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The Techno-Politics of Big Infrastructure and the Chinese Water Machine

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ABSTRACT: Despite widespread recognition of the problems caused by relying on engineering approaches to water management issues, since 2000 China has raised its commitment to a concrete-heavy approach to water management. While, historically, China's embrace of modernist water management could be understood as part of a broader set of ideas about controlling nature, in the post-reform era this philosophical view has merged with a technocratic vision of national development. In the past two decades, a Chinese Water Machine has coalesced: the institutional embodiment of China's commitment to large infrastructure. The technocratic vision of the political and economic elite at the helm of this Machine has been manifest in the form of some of the world's largest water infrastructure projects, including the Three Gorges Dam and the South-North Water Transfer Project, and in the exporting of China's vision of concrete-heavy development beyond its own borders. This paper argues that China's approach to water management is best described as a techno-political regime that extends well beyond infrastructure, and is fundamentally shaped by both past choices and current political-economic conditions. Emerging from this regime, the Chinese Water Machine is one of the forces driving the (re)turn to big water infrastructure globally.

KEYWORDS: Water development, infrastructure, techno-politics, South-North Transfer, China

INTRODUCTION

Writing at a time when much of the world seemed to have moved on from big engineering solutions to water management issues, Gavan McCormack took aim at the enchantment of China's leaders with the modern paradigm of water management. Officials and scholars concerned with sustainable water management in China, he argued, have failed to seriously engage with, "the global discourse on hydro engineering, including the realisation that much of what has been done in the twentieth century has been a catastrophic failure – from the Rhine and the Mississippi, to the Nile, the Murray-Darling, and the Oxus" (McCormack, 2001: 23). He attributed the deep-seated belief in engineering solutions and the blindness to these historical shortcomings to multiple factors, including traditional notions rooted in Wittfogel (1963) of the link between river control and political-economic power, as well as the very concept of modernisation. In China, these factors converge in a now post-Socialist bureaucratic state to produce a context in which shifting away from engineering-heavy forms of water management may be far more challenging than it is elsewhere (McCormack, 2001: 26).

Given the current state of China's water resources – with more than two-thirds of its cities facing shortage (Liu and Yang, 2012: 649) and more than 600 million people exposed to water scarcity

(Growing Blue) – China stands to gain considerably from exploring alternative management approaches, particularly those focused on the demand side. And indeed, China does pursue 'soft' demand approaches, including the 'three red lines' (targets on total water use, water use efficiency in industry and agriculture, and water quality improvements on national and regional scales), and the introduction of water users' associations for irrigation districts (Nickum, 2010). Despite these ongoing experiments with both local and larger-scale demand-side measures, China has since 2000 appeared to reinforce an infrastructure-based, engineering-heavy water management paradigm. The most obvious manifestations of this paradigm are not only the world's largest dam and the world's largest interbasin water transfer project, but also hundreds of other smaller-scale dams and transfers around the country (Chinese National Committee on Large Dams, 2008). Another manifestation is the financing of concrete-heavy water management beyond China's borders through dam building in Southeast Asia, Africa and Latin America. In this paper we outline how this doubling down on big water infrastructure has come about, by describing the evolution of China's approach to water management. What we identify is a techno-political regime, made up of infrastructures and other technologies, ideologies, and networks of institutions, their practices and the capital they are able to mobilise: a regime fundamentally shaped by both past choices and current political-economic conditions. What we also identify though, emerging from and embodying this regime in recent decades, is a particular assemblage that has been called the Chinese Water Machine (see Webber and Han, forthcoming). It is the nature and networks of this Machine that best explain why China has not turned away from big infrastructure, and why it is increasingly exporting a particular vision for water management beyond its borders.

By drawing on the concept of techno-politics – "the strategic practice of designing or using technology to constitute, embody, or enact political goals" (Hecht, 2001: 256) – we demonstrate how technical water management choices in China are not only mediated by current political-economic forces, but also constrained by technical choices inherited from the past, and to some extent promoted by international actors. Engineered infrastructures, while 'thick' with politics (Bijker, 2007), are only one element of a broader techno-political water management regime comprising "linked sets of people, engineering, and industrial practices, technological artefacts, political programmes, and institutional ideologies" (Hecht, 2001: 257). We argue that the infrastructure-driven water management regime that predominates in China today reiterates deeply rooted ideas about the control of nature, but merges these with a technocratic vision for national development in which water management is a key tool. Implicated in this national project are ideas about national identity, economic progress, the role of science and technology in development, and the material realities of water itself. As such, the regime is co-produced by water and by political subjectivities. But this regime operates in a bureaucratically fragmented system and also produces more decentralised and localised water management practices. To explain the renewed momentum behind big water infrastructure, we must look to an assemblage emerging from this regime – the Chinese Water Machine.

The paper begins with a discussion of the historical roots of Chinese views on nature and outlines three inheritances from pre-reform water management system: technological, socio-economic, and institutional. Next, we draw on the idea of a techno-political regime to describe the interplay among national identity, technological control of nature (in this case, the control of water through physical infrastructure), and economic development in China's water management in the post-Mao era. Finally, by examining two mega-projects, we identify the contemporary institutionalisation of the Chinese Water Machine, which enrols both domestic and international actors. The discussion of these projects is brief; and space precludes any discussion of any other among the thousands of water projects that litter the Chinese landscape.

INHERITANCES: WATER INFRASTRUCTURE IN PRE-REFORM CHINA

The present-day management of water is necessarily shaped by the technological, social, and institutional choices of the past, the inheritances within which current managers must propose their own actions (Arthur, 1989; Cowan, 1990; Barnes et al., 2004). During the Imperial (206 -1911 CE), Republican (1912-1949 CE) and Maoist (1949-1976 CE) periods, emerging environmental and social needs combined with Confucian (and to a lesser extent, Daoist) conceptions of controlling nature to produce specific practices of dike maintenance, to create a major centre of agricultural production and population, and to begin to institutionalise a techno-political regime geared towards engineered solutions to the material challenges presented by China's water resources. The legacies of these particular types of water management projects include constraints that are manifest in the form of a technological lock-in, a social lock-in, and an institutional lock-in.

Imperial period

Various scholars have outlined the material influence of particular traditions on water management in Imperial China. While we risk oversimplification (and perhaps romanticisation) in this brief discussion, there is general agreement among environmental historians that the history of Chinese water management is an interplay between a broadly Confucian and a broadly Daoist conception of people-environment relations (Perdue, 2010; Tilt, 2015; Pietz, 2015). Confucian writings emphasise the pivotal role played by humans in the built environment: ordering the landscape, transforming it, and using it for economic purposes, especially cultivation (Tilt, 2015: 45). By contrast, Daoism emphasises harmony and continuity between humans and the natural world (Tilt, 2015) – not that people defer to the environment, but that they adjust their responses so that the natural order is modified by humans in a way that takes into consideration the stability of the landscape and the ability of the land to produce food in the face of natural forces of climate and soil fertility (Chan, 2017; Pietz, 2015: 38; Weller, 2006).

Cross-cutting the Confucian-Daoist interplay is a distinction between central state and more local approaches to water management. Pietz and Giordano (2009), for example, report that water control projects on the Yellow River in Ming and Qing times were typically centrally planned and conceived, but the construction and labour were provided locally. Du and Woodworth (2011) demonstrate how, during the late Qing and early Republican periods, networks of non-state actors were decisive in maintaining irrigation systems in China's northern frontiers. Other examples are provided by Finnane (2004) and Perdue (1987). Then (as now) the management of water in China is an activity that involves society at all scales; to focus on one is certainly to miss important details.

Confucian approaches seemed to dominate the major water management tasks undertaken during the imperial era (pre-1912). The Dujiangyan irrigation system, originally engineered more than 2,000 years ago to promote sand discharge, flood control and water distribution on the Chengdu Plain, is one example of such an approach (Cao et al., 2010). Similarly, in the middle and lower reaches of the Yangtze, in the Pearl River Basin and in basins of far southwestern China, the principal task throughout the imperial period was to construct and maintain terraces and irrigation systems for rice cultivation. On the North China Plain, swamps were drained and the Yellow River dykes were constructed to prevent floods and to extend irrigation in order to stabilise food supplies (Pietz, 2015: 28-69). These were some of the primary tasks of the legendary Yu the Great (ca. 2200-2100 BC), the (perhaps mythical) founder of the first Chinese dynasty, credited with enabling a stable agricultural system and laying the foundation for imperial rule through water control (Pietz, 2015: 16-17). Nonetheless Daoist themes are also evident. In general, Daoists were more sceptical than Confucians of the benefits of intervening in processes of nature by large-scale constructions (Chan, 2001; Marks, 2012); so for example, some attempts were made to manage the Yellow River by means of a distributed system of streams contained within low dykes in order to give the river greater latitude in defining its own course

(Pietz, 2015: 44-47). Likewise, the Grand Canal was constructed to bring food from the Yangtze Basin northward – recognition of the natural comparative advantage of the south in food production.

The culturally and politically inflected choices of technologies of water management utilised during the imperial period have enduring legacies. The first of these is a form of technological lock-in. For example, following debates over appropriate ways of preventing flooding on the particularly unruly Yellow River, beginning in the twelfth century the government adopted a policy of raising the river's dykes 15-20 centimetres per year (Yu, 2002). As the riverbed was raised over time through accretion from the heavy sediment load, secondary 'production dykes' had to be built above the original dikes, causing the river to 'hang' higher and higher above the floodplain – in some areas the river channel is now 6-13 metres above the floodplain (Yu, 2002, 2006). A late imperial proverb reads: "River water flows above the heads; people walk below the river" (Yu, 2002). As the population in the vulnerable floodplain below the 'hanging river' portion of the Yellow River has increased, it is hardly possible to envisage living with a Yellow River that is not contained by such dykes. Whatever other forms of management are entertained – including flood-retention basins and land use controls – removal of the dykes would now threaten the lives of the hundreds of millions of people who live on the North China Plain.

The second form of lock-in produced by the water management systems of imperial times is socioeconomic. As the land was drained to make it more suitable for cultivation, irrigation extended and the Yellow River better contained, the North China Plain became a centre of agricultural and, therefore, economic production. Growing much of the food on which the Chinese people as a whole rely – including significant yields of millet, sorghum and cotton, as well as 45 and 60% of China's maize and wheat, respectively (Yang et al., 2015: 428) – the region became home to tens of millions of farmers. However water is managed, and however water acts now and into the future, the Chinese government must provide sufficient resources with which this population can sustain itself at current standards of living and continue to produce sufficient food to satisfy "China's obsession with having a high level of national grain self-sufficiency" (Wong and Huang, 2012: 11). These forms of technological and socioeconomic lock-in worked to constrain Republican and Maoist choices of water management technologies (as described below), and they continue to constrain options in the post-Mao era.

Republican and Maoist eras

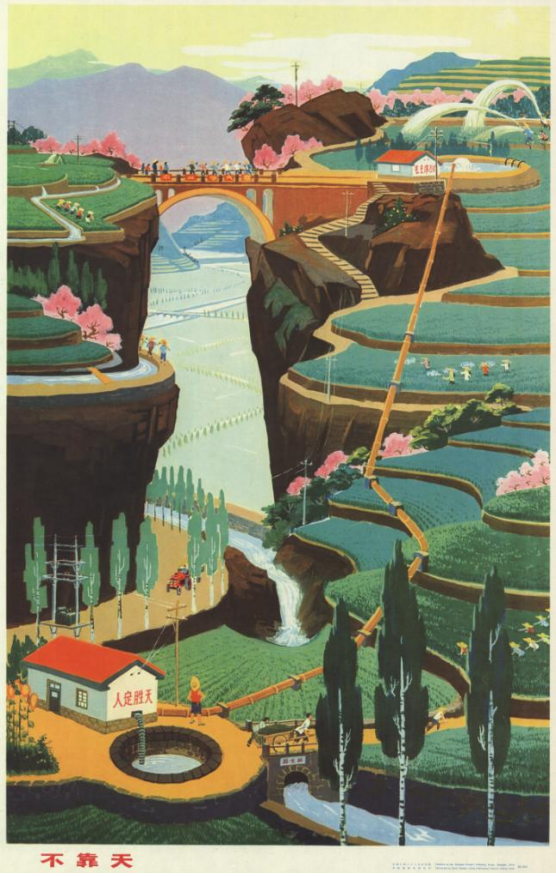
After the moral, cultural and material breakdowns of the Qing Dynasty (Fairbank and Goldman, 2006: 217-254), the Republican period (1912-1949, which includes the Warlord era, the Nationalist government, and the Second Sino-Japanese War) initiated several changes to water management practices that were later intensified under Mao Zedong. The most important of these might be called a nationalist embrace of technological modernism. Following a succession of embarrassing defeats at the hands of colonial powers, it was argued that China needed to be unified, to become modern, and to reclaim its place in the world; the adoption of modern technologies was critical to this process. Some proponents of the May Fourth Movement of 1919 argued for a rejuvenated, unified China that adopted Western technological power but maintained some essence of Chinese culture (Spence, 2013).

In this climate, the concept of multipurpose river-basin planning – using water-based power generation, irrigation and transport for the development of an entire basin – was derived from such sources as overseas-trained Chinese engineers, Dutch and American engineers, and even specific international examples like the Hoover Dam and the Tennessee Valley Authority in the United States (Pietz, 2015: 70-129). One of the most spectacular examples was a proposal from the U.S. Bureau of Reclamation for a dam on the Yangtze River at Three Gorges (Sneddon, 2015). Alongside this renewed interest in infrastructure was a new commitment to centralisation as a way of providing the resources for basin-wide development and of overcoming inter-provincial disputes. The Huai River and Yellow River Conservancy Commissions were both established in the 1930s (though an earlier iteration – the

Yellow River Administration – was established by the Qing Dynasty in the 1600s (Pietz, 2015). Finally, centralised, top-down technology-based basin planning was the natural domain of engineers (Pietz, 2015), whose skills were highly valorised. These initiatives around multipurpose river basin planning provided one basis from which a third form of lock-in, this time institutional, would in time emerge.

Although the Mao-era effort to conquer nature might be thought of as an extreme example of the modernist dichotomisation of humans and nature, quite distinct from the (romanticised, but nonetheless powerful perception of) Chinese values of harmony and sustainability, it may also be understood as "an extreme form of a philosophical and behavioural tendency that has roots in traditional Confucian culture" (Shapiro, 2001: 8). Some innovations made during the Mao period have played a significant role in shaping water management options for contemporary China. The first of these was a massive expansion of irrigation, especially on the North China Plain. Figure 1, a 1975 poster from Xian on the far western edge of the North China Plain, depicts a swath of terraced fields and a pump irrigation system drawing from a channelised stream with the caption, 'Not dependent on the sky'. This figure reflects the sense that irrigation could free agricultural productivity from the constraints of nature, creating an infrastructure for the on-demand transfer of surface water and groundwater to fields. Chinese governments had become locked into supporting the agricultural population of the Plain during the imperial era, as we have seen; but Mao's expansion of irrigation eventually led to both huge increases in agricultural output (thus reinforcing the socioeconomic lock-in) and the beginning of the use and overuse of groundwater resources in northern China (Liu et al., 2001; Pietz, 2015).

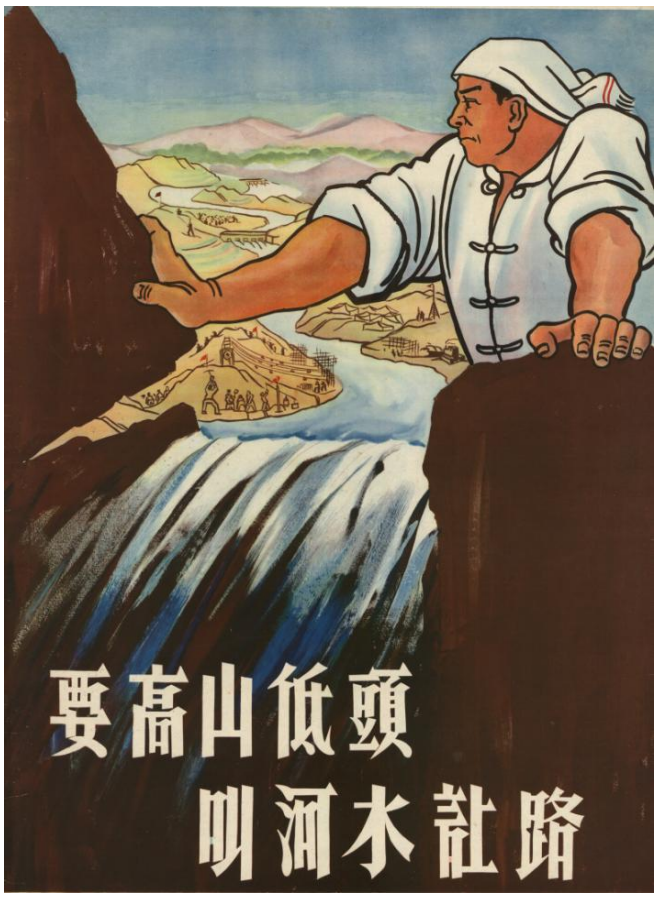
Figure 1. 'Not depending on the sky' (1975).



Source: Xian Mechanical Workers Art Group, International Institute of Social History (Amsterdam).

Secondly, the Maoist era saw the construction of several dams that would later enable multipurpose river basin planning; Sanmenxia at the Shanxi-Henan border on the Yellow River was the most important of these. The dam itself was constructed between 1957 and 1960, in order to control flooding of the Yellow River on the North China Plain, to reduce the rate at which sediment accumulated within the river and to provide water for irrigation during the summer; in addition, power generators were commissioned between 1973 and 1975 (Pietz, 2015: 158-174). Third, despite the so-called 'high modernism' of Sanmenxia, much of the new infrastructure for water management in Mao's time was actually constructed locally, by means of mass mobilisations (Pietz, 2015: 194-217). Although a shortage of finance was one reason for the intensive use of peasant labour, the very act of working together was – whether effective or not – intended to serve the political end of producing communist citizens. In other words, mass mobilisations themselves were techno-political. They had the side-effect of temporarily muting centralised and technocratic tendencies. While the mobilisations were techno-political, it should be noted that the most commonly invoked means of bringing nature (and importantly, water) 'under submission' was through hard, hands-on, manual labour, rather than through advanced technologies. Figure 2 is a typical depiction of this understanding of the relationship between humans and nature that underpinned water management policies and projects during the period. There has been a marked shift in the reform period away from these kinds of mobilisations, as we discuss below.

Figure 2. 'Make the high mountains submit and the rivers give way' (1958).



Note: "Every kind of difficulty has to give way before Communists, just as in the saying 'Mountains bow their heads and rivers give way'" [Mao Zedong Speech at the National Conference of the Communist Party of China, March 1955, reprinted in Mao (1977: 157)].

Source: Stefan R. Landsberger Collection, International Institute of Social History (Amsterdam).

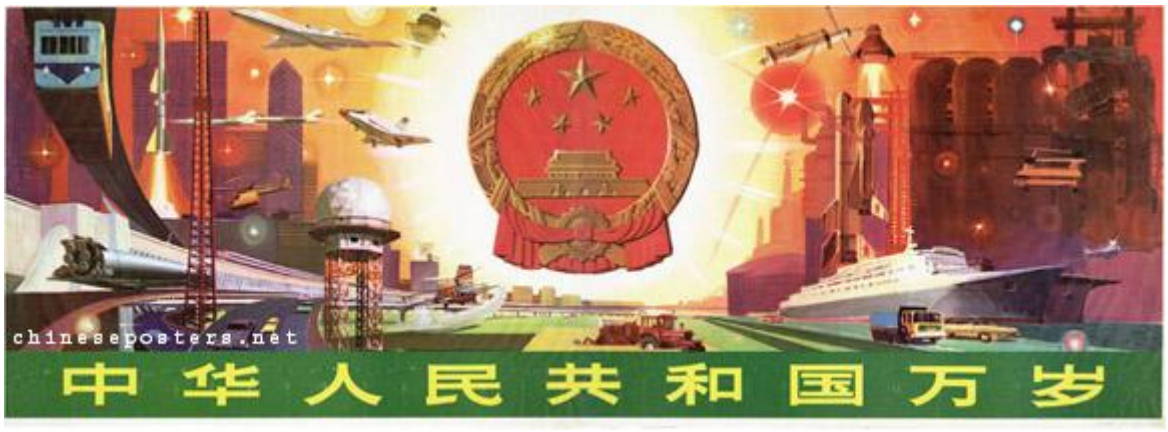
Evidently, therefore, any present-day water management paradigm in China will be constrained by the technological, socioeconomic, and institutional choices of the past. Onto traditional Chinese conceptions of controlling nature has been superimposed a new set of conditions regarding dyke maintenance, protection of a major food bowl and its hundreds of millions of inhabitants, and the gradual institutionalisation of a technocratic network geared towards engineered solutions (tempered by Mao's mass campaigns). China's historical techno-political water regime is not simply defined by big infrastructure: ideological, institutional, and socioeconomic change all shaped water management practices. Further, the materiality of water has shaped this regime. The high silt content of the Yellow River in particular stretched the capabilities of imperial water managers, peasant armies building small-scale dams and levees, the Russian experts who designed Sanmenxia, and a host of later Western experts: as Mitchell (2002) observes, human infrastructures may aim to stabilise water, but such intentions always encounter unexpected responses.

The reform era: Techno-politics and water control

Having traced the genealogy of technological, social and institutional inheritances from pre-1978, in this section we demonstrate the ways in which technological water control projects in post-Mao China are co-produced with notions of national identity and political subjectivity. As Hecht (2001: 287) has shown in the context of post-World War II France, technological development can serve as a platform from which national leaders can renegotiate national identity. Emerging in the late 1970s from a period of similar national trauma, the People's Republic of China (PRC) embarked on a path of 'reform and opening up' (*gaige kaifang*) that has led to dramatic social and economic change over the past 40 years. This era of national reinvention has offered the country's leaders an opportunity to renegotiate China's identity on the global stage with science and technology as a foundational pillar of reform. Figure 3, a propaganda poster published by the People's Art Publishing Company (*Renmin Meishu Chubanshe*) at the beginning of the reform period in 1979, is a clear example of the government's emphasis on technology (particularly large infrastructure projects) in its vision of China's future. With the national emblem of the PRC at its centre and the phrase, 'Long Live the People's Republic of China' sprawling across the bottom, the poster depicts a highway, railroad, several airplanes, an observatory, mechanised agriculture, the trappings of a space programme, and what appears to be a dam or large public works project. Some have argued that the myth of science, clearly on display in Figure 3 and in many other illustrations like it, has become the legitimating myth underlying economic reforms and that 'scientification' is China's answer to the problems of modernity (Bakken, 2000). We explore what this means for China's techno-political water regime in the following section.

With reform in full swing, the 1980s saw a transition from mass mobilisations to the unleashing of a technocratic elite. More than their predecessors, Chinese contemporary leadership apparently embraces the notion that modern problems (which themselves sometimes originate from technological change) can only be addressed by the application of more technology, and that government should consist of experts, particularly scientists and engineers (Cheng and White, 1991). Indeed, Party members with technical or engineering degrees held greater than 50% of top political posts in China as of 2000 (Tilt, 2015: 41). Three of the last four Presidents of the People's Republic of China since the early 1990s and three of the last four Premiers in office since the late 1980s were trained as engineers. The project of reshaping a modern national identity and creating national political subjects has been pursued in no small part through technological development and by what Tilt (2015: 46) refers to as the "dictatorship of engineers" at the helm of the Chinese government.

Figure 3. 'Long Live the People's Republic of China' (Zhonghua renmin gongheguo wansui), 1979.



Source: Stefan R. Landsberger Collection, International Institute of Social History (Amsterdam), (Designed by Gao Quan and Yang Keshan; Published by Renmin Meishu Chubanshe).

Dams and other water infrastructures have been described as "concrete, rock and earth expressions of the dominant ideology of the technological age" (McCully, 2001: 2), a view understood by Premier Li Peng (1988-1998) and President Hu Jintao (2003-2013), both trained as hydropower engineers and instrumental in moving forward the two largest hydro-engineering projects on Earth. These projects, the Three Gorges Dam and South-North Water Transfer Project, provide a window into the complex linkages among national identity, economic growth, and techno-politics, as framed by the inherited technological, socioeconomic and institutional lock-ins discussed above. Of course, these linkages have other manifestations in China: the massive expansion of roads and high-speed rail, the largest airports in the world, the rapid construction of new cities, and the rapid destruction of rural housing. But water infrastructures seem to merge technocratic visions for development and the control of nature in particular ways, which we explore below.

While the Three Gorges Dam Project was initially conceptualised well before the reform period (Dai et al., 1998), it was not until Premier Li Peng and the leader of China's post-Mao transformation, Deng Xiaoping, stepped up as major proponents in the late 1980s that a plan began to take shape. Construction began in 1994 and today the dam spans more than two kilometres across the middle reaches of the Yangtze River in central China and stands more than 200 metres high (Gleick, 2009). Other than species loss, cultural destruction, sedimentation, and security concerns, the most contentious aspect of the world's largest dam has been the displacement of at least 1.13 million people, which has had far-reaching effects including regional and economic restructuring (Wilmsen, 2016).

Postcolonial critiques have framed infrastructure projects like the Three Gorges Dam as icons of modern development, involving the nation state and bureaucrats-as-experts, belief in ideas of progress, rationality, individualism and universalism, and capitalism or state socialism (Escobar, 1995, 2003). Proponents of the dam argued that it communicated to the world that China was now a modern nation. As final plans for the dam were being drawn up, Premier Li Peng wrote that: "the construction of the Three Gorges Project will speed up China's modernisation process and improve the overall national strength" (Li, 1992). Later, President Jiang Zemin declared that China's growing strength made it possible to build the dam, fulfilling the dreams of generations of Chinese scientists (O'Neil, 1997). Li and Jiang were playing on the ambitions and yearnings of those who, since the late 19th century, sought to overcome China's self-identified legacy of weakness and indecisiveness following a series of defeats by foreign powers (Boxer, 1988). In contrast, opponents labelled the dam a "symbol of uncontrolled

development" constructed in brazen defiance of Daoist ideals of knowing one's limits (Dai et al., 1998: 4) and eschewed the idea that the dam in any important way informed national identity.

Whatever the machinations over the decision to build the dam, it thus came to be seen as a showcase of China's opening up, China's ability to rely on its own technological capacity without abandoning national independence to outside interests, and its enduring capacity to dominate nature (Sanjuan and Béreau, 2001). But other discourses were also enrolled in the project. Claims were made that the dam would help to unify levels of development across China by reducing interregional disparities in access to jobs and investment, and by providing the energy to power China's Great Western Development Strategy (Webber, 2012). Three Gorges therefore started to represent the unique brand of modernity 21st century China has sought to produce for itself, one that uses visions of technological praxis in which the engineer is a "good god" (Sze, 2015: 86) to inform national identity, economic development, and political legitimacy. The dam updated the technological lock-in of earlier periods and accelerated the coalescence of the Chinese Water Machine (see below).

Like the Three Gorges Dam, the South-North Water Transfer Project (SNWTP) is a water infrastructure project of a size and scale produced uniquely by the modern Chinese Water Machine. At a massive cost and through the resettlement of over 300,000 people, the project connects four major river basins, three megacities, six provinces and hundreds of millions of water users and polluters (Barnett et al., 2015). The project's legitimacy in the face of demand-side or policy-driven alternatives to addressing severe water stress in and around Beijing relies on two key discourses: the naturalisation of water scarcity in North China, and the environmental benefits of the project (Crow-Miller, 2015). These discourses still have a national focus – the 'balancing' of water between North and South China – but they are also partially the product of the socioeconomic lock-in seen during the imperial and later periods in the North China Plain. The project makes possible the consolidation of a mega-economic region joining Beijing, Tianjin and Hebei (including Xiongan New Area) to rival other economic (and power) centres – the Yangtze River and Pearl River deltas – and thereby updates and reinforces the lock-in of earlier water management infrastructures. The continued heavy industrialisation and urbanisation of an area with limited water resources is further naturalised, and reinforces the stability of China's techno-political water regime. And rather than removing the need for further supply measures, the SNWTP is catalysing yet more smaller-scale transfers (such as that it Shaanxi described by Pohlner, 2016).

As a hybrid of technology and politics, the SNWTP can be read as a physical embodiment of the regime at a particular point in time, privileging concrete over management, favouring large-scale and capital-intensive projects, and pursuing supply-side water management approaches over alternatives that address underlying causes of water scarcity such as pollution (Webber et al., 2017). The SNWTP has also worked to create a new socioeconomic lock-in by reinforcing the political and economic primacy of Beijing (see Crow-Miller, 2014), and the North China Plain as a scalar unit. The SNWTP is not only reflecting the technological, socioeconomic, and institutional choices of the past, but is already producing a new set of constraints to be inherited by China's future decision-makers. Like the Three Gorges Dam, this mega-project has further consolidated the Chinese Water Machine.

We do not wish to suggest that China's techno-political regime does not change, nor that it is incapable of producing other kind of effects. Local, small-scale and alternative approaches co-exist with big infrastructures in China. For instance, people do not everywhere accept water from centralised facilities, sometimes preferring instead household-based solutions to water shortages (Clarke-Sather, 2016). Citizens' groups and non-government organisations have emerged to demand that officials attend to issues of water quality and pollution rather than to issues of bulk supply of water (Wang, 2010): one of many is the civil action group Nanjing Citizens Under Heaven (Fan, 2013). Other groups have taken polluting companies to court, demanding compensation (Xinhua, 2012).

Furthermore, two narratives about water management in China coexist now, as in the past. One – the dominant one – is about supply and infrastructure; it is exemplified by projects like the Three Gorges Dam and the SNWTP. The other does have some local or non-government manifestations, but is most powerfully represented by centralised policies of demand management. Increasingly, it is understood that the demand for water in China has to be constrained and that greater care has to be taken to protect existing waters (Liu and Zhao, 2012; Wang, 2012; Dai, 2014). This understanding was embodied in the Ministry of Water Resources' 'Most Stringent Standards' or Three Red Lines, which set targets for total water use, water use efficiency, and ambient water quality (MWR, 2012). These standards continue the tradition of imposing centralised targets that are to be met by provincial and lower-level governments, and are subject to the same problems of principal-agent coordination (Moore, 2013). The recognition of the need to manage demand is also embodied in the tentative experiments in more market-oriented approaches to water management, such as water users associations (Nickum, 2010) and water trading, that are encouraged by the World Bank and other economists (Moore, 2015).

There are thus multiple players engaging in water management in China. Citizens and non-government organisations have some voice, but it is weak and dispersed. Traditional managerialists within the central bureaucracy continue to espouse setting standards for local implementation. The World Bank and others promote market-based solutions. But more effective than these is making changes on the ground, which are the supply-side and infrastructure policies espoused by the China Water Machine. So, to understand the momentum behind big water infrastructure we need to describe the networks and machinations of the Chinese Water Machine in more detail.

THE CO-PRODUCTION OF THE CHINESE WATER MACHINE AND BIG INFRASTRUCTURE

The reform era's exemplary projects, the Three Gorges Dam and the SNWTP (South-North Water Transfer Project) have assisted in the formation of a network of organisations that we have called the Chinese Water Machine (Webber and Han, forthcoming). The network includes huge state-owned corporations (such as Power China, Sinohydro, Energy China, China Three Gorges Corporation, Dongfang Electric Machinery and Haerbin Electric Machinery), smaller bureaus (such as the Changjiang Institute of Survey and Design), research institutes (including the China Institute of Water Resources and Hydropower Research), universities (including Hohai University, Tsinghua University and Wuhan University), the Ministry of Water Resources, domestic and foreign water supply companies (such as Suez, Veolia, Beijing Enterprises Water Group and Beijing Capital Group) and some provincial governments. The Machine also includes organisations and networks domiciled outside the country – international development banks, foreign government departments and universities, foreign contractors and suppliers (such as Hydro-Quebec, DHI, AGT, Alstom, Siemens and Voith) and other international organisations (International Commission of Irrigation and Drainage, International Water Resources Association, World Water Council, International Hydropower Association, International Commission for Large Dams, UNESCO, International Union for the Conservation of Nature, World Wildlife Fund and The Nature Conservancy). The Machine is in many ways a modern, more complex version of the hydro-bureaucracies that existed in many countries in the last two centuries (Molle and Wester, 2009); no doubt similar networks exist in other countries.

Though it has roots in the pre-Mao era, the Chinese Water Machine emerged as one of the explosive changes that has characterised China in the past 40 years. During the reform period, China's technical capacity to produce complex goods, to manage complex organisations and to mobilise huge volumes of physical capital expanded enormously (Kong et al., 2012). The construction of the Three Gorges Dam is sufficient evidence of this. At the same time, the growth of China's population from 950 million to 1.4 billion, the growth of its constant-price gross domestic product at an average annual rate of over 9.5% and the even more rapid expansion of its manufacturing sector placed increasing demands on water

resources, both for consumption and as a sink for wastes. Now, in the words of China's then-Minister of the Environment, Zhou Shengxian, "In China's thousands of years of civilisation, the conflict between humanity and nature has never been as serious as it is today" (quoted by Economy 2011), who goes on to claim:

> What is the biggest challenge that China faces? Corruption, the gap between the rich and poor, and the rapidly aging population often top the list of answers to this question. Yet a closer look suggests that the greatest threat may well be lack of access to clean water. From 'cancer villages' to violent protests to rising food prices, diminishing water supplies are exerting a profound and harmful effect on the Chinese people as well as on the country's capacity to continue to prosper economically (Economy, 2011).

Growing technical capacity and the increasing centrality of water to China's development provide means and context, but the critical change underpinning the emergence of the Chinese Water Machine has been a series of reforms to China's bureaucracies and corporations.

The Water Machine began to emerge as state-owned enterprises (SOEs) were distanced from, and empowered in relation to, the government. In Mao's era, corporations were arms of the various ministries, producing much as directed and turning net income over to the ministries (Naughton, 1995). Successive waves of reform permitted corporations to produce outside the plan, set performance contracts and allowed corporations to retain a share of their profits, introduced professional managers and new forms of corporate organisation, and most recently closed them, sold them off or merged them into corporatised state-owned entities (Wang, 2012; Lin and Milhaupt 2013) that are wholly owned by SASAC.

Enterprises were progressively disengaged from the command of administrative bureaus (Keister 1998, 2009). The degree of independence of state corporations from government and Party is still debated (contrast the views of Naughton, 2008 and those of Wang, 2012 and Lin, 2014). However, the degree of ministerial control over corporations is less important than the fact that ministries, Party and corporate interests are all represented in formulating policy. Ministries, Party and corporations are bound together through the networks that comprise the social assets required for appointment as a senior manager and that are created as bureaucrats and corporate managers swap roles (Xi 2011; Lin, 2014).

Simultaneously, university programmes were established or realigned to meet the needs of the Ministry of Water Resources and the emerging corporations. Ministries funded programmes in water engineering, research on water management and training engineers to design, construct, manage and run the products of the Machine. For example, Tsinghua University's Department of Hydraulic Engineering now has a State Key Laboratory of Hydroscience and Engineering and six institutes. Its 99 faculty members and staff include seven academicians, the highest level of honour for Chinese scientists (see tsinghua.edu.cn). The core school of the North China University of Water Resources and Electric Power (Zhengzhou, Henan), the School of Water Resources, together with the Schools of Electric Power, Resources and Environment, Civil Engineering, and Environmental and Municipal Engineering, offer 42 undergraduate and 31 graduate programmes on water management. The university is co-sponsored by the Ministry of Water Resources and Henan Province. Hohai University responded to a request from the Ministry of Water Resources to establish an undergraduate programme in population resettlement in 1988 (NRCR, 2013). The National Research Centre for Resettlement was approved by the Ministry in 1992 to train graduate students and to undertake research and resettlement planning. Such programmes provide expertise to the corporations and institutions in the Water Machine.

Thus, by the early to mid-1990s, there emerged a Ministry of Water Resources and more or less separate corporations, all engaged in planning and constructing water management projects in China. University programmes trained the personnel for these tasks. The international development banks provided (or leveraged) many of the funds that financed the activities of these corporations and

programmes. As China opened up, the World Bank and Asian Development Bank brought a project-based sensibility to water management, in which large (hundreds of millions of dollars) individual projects overpowered any sense of water management at a local scale. In the 1980s and 1990s, the World Bank provided over USD 3 billion for dam construction to China (21.1% of the total costs of the invested projects), USD 3.2 billion for urban water supply projects (31.8%), and USD 1.8 billion for agriculture and irrigation projects (28.3%) (Varley, 2005). These funds attracted Chinese and overseas corporations into the market of water management and consolidated the capital-intensive, project-based approach within the Ministry of Water Resources and its local bureaus. The scale of projects encouraged corporations to become large enough to compete as contractors and to acquire the Western management expertise that would endear them to the committees that evaluated tenders.

The construction of the Three Gorges Dam spawned several members of the Water Machine (including China Three Gorges Corporation), strengthened the technical capacity of others (including Haerbin Electrical Machinery, Dongfang Electrical Machinery, Gezhouba), led to the creation of nationally organised power grids and their controlling companies, and fostered strong links between these corporations and foreign equipment manufacturers and contractors (Webber, 2012). When the dam was completed in mid-2012, China had large, technically sophisticated water-engineering companies that could build the ambitious water management projects being planned in the 1990s and 2000s. By then, the corporations were cooperating with each other in constructing projects (Haerbin, Dongfang and Gezhouba as well as many foreign corporations that contributed to the Three Gorges Dam, under the general management of China Three Gorges Corporation) and in proposing projects (such as the new dams now being built on the Jinsha River). Meanwhile the inter-institutional transfer of personnel between the Ministry of Water Resources and the corporations intensified the links between them.

The linkages between corporatised enterprises, ministries, departments, universities and foreign corporations thus emerged through personnel transfers and through flows of money, materials and plans during the construction of such huge projects as the Three Gorges Dam. These material linkages are supplemented by interactions within water-related international forums and congresses, which became increasingly common in the 1990s. Examples of these forums are those organised by the International Water Resources Association, World Water Council, Yellow River Conservancy Commission, International Hydropower Association and International Commission on Large Dams (Webber and Han, forthcoming). These forums are public spaces within which the members of the Water Machine interact and consolidate the links that make a network. Networks are made by people (representing organisations) talking, exchanging information, recognising common interests and forming alliances; congresses facilitate this activity. There are also opportunities for Chinese corporations and other members of the Water Machine to consolidate networks within China – within the China Committee for Large Dams and the China Society for Hydropower Engineering, for example. The Ministry of Water Resources provides staff for some organisations, including universities, and recruits personnel (including State Council Three Gorges Project Construction Committee Executive Officers). Other executives move in and out of bureaucracies.

While the Machine is largely Chinese, on its periphery are international organisations and corporations domiciled in other countries. The International Hydropower Association is international, as are such environmental organisations as The Nature Conservancy and the International Union for the Conservation of Nature. European and US corporations, including GE and Siemens, sometimes play a role in the Machine. Congresses and forums bring together institutions, corporations and governments from around the world. These actors help to maintain the legitimacy of China's techno-political water management regime. The effects of the Machine thus have global and multiple national sources: the dam-building activities of Chinese corporations depend on material and expressive support from corporations, governments and institutions around the world. Since the 'Going Out' policy of the 10th Five Year Plan (2001-2005), China has built approximately 75 dam projects beyond its borders, filling

the gap made by the growing unwillingness of international donors to fund big dams (Kirchherr et al., 2017). The latest example is a joint venture just announced by Nepal Electricity Authority and China Three Gorges Corporation to develop a hydropower plant in mid-west Nepal (Xinhua, 2017). The reach of this Machine is therefore increasingly global: its international networks and activities act as a bridge between a mythologised past and a coveted future (Hecht, 2001), one in which China exports its technological strength and historical control over nature to the developing world.

Hecht (2001) argues that technologies do not merely have symbolic importance, but are the outcomes of cultural processes in which ideas about national identity play an important role. The Three Gorges Dam and the SNWTP are both water technologies in which people, infrastructure, political programmes, and past choices coalesce to reproduce ideas of Chinese nationhood and modernity. What distinguishes China's current water management paradigm from earlier periods is the institutionalisation of the Chinese Water Machine. Its capital is used to pursue concrete-heavy water infrastructure projects that serve the political and economic agendas of the Machine's constituent parts and create new sources of lock-in that try to ensure its long-term relevance. It is a particularly Chinese machine not only because it is activated by money that flows (largely) from the central government, or because many of its members were spawned through the reforms and constructions of the 1990s, but because it is held together in part by the particular mix of self-interested actions and government direction that inform so much of individual, corporate and government life in China (Sigley, 2006). The Machine is of course vulnerable to competing interests within its networks, and is challenged by the materiality and mobility of water in a way that other kinds of assemblages (for instance around rail or housing infrastructure) are not – for example, the Three Gorges Dam is challenged by siltation, and the heightened risk of earthquakes and landslides produced by the weight of water trapped behind the dam. The technological lock-in of the SNWTP may yet be challenged by the polluted waters that flow into it from Yangtze tributaries, or by adequate rainfall moderating the effects of drought in North China and thereby reducing demand for the more expensive diverted water.

CONCLUSIONS

China's enduring embrace of 'high modernist' water infrastructure hides a complex story of institutional, social and technological decision making that stretches back to the imperial period. Its current techno-political water management regime reflects these legacies, but has also developed in new directions since reform and opening up – in particular, the consolidation of a far-reaching Water Machine that enrols domestic and international state and non-state actors. Combined with the enduring legacy of past water management decisions and the placing of science and technology at the centre of post-Mao national reinvention, a strengthened China Water Machine continues to bring complex, large-scale, concrete-heavy supply infrastructure to the fore of China's approach to water management.

Given the ideological, institutional and social inheritances of China's techno-political regime, its embeddedness in a broader project of modernisation and nation-building, and the increasing role of the Chinese Water Machine in carrying this regime, any critical perspective on big infrastructure for water management is likely to be marginalised, if it can develop at all. At the ceremony marking the closure of the Yangtze River by the Three Gorges project, Jiang Zemin said: "Since the twilight of history, the Chinese nation has been engaged in the great feat of conquering, developing and exploiting nature" (Jiang, 1997). China now appears to be expanding this vision not only domestically, but exporting it to other parts of the world. Without diminishing the role of local politics, the Chinese Water Machine is likely to be implicated in any resurgence of concrete-heavy forms of water management around the world; arguably it already is.

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