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ADVANCED REVIEW

Liquid futures: Water management systems and anticipated environments

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Climate change and its impact on hydrological dynamics have become key topics of concern among water managers and policy makers in many parts of the world. Yet while practitioners often frame adaptation to a climate-changed future as a novel issue, ideas about future environments have long influenced systems of water management. Reviewing ethnographic and historical accounts of waterscapes across the globe, this article examines the relationship between imagined environmental futures and the policies, practices, infrastructures of water management and legal frameworks. We show, first, how conflicting ideas about environmental stasis and perturbation have been built into water networks across space and time. In some cases, notions of radical landscape change have underpinned these systems, as in programs dedicated to land "reclamation" or interbasin water transfer schemes. In other contexts, water systems have developed based on visions of long-term sociohydrological stability. Second, we highlight how contrasting notions of human capacity to change environmental outcomes have played into water management systems. In some cases, there has been an assumption of the potential for and desirability of full human control; in others, there has been more recognition of the limits of such mastery. Exploring the wide range of environmental imaginaries mobilized through water management, we contextualize contemporary efforts to build resilient, "climate proof" waterscapes.

This article is categorized under:
Human Water > Water as Imagined and Represented
Science of Water > Water Quality

1 | INTRODUCTION

Images of melting icebergs, creeping deserts, and crisped agricultural fields abound in mainstream political and environmental discourses, mobilized as potent symbols of the novel environmental challenges and configurations brought about by global climate change. Predictions of radically altered waterscapes and new water management concerns, such as extended droughts, sea level rise, violent flash floods, and faster-melting snowpacks, figure prominently in these discussions. Fears of water flows beyond and below familiar thresholds drive projects oriented toward achieving "water resilience."(Rockstrom et al., 2014) These projects exemplify how environmental futures can shape resource politics and governance in the present, impacting contemporary institutions, laws, and infrastructures of ecological management (Ferry & Limbert, 2008; Limbert, 2010; Mathews & Barnes, 2016). Such anticipated environments are one of a number of different futures that are folded into the present, with significant social, political, and material consequences (Adams, Murphy, & Clarke, 2009; Appadurai, 2013; Guyer, 2007; Rosenberg & Harding, 2005).

Yet while anthropogenic climate change has brought questions of the future to the fore, in this article we argue that assumptions about and images of future environments have long structured systems of environmental management, particularly when it comes to water. To explore this topic, we surveyed literature on water management within the disciplines of anthropology, geography, and environmental history. This review examines texts from these fields that engage with questions of futurity through accounts of the logics and frameworks that underpin water systems. We include both works in which water managers and users explicitly engage with visions of future environments, and those in which such imaginaries are implicit in the structure of the water network. Scoping the literature in this manner allows us to examine how notions of anticipated environments shape infrastructures, institutions, and practices of water management across space and time. Probing how futures have affected water management systems in the past, we provide valuable contextualization for contemporary efforts to achieve "water resilience" across scales and locales.

We define water management broadly as encompassing a range of systems dedicated to water provision, flood control, and water quality. While there has been interesting work on lakes and oceans in which the water is largely a background or a setting for the analysis(Helmreich, 2009; Orlove, 2002; Starosielski, 2015), we focus on cases where the water itself is an object of human efforts to control and order. In exploring how these water management arrangements have been influenced by ideas about future environments, we take an expansive conceptualization of environments as interlinked human, animal, and plant communities within a landscape. This framing allows us to follow recent scholarship that approaches urban spaces as inhabited environments, rather than the antithesis of "nature."(Rademacher, 2015; Rademacher & Sivaramakrishnan, 2013) Environmental futures are thus a function of the temporal trajectories of both their "physical" components (e.g., altered precipitation or temperature patterns) and their "human" components (e.g., larger populations or landscape transformations).

In reviewing the literature, we draw out two key themes. The first is stasis versus perturbation. To what degree have water management systems at different points in time been underpinned by assumptions of systemic constancy or disruption? Which components of environments may be assumed to be static and which dynamic? How may practices of water management challenge these underlying assumptions? Accounts historicizing the concept of the hydrological cycle show that assumptions of balanced flows and systemic regularity within a watershed have a particular, social history, suggesting that notions of stability within the waterscape vary across space and time (Linton, 2008; Tuan, 1968). The concept of the hydrosocial cycle, a socionatural process through which society and water constitute one another, gestures toward the coproductive relationship between water management practices and the categories used to interpret the resource (Linton, 2010; Linton & Budds, 2014). We proceed from a recognition of this dynamism, and attend carefully to the varying expectations of stability built into different water systems.

The second key theme is human mastery over the environment. As future visions come to play on the present, a central question is the degree to which humans are able to control water and land. To what extent are systems of water management premised on the notion that people can effectively create the waterscape they deem most desirable? How does the scale of a water management challenge affect how people perceive their agency to address that challenge? In what ways does the production of knowledge about the waterscape affect these expectations? Exploring the range of assumptions about the possibility for human control over nature through water management systems, we trace the perceived relationships between human action and environmental futures.

Through this analysis, our review highlights some of the larger social and political stakes of water management. Practices and institutions of water management are always imbricated with the arrangements of power and politics in the society they serve. This in mind, we attend to the question of whom, exactly, a future waterscape is designed to serve (or to disappoint), and how those beneficiaries may be divided by lines of social difference such as class or race. We look, also, at the ways in which ideas about water futures become enrolled in broader political, territorial, and state-making processes.

We organize our account into three sections. We begin by analyzing literature on some of the oldest forms of water management, the long-lasting irrigation systems developed before the 19th century, many of them governed at the local or regional scale. In the section that follows, we examine large-scale, state-led programs of water development of the 19th and 20th centuries. Finally, we focus on contemporary water networks—typically, legacy systems from the high modernist period—and notions of futurity that have emerged in recent decades. We conclude by reflecting on the connections across these modes of water management.

2 | LONGSTANDING IRRIGATION NETWORKS

Irrigation networks are among the oldest forms of human manipulation of water and were central to the foundation of early civilizations like Ancient Egypt (Butzer, 1976). Designed to address a mismatch across time (and space) between supply and demand, to provide water when (and where) it would otherwise not be available, irrigation systems are inherently temporal

in their structure and operation. So what role will the future temporalities play? How have irrigation networks been influenced by visions of future environments? And what kinds of future visions have shaped irrigation systems? Examining the literature suggests considerable variation between networks.

Despite the wealth of anthropological analyses of long-enduring irrigation systems, few focus on notions of waterscape futurity (Kelly, 1983; Rasmussen & Orlove, 2014). When ideas about the future enter these texts, they often do so by way of engagement with the "hydraulic hypothesis," a teleological argument contending that the centralization of water management leads to "despotic" forms of social control (Steward, 1949; Wittfogel, 1957). Scholars' attention to this theory of a sociohydrological trajectory frequently displaces substantive analysis of the assumptions about a system's or local environment's future that structured sociohydrological practices (Mitchell, 1976; Orenstein, 1965). But while much of the older irrigation literature does not directly address how network participants thought about local environmental futures, texts that do explore the question suggest that local understandings of the systems were often founded on a sense of either the threats or opportunities of ecological change.

Accounts of some perduring systems reveal that one particular imagined future animated many irrigation arrangements: a vision of local socioenvironmental collapse should the water management system cease to function in its regular manner. For instance, in the case of Balinese water temple networks, the religion that governed water practices foretold of an influx of crop-killing pests should communities not properly carry out the rites. Such a lapse in ritual practice, and the resultant impact on the agricultural system, would shatter the precarious systemic stasis with which residents were familiar (Lansing, 1991). That this vision became a reality when the introduction of Green Revolution rice led to a replacement of the water temple system with bureaucratic irrigation management reinforced this sense of systemic fragility (Lansing, 1991, 2006). A similar sense of an irrigation system serving as a crucial buffer against rapid environmental (particularly agricultural) decline has been recorded in the *acequias* of Northern New Mexico (Rodriguez, 2006). Such a focus on the potential for future collapse suggests that in many places, carefully managed water has been understood as a tenuous human achievement. The underlying assumption of two possible states—either functioning or collapsed—indicates that these systems of water management, and the socioecological arrangements they enabled, were largely understood as stable. This vision of stability occludes the possibility of dynamism and the varying degrees of potential function or dysfunction.

In other scholarship, which tracks the historical evolution and diffusion of irrigation techniques within or between locales, we see that a desire to bring more land into cultivation or to buffer a community from droughts or floods spurred the implementation of changes to the waterscape. In other words, irrigation networks were all about transforming the local environment. Accounts of the long histories of irrigation in Oman (Wilkonson, 1977), Tokugawa Japan (Kelly, 1982), and Valencia (Glick, 1970) suggest that the expansion of permanent agricultural acreage through irrigation and flood control measures was imagined and pursued over an extended period. These largely historical accounts trace dramatic changes in local environments actualized through these evolving systems of water management. The notion that a new kind of controlled hydrological environment might be achieved and sustained structures these accounts of waterscape change.

In contrast, an acknowledgement of humans' lack of control over water—and the need to respond to hydrological variability—characterized other arrangements of irrigated cultivation. Studies of longstanding irrigation networks detail the range of techniques used to manage for and respond to local climatic fluctuations, particularly in the form of drought (Geertz, 1972). Over time, highland communities in the Andes, for example, have developed intricate mechanisms of adjusting irrigation water allocations during periods of scarcity (Trawick, 2001a, 2001b). In other sites, communities relied on sporadic deltaic flooding to determine the spatial patterns of their settlements and agricultural cultivation (Strang, 2009). Built around an expectation of environmental variation, these systems of management were oriented toward a future of expected perturbation.

The range of imagined futures discussed above—catastrophic waterscape collapse, expanded irrigated cultivation, regular desiccation, or inundation—suggests that the possibility of a waterscape and local environment different from the present, be it disastrous or unprecedentedly bountiful, has long-shaped approaches to the resource, particularly those in which flows are aggressively managed. Underpinning these varied visions of the future are contrasting notions of agency, humans sometimes appearing as the drivers of change, other times being positioned as subject to the whims of nonhuman natures. This has political ramifications in terms of the degree to which powerful figures in a community can claim control over water supplies as part of their authority. At the same time, these modes of approaching the future are distinct from the more explicit efforts to fully control nature characteristic of the 19th and 20th century's large-scale, state-driven systems of water management, which we turn to next.

3 | "MODERN" WATERSCAPES AND MORE VERDANT FUTURES

In many cases where scholars have explicitly engaged with notions of futurity, the water management arrangements they are looking at have been justified by particular visions of "improved" environments. A desire to minimize the experience of

environmental perturbation for certain landscapes—in the form of "too much" or "too little" water—unifies almost all of these visions. Over the past two centuries, water managers have sought to rationalize waterscapes through large-scale schemes to tame rivers or green deserts, framing those efforts as solving the problems of hydrological variability by producing conditions of managed abundance. The nation-state has played a key role in the development of almost all of these large-scale networks of water management. Many have observed a key corollary to this process, detailing how states themselves are produced through the work of imagining, building, and maintaining such water systems (Alatout, 2008, 2009; Carroll, 2012; Pritchard, 2011). As such, we view the modes of water futurity these projects entail as both conditioned by and productive of broader state formations and temporal imaginaries during the 19th and 20th centuries.

These large-scale water management projects typically proceeded through practices and discourses in which nonhuman nature was made legible and "manageable." Waterscapes became sites for technocratic rationalization and regularization for the sake of economic expansion (Carse, 2014; Hays, 1959; Mitchell, 2002; O'Neill, 2006; Sneddon, 2015; White, 1996). This approach to nature is often characterized as "high modernist" and reflects the way that many state actors in the 20th century approached programs of environmental management (Scott, 1998). The case of the Tennessee Valley Authority (TVA)—an aggressive river basin management scheme initiated in the 1930s—suggests the far-reaching socioenvironmental dimensions of these imagined futures (Scott, 2006). The TVA was conceived as a conduit to rural development that would prevent flooding, provide hydro-electricity to the countryside, and bring steady work opportunities and a civilizing state presence to a remote region. As this example suggests, high modernist water management schemes were often built on the belief that a radically different socioeconomic order could be created through environmental rationalization.

Projects of land "reclamation" are exemplary of this type of intervention, and of the robust notion of human mastery over nature that they entail. Whether the land in question was being reclaimed from swampiness (Carroll, 2012) or aridity (Barnes, 2012; Worster, 1985), the goal was to achieve a landscape's most desired function, as determined by state planners and funders. Highly engineered projects of "flood control" proceeded from a similar confidence in engineers' abilities to keep certain spaces dry (Gumprecht, 2001; Orsi, 2004). These efforts often resembled the 20th century state projects of environmental management that were based on ecological concepts like the "climax community," wherein notions of a "best environment" possible in a particular space led to the criminalization of longstanding local ecological practices (Fairhead & Leach, 1996; Worster, 1994). As this comparison suggests, power relations played a key role in determining which visions of the future waterscape gained traction.

Similarly, interbasin water transfer projects were founded on ideas of future environments that classified certain water demands as "legitimate," and thus deserving to be slaked through dams and pipelines, while others were deemed unnecessary. The early 20th century conflict between the city of Los Angeles and the residents of the rural Owens Valley is a famous example of such a differentiated project of future making, as the more populous city was granted the valley's water to provide, per president Theodore Roosevelt, "the greatest good for the greatest number." Hoffman, 1981; Kahrl, 1982The outcome in this instance—feeding an expanding city while drying a hinterland valley—is suggestive of the exclusions and occlusions on which many high modernist projects of legibility were premised. In service of the desired "rationalization," certain landscapes and populations were made invisible, often through desiccation or reservoir inundation (Piper, 2006; Righter, 2005; Worster, 2008). As the Owens Valley case suggests, the future landscapes *not* imagined in justifying large-scale interventions were shaped by these interventions just as much as those that *were* imagined and targeted for ordering.

Legal frameworks have often been an important backdrop to these infrastructure projects (Akhter, 2015; Sneddon & Fox, 2006). These legal arrangements, too, have been underpinned by particular assumptions about the future. In the case of the Nile, a river basin shared by 11 countries, the 1959 Nile Waters Agreement allocated fixed volumes of water to downstream riparian states, Sudan and Egypt, based on historical flow patterns. The assumption was that past flows were an adequate guide to the future—an expectation that subsequent patterns of decadal variability and climate model projections have brought into question (Barnes, 2017; Conway, 2005; Muehlmann, 2013). Other cases in which treaty framers assumed that a river's source would remain constant into the future have also been unsettled, leading to challenges within the allocation regime (Erie, 2006; Fleck, 2016; Reisner, 1986). An assumed environmental constant—precipitation—thus produces problems for a water management system when its constancy erodes.

In terms of metropolitan areas, imagined futures of modern, ordered urban spaces have shaped water management systems. These visions have been accompanied by imagined trajectories of population growth and projected increases in water demand (Anand, 2017). In many cases, urban water provision systems reshaped entire regions in the service of these aspirations (Gandy, 2002; Piper, 2006). Notably, the water infrastructure itself, including dams, pipelines, and even in-city water towers, served as a symbol of the modern future made material during this period (Kaika, 2006; Kaika & Swyngedouw, 2000; Mitchell, 2002). Not only did the idea of creating a particular kind of urban environment drive the production of the infrastructure, but the material networks themselves communicated that sense of such a better world coming-into-being through human technical ingenuity.

Setting aside the symbolic power of these infrastructures, it seems clear that water managers did not necessarily anticipate a uniformly bountiful future of urban water provision. The realization of these visions of safe, steady, universally accessible urban water systems has almost always been incomplete, particularly in the Global South, suggests the quietly exclusionary nature of many such visions (Anand, 2011, 2017; Gandy, 2008; Swyngedouw, 2004). The selective, racialized introduction of water meters in South Africa—an intentionally disciplining water provision technology—in a number of cities indicates that for many water managers, the imagined future of provision has long been differentiated across race and class (Loftus, 2006; von Schnitzler, 2008; von Schnitzler, 2013).

Thus, ideas of threat prevention and system rationalization were widely used to justify the development of large-scale water management networks in the 19th and 20th centuries. However, as many of the texts cited here show, the "modern" environments and hydrological arrangements produced benefits that were not equally shared across social groups. They also produced new, unevenly distributed forms of perturbation to fear and manage. The following section explores the proliferation of threatening water futures since the apex of the high modernist engineering paradigm.

4 | COLLAPSE PREVENTION AND TRIAGING THE FUTURE

Increasingly, anticipated futures of imminent crisis structure thinking and discourse around systems and institutions of water management worldwide. The idea that we may have reached, or be near reaching, "peak water" encapsulates this sense of crisis (Gleick & Palaniappan, 2010). In some cases, these imaginaries are directly linked to the material realities of global climate change and its projected impacts, in the form of water shortage or inundation (Cohen, 2016; Günel, 2016; Hastrup, 2014; Koslov, 2016; Orlove, 2016; Stensrud, 2016a). Within such projections, the fact that humans may shape water scarcity and plenty in any particular time or place just as much as climate is relegated as global climate becomes the primary agent of change (Barnes, 2015). In other contexts, managers place the emphasis more on long-term local and regional environmental trajectories as the drivers of feared outcomes, rather than globally scaled ecological threats. These challenges often get glossed as the result of "too much" of what modernity, development, and ongoing capitalist expansion have wrought. Recent accounts of water management in Australia are exemplary of this type (Allon & Sofoulis, 2006; Sofoulis, 2005; Strang, 2009). A study of concerns over water conflict and pollution in two Australian river catchments details the widespread belief that the current arrangement of too many people carelessly using too much of a vital resource has put local communities on a trajectory toward ruin (Strang, 2009).

Ironically, concerns about water supply depletion may be used to justify an intensification of the high modernist water development paradigm that produced those very problems in the first place. We see this tendency when fears of future scarcity are mobilized to justify building additional dams and aqueducts, or new water production technologies like desalination and recycled water (Günel, 2016; Meehan, Ormerod, & Moore, 2013; Stensrud, 2016b; Strang, 2009; Swyngedouw, 2013). In many cases, these efforts to produce new liquid futures are shaped by principles of "good" water management forged in the international community, like cost recovery, user participation, and sustainability. Sometimes, novel projects of ecosystem management are enacted in the name of "securing" stable water supplies. Such projects often encompass different spatial or legal logics even if they fail to challenge dominant modes of water consumption (Carse, 2012; Lakoff, 2016; Randle, 2016). Urban political ecologists have been quick to note the ways in which projects of this kind represent continuities rather than breaks from processes of capitalist urbanization. These observations are bolstered by framings of such efforts as "sustaining" existing sociohydrological arrangements (Gandy, 2014; Kaika, 2004; Swyngedouw, 2015). Scarcity-justified efforts to privatize water systems, framed within discourses of future stability through market efficiency, have been analyzed in similar terms (Bakker, 2005, 2010; Strang, 2004). In all these cases, the high modernist ideal of a rationalized, wholly human-controlled future waterscape continues to animate water management efforts, despite evidence that such an outcome is increasingly out of reach.

Accounts of responses to water pollution also document anticipated futures of further waterscape degradation and broader forms of environmental risk. These studies elaborate a widespread sense that unless the current course of development and waste management is remediated, the rivers, basins, and water infrastructures in question will decline to a catastrophic, potentially even unusable, extent (Alley, 2002; Gandy, 2002; Kaplan, 2011; Karvoven, 2011). These concerns are, in some circumstances, mobilized to limit further development, halting or moderating landscape transformation. In Kathmandu, building and settlement restrictions enacted to improve the environmental quality of the city's riverbed are an example of this (Rademacher, 2011). In contrast, in cases of dam removal and river restoration, the desirable future is discussed as a return to the landscape's earlier, "more natural" configuration (Fox, Magilligan, & Sneddon, 2016; Lave, 2012). All of these efforts suggest the emergence of waterscape futures articulated in terms of an idealized environmental past. This is a considerable departure from the visions that underpinned earlier eras of water management.

Increasingly, discussions of the waterscape's future are mediated through the tools of hydrological and climatological modeling. While these forecasts are technically sophisticated, in many cases they are also based on partial, fragmented data from existing water networks, the incompleteness of which is rarely acknowledged in state accounts of the systems (Anand, 2015; Bjorkman, 2015). Although predictions for the future of water are typically articulated by state agencies as technical, numerical assessments, in practice they can be uncertain and politically mediated (Ballestero, 2015; Barnes, 2016). Once released, the figures become enrolled in a range of narratives and framings of local water in/security (Brooks, 2016). The rise of this mode of representing waterscapes and their trajectories suggests a shift in the terms with which water futures are claimed and framed. At the same time, while the tools and framings are new, there is a continuity between such efforts to make water (and its future) legible and similarly-motivated efforts from previous decades. Despite the uncertainties of climate change, the notion of natural systems as knowable and predictable persists.

The consistent theme throughout these accounts of contemporary water management systems is a sense that, barring dramatic intervention, the future is a time of waterscape decline. Across a diversity of systems, water managers have come to read their networks according to a narrative of a downward telos. Framing contemporary arrangements of water and overall ecological management as either tenuous or dangerous achievements, these visions of future waters align with a general trend toward ecological anxiety during the current period.

5 | CONCLUSION

Our analysis makes clear that imagined water futures have long shaped practices and institutions of water management. The dominant modes of imagining the waterscape-to-come have varied widely across space and time. Enduring irrigation networks have been understood as buffers against local environmental collapse, as tools for dealing with expected climatic and hydrological variability. They have also served as conduits for achieving desired landscape transformations, expanding cultivated acreage and supporting larger populations. High-modernist waterscape interventions extended and intensified such visions, driven by a desire and belief in the human ability to radically rework and control the environment through new infrastructures and institutions of water management. Water managers envisioned and aspired to produce an experience of minimal environmental disruption related to water, in the form of either scarcity or inundation. These efforts to produce a steady, "modern" experience of the environment both reflected and helped produce dominant state notions of temporality and futurity, as well as a robust sense of humans' ability to control the waterscape. Increasingly, assumptions of ongoing (or future) environmental decline underpin efforts to change the waterscape. The sense that the water arrangements wrought by the high modernist paradigm hold the seeds to their own destruction—or at least polluted and inadequate watercourses supplies—hangs over these systems. This regret for the loss of "pristine" past waterways is structured by a fear of coming perturbation or collapse.

Given all of this, we can read climate change-driven efforts to produce "resilient" water systems as continuations, rather than aberrations within the long history of water management. Anthropogenic climate change may necessitate calculative, representational, and infrastructural tools to know and manage the future that are novel in their scale and scope (Hastrup, 2013). Yet we should see these initiatives in their broader context, as the latest in a long line of human efforts manage systemic variability and produce particular forms of desirable environments. We should also seek to learn from past mistakes and exclusions as we pursue these emergent water ideals.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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