts, the Qing simply could not keep up with the increasing demands of water management.[65]

A commitment to the technological solution of higher dikes coupled with the ineffectiveness of the YRA led to control bottlenecks. A series of serious dike breakages occurred in 1841, 1842, and 1843, and others occurred in 1851, 1852, and 1853. By the time of this second set of dike failures in the 1850s, imperial commitment to North China's hydraulic system was vacillating. In part, this was due to other urgent threats to the Qing state, including the Taiping Rebellion (1850–1864) and the growing European presence in South China. A buildup of silt in the estuary and the downstream stretches of the Yellow River backed up the entire flow and increased pressure on dikes.[66]

The most serious dike break came in 1855. Heavy rains in the upper- and midstream riparian regions generated massive runoff into the Yellow River. On June 19, the Yellow River overtopped dikes at Tongwagxiang in Henan Province. Within a short period, the roiling waters dissolved the loose soil of the northern dikes, carving a breach 5 kilometers wide and, within a day, leaving the original downstream channel completely dry.[67] Water released by the breach poured into the adjacent landscape, which lay 7 to 10 meters below the elevated riverbed (the "hanging" river). Under the weight of such a huge inflow of water, flooding spread across thirty counties in Henan, Jiangsu, and Shandong provinces. Eventually, water flowed eastward to the sea in two large swaths, to the north and to the south of the Shandong highlands.[68]



Yellow River drainage after 1855 dike break

The Yellow River remained uncontrolled for thirty years. The Qing dynasty hesitated to commit itself to renewed efforts to regulate the flow of the river. During these decades, vigorous debates took place among regional officials over how to reimpose hydraulic control. One school of thought advocated plugging the gap at Tongwaxiang and returning the flow to the former riverbed. This perspective was advocated by Shandong provincial interests, now burdened almost solely with managing the lower reaches of the Yellow River. A second school of thought advocated making the current northeasterly course permanent by constructing dikes and other control structures. This approach was championed by interests in Anhui and Jiangsu Provinces, which for the moment did not have to worry about the lower course of the Yellow River. Despite the urgency reflected in these petitions to the court, the Qing government prevaricated. As noted above, the imperial court had other concerns centered on domestic rebellion and treaty relations with the West. In the absence of alternative control strategies, the Qing government was forced to recommit itself to a system of control that relied on levees and related control structures. Qing authorities also had little choice but to accept the new course of the Yellow River. As was vehemently argued in petitions supporting the new course, the expense of restoring the river to its pre-1855 bed would have been prohibitive. The sixth major course change of the Yellow River was honored by the imperial court.[69]

The longer-term consequences of the Yellow River's 1855 course change profoundly affected the North China Plain. First, the shift prompted a retreat from state management of the rivers of the North China Plain. The course change debilitated tribute transport on the Grand Canal. An attempt to revive canal shipments was made, following a failed experiment with ocean shipping, but the days of the tribute system were numbered, as tribute obligations formerly in grain were increasingly converted to silver payments. Because regulation of the transport system was no longer necessary after the shift of the Yellow River, the YRA was abolished in 1861. The dismantling of the old institutional structure responsible for central water management on the North China Plain was followed by the abolition of the grain tribute system in 1904. This withdrawal of central administrative sponsorship of water management projects was one component of a larger shift in statecraft in the mid-nineteenth century, as competition from imperialist powers posed an existential threat to the dynasty. Intent on creating a modern industrial sector that could strengthen the dynasty's prospects for survival, Qing policy shifted investment from the interior to the coastal regions, where modern industrial bases could more efficiently be established. Beginning in the mid-nineteenth century, the long-held priority of "reproductive statecraft" that subsidized the well-being of ecologically marginal areas of the empire, such as the North China Plain, was gradually abandoned by the imperial state. This change in statecraft essentially left local interests on the North China Plain to their own devices. The late imperial devolution of water management to local and provincial purview meant that broader planning for controlling the water in the region would be plagued by a lack of consensus and would pit inter- and intraprovincial interests against one another.[70]

The second longer-term consequence of the 1855 Yellow River course change was a deterioration of the ecological foundations of the North China Plain. It is precisely beginning in this period that increasing numbers of Western missionaries visiting the North China Plain would call the Yellow River "China's Sorrow" and report to their constituencies back home that North China was a "land of famine." As summed up by the historian Mark Elvin:

> The same skill in water control that had contributed so greatly to the development of the Chinese economy . . . slowly fashioned a straitjacket that in the end hindered any easy reinvention of the economic structure. Neither water nor suitable terrain was available for further profitable hydraulic expansion. . . . Deadliest of all, hydrological systems kept twisting free from the grip of human would-be mastery, drying out, silting up, flooding over, or changing their channels. . . . No other society reshaped its hydraulic landscape with such sustained energy as did the Chinese, nor on such a scale, but the dialectic of long-term interaction with the environment transformed what had been a one-time strength into a source of weakness.[71]

In other words, by the late nineteenth century, the North China Plain had entered a period of environmental breakdown that lasted well into the twentieth century.