16 Infrastructure Hydromentalities

Water Sharing, Water Control, and Water (In)security

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Introduction

This chapter addresses interrelationships between water security and water infrastructure. The premise of the chapter is that water security is defined by an ethos of, and attempts at, water sharing amongst users experiencing water variability and scarcity. As is explained below, sharing partially meets the Grey and Sadoff (2007) concept of security achieved through water sufficiency: 'the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production' (p545). The chapter proposes a water-management framework (termed *water meta-control*) that puts 'share management' alongside 'demand management' and 'supply management' and explores all three via an infrastructural lens. I argue that choices over structures for controlling water are greatly influenced by past and current infrastructural fashions and trends that I term *hydromentalities*. Cultural and sociopolitical influences arbitrate engineers' choices, while views held by water users are intangibly mediated by arrays of nearby and distant infrastructure. Without deeper reflection, water infrastructure will be unable to meet the growing challenges of climate change and water distribution (Pahl-Wostl, 2007; Giordano, 2013). By considering an infrastructural lens, I offer this definition: Water security seeks, and is consequent to, the sharing of water surpluses and deficits between different users mediated by the designed architecture of water infrastructure deployed to address the spatial, temporal, and scalar complexities of demand and supply. Although this definition ostensibly corresponds with a narrow volumetric deterministic concern for water (in)security (Zeitoun, 2011), this framework seeks to highlight the interplay between water security, the challenges and technologies of control, and cultures of water engineering.

In a context of growing water competition and variability, water insecurity may be characterised by volumetric shortfalls and poor timing and misallocation of water resulting in uncertainty and inequity amongst users. These intertwined effects are mediated by the types of infrastructure selected for different sectors (e.g., irrigation). However water insecurities (insufficient and poorly distributed water volumes) arise because these infrastructures are not considered coherently. Thus, water insecurity results not only from a lack of infrastructure to face water-related impacts of climate change (Jowitt, 2009), but also from how infrastructure is put together to serve increasingly interconnected users and sources. Because water is distributed by being divided (flows bifurcate), infrastructure ostensibly for one purpose jointly determines water supply for other sectors and thus affects the manageability of water apportionment. Moreover, present-day infrastructure as an expression of previous fashions is unlikely to have arisen as a single impartial coherent plan ready to face contemporary problems. Furthermore, infrastructure is costly, long-lived, and not easy to alter (Stakhiv, 1998; Giordano, 2013).

Enhancing water supply and control across multiple users and scales is difficult, elusive, and socially mediated. A question arises: Can we design river basin, irrigation, environmental, and domestic/sanitation infrastructure in ways that fit together to promote the timely, transparent, and accurate placement and allocation of water for productive and protective human/ecological needs, while offering communities opportunities to reflect on their space, technology, and context-mediated water knowledge? To examine this question, a theoretical framework termed *water meta-control* is proposed. This framework addresses the control structures employed for apportioning water to multiple sectors, uses, and users from local to regional scales. I consider control in this comprehensive sense to be missing from engineering debates. Instead, water technologies and debates are diminished by reference to trends and fashions such as 'small scaleness'. For example, small-scale irrigation received great interest in the 1980s and has continued to dominate donor and researcher interest.[1] This prompted Scott in 1996 to redefine 'appropriate technology' away from being simple, small-scale, low-cost and non-violent to being based upon technique, knowledge, organisation and product (Scott, 1996). This is less prescriptive and more accommodating of the complex interrelations between water, technology, and people.

Within the word limits of this chapter, the framework is far from comprehensive and cannot be used to reconfigure water infrastructure. Rather, the 'design biases' of the framework serve as a reminder for engineers and social scientists to think more cautiously about water engineering and water security outcomes. I move beyond storage as the means to solve water insecurities/scarcities because without a parallel emphasis on sharing, water securitisation via supply augmentation may not remove water insecurities (and perceptions thereof) during periods of scarcity or when demand increases to take up the new supply.

The chapter is theory-based and informed by my PhD research conducted in the 1990s on irrigation design-management interactions. As such, this chapter is concerned with insecurities arising out of scarcity, not those associated with damage caused by floods (Stakhiv, 1998; Grey and Sadoff, 2007) for which different types and functions of infrastructure are required.[2] This analysis incorporates as only one factor the problem of individual or cumulative infrastructure sizing and capacity to address changing river regimes as a result of climate change (Rogers, 1997).

Water Control and Water Security

I use the term *water control* for describing the challenge of a water apportionment (rather than as meant in the political sense of 'taking control of water', e.g., Boelens, 2008) that encapsulates an aspiration to improve the sharing and placement of water for the many, not to securitise water supplies for the benefit of a few. This is water control in the manner explored by the World Bank (Plusquellec, 1994) and FAO (Renault et al., 2007) in their irrigation studies, but especially as defined by Bolding et al. (1995), where the authors defined water control as central to the political economy of water distribution. This paper also suggests that without explicit reference to infrastructure-induced control, different users gain at the expense of others, particularly benefitting during times of water contraction and scarcity. Nevertheless, it would be naïve to suggest that the two senses of control are unrelated; questions arise over whether poor apportionative control plays into the hands of those wishing to 'take control' over water.[3]

Stepping back, I believe that four physical 'drivers' imprint themselves on patterns of water distribution. This chapter seeks to highlight the role of infrastructure as one of those. Three other drivers are: rainfall patterns influenced by weather and climate (influencing the severity, location, and unpredictability of droughts and floods); the topography and natural drainage patterns of the catchment (influencing the runoff characteristic and location of streams, floodplains, and wetlands); and the soils and geology of the catchment (influencing runoff and water in soil and aquifers).[4] These four suggest that water security emerges from a natural and human placement of water in the volumes required in ways that communicate to water users the manner, proportions, and volumes of water that can be stored, pumped, abstracted, conveyed, and divided.[5]

I distinguish water control and meta-control. The former tends to see apportionative control as sitting within sectors or in particular localities; it draws on well-worn technological procedures and leads to discrete infrastructure packages such as canal systems. Metacontrol encapsulates a broader field of control covering all scales (from fields up to river basins) from local to distant localities; it addresses all users and sectors; and it selects multiple technologies from different schools of technology. It is the wider vision of this water control that shapes river basin infrastructure architectures. Readers will note that I take the river basin as the unit of water management to examine water meta-control.[6]

Supply and Demand Management—and Water Security

This chapter allies water security to water scarcity and takes the view that water security comprises two main dimensions: improving the volumetric sufficiency of the balance of supply over demand, and the distribution of that adequacy (whether in surplus or deficit) more equitably to multiple and disparate users. This dual approach argues that water security is not solely predicated on creating positive surpluses. In parallel to this adequacy puzzle, society also faces challenges related to the distribution of surpluses and shortages to many users and uses. Moreover, this distribution should be seen as fair and transparent and therefore it has social 'equity' and informational dimensions beyond quantitative aspects.

One of the most common entry points for addressing the first part (adequacy) is to solve the equation of supply over demand either through supply management or demand management (Tortajada, 2006; Lautze and Giordano, 2007). I shall explain their common understanding before explaining how they might also address water sharing. Supply management is the notion that in order to solve scarcity, more fresh water needs to be sourced, built, or otherwise obtained. Five examples of supply management include dam building (Lautze and Giordano, 2007), installing boreholes (or deeper boreholes), inter- or intrabasin transfers of water (Gupta and van der Zaag, 2008), catching rainwater in small storage bodies (Wisser et al., 2010), and desalinising salt water (Tortajada, 2006).

Demand management attempts to solve water scarcity/sufficiency by reducing demand and is usually understood by three parts. The first is the reduction of the net demand; in other words, the cultural, political, and economic decisions that affect the original source and amount of demand. Examples include decisions over the total number of houses built in a given area or publicity efforts to reduce garden watering during a drought. The second is the reduction of inefficiencies and losses in meeting net demand (in other words, the reduction of the gross demand for a given net demand). The third is pricing water so that the cost of using the resource pushes down net demand and nonbeneficial losses (exemplified by rising tariffs in Singapore described by Tortajada, 2006). Although infrastructure is more commonly associated with supply management, infrastructure is also required to deliver demand management—for example, equipment to reduce losses, to meter, and to precisely place water. However these two 'paradigms' are rarely analysed in terms of water sharing. For example, Pahl-Wostl (2007) refers to supply and demand infrastructure to reduce variation in supply and demand but omits the topic of water sharing elicited by the same infrastructure.

Infrastructure Design-Management Interactions

For the purposes of addressing catchment societal water security via a meta-control infrastructural lens, I adopt 'design-management interactions' from an irrigation perspective and apply them to the whole catchment. Design-management interactions were expressed adroitly by Bos in 1987: 'water management in future irrigation schemes could be improved if systems were designed in such a way that their proper management would be as easy as the mismanagement of existing systems' (Bos, 1987). This question asks if we can 'design in' water apportionment in ways that fit formal and informal property rights and supply and demand patterns over time and space (Lankford and Mwaruvanda, 2007). My rationale for applying this irrigation perspective to the catchment is threefold. First, canal systems are proxies of the problem of apportioning and scheduling water to different sectors within a catchment. They share features such as hierarchies of networks, limited (or absence of) within-system storage, the timing and times of flows, and social perceptions about water distribution in the face of lack of information or poorly designed networks. In other words, water sharing is not effected by giving storage to each irrigator but by the bifurcation of canal flows. This relationship between sufficiency and distribution was identified by Stakhiv (1998, p160):

> In fact, it can be said that much of water planning is inherently concerned with implementing anticipatory measures that are designed to either meet future demands or avoid future damage due to floods and droughts. It should be recognized that the origins of water resources management lie with the rise and evolution of civilizations, centering on the need to control and distribute water for agriculture.

Second, with increasing scarcity and basin closure, rivers take on canal-like properties of distributing water to competing sequential users with limited room for error and environmental flows. Third, irrigation is a major water consumer in semi-arid basins, influencing river hydrologies by placing abstractive and depletive infrastructure in the catchment.

In highlighting this topic, I reflect on an influential debate that originated with Lucas Horst in Wageningen University (Diemer and Slabbers, 1992), who argued that two solutions should be applied to the question of apportionment of water in canal systems: simplification and automation (Horst, 1983). Simplification argues that gates used to adjust flows on irrigation systems are built very simply so that humans can make adjustments 'easily'. Automation favours taking humans out of the picture by introducing the use of computer- and radio-controlled gates or self-actuating gates. Yet other 'schools' of design can be considered, for example, structured systems (Lankford and Gowing, 1997; Albinson and Perry, 2002), which argue that water apportionment arises from more than just gate technology. Instead matters such canal density, the ratio of command areas to flows, stricter irrigation scheduling, and the fit between gate sizing at different canal levels also play a role. Choices between design schools provide the basis for a water meta-control framework.

A Proposed Framework for Water Meta-Control

A proposed framework for water control is given in Figure 16.1. This framework captures the question phrased by Molle and Mamanpoush (2012): 'the actual apportionment and distribution of water and how management incorporates, and responds to, hydrologic variability and uncertainty. Water sharing may be more or less responsive to this variability, and diversely transparent/equitable and technically efficient'. This question (and the framework of this chapter) distinguishes three dimensions to how society, working through engineers and artisans, approaches the sharing of varying

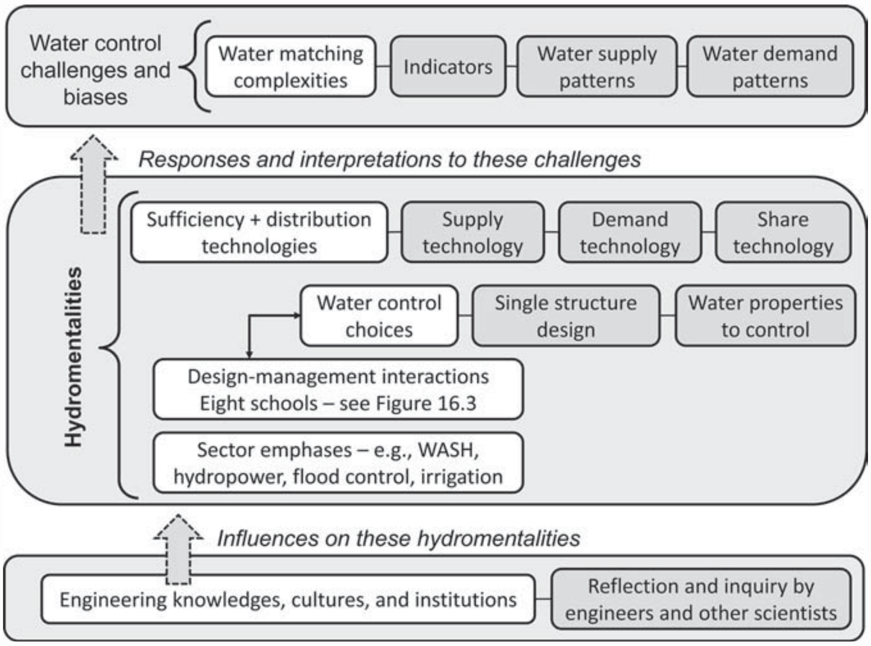

Figure 16.1 Water metacontrol framework leading to water architectures

amounts of river basin water. Each is covered by a grey cell in Figure 16.1 and by a subsection below.

Water Control Challenges and Biases

The challenge of water control arises from the complexities, uncertainties, and patterns of supply of and demand for water (Rogers, 1997). Individually these are complex, but it is the overlay or matching of supply influenced by many factors (for example, slopes and relief, crops, agrometeorology) and demand influenced by many factors (for example, command areas, soil properties, population, households, and per capita demand; urban and industrial factors) that create complex patterns of excesses and deficits in turn to be managed by people using infrastructure. These patterns require indicators that assess how well management is provided; indicators such as equity, adequacy, and efficiency are commonly known. These indicators also establish a question over the design of the type and prevalence of measurement structures to allow performance to be assessed.

Hydromentalities

There are four types of hydromentalities that respond to the water control challenges discussed above: sufficiency and distribution technologies, water control design, design-management interactions, and sector emphases. I contentiously cast these hydromentalities as interpretable, subject to preferences, and for the most part lacking critical awareness. In other words, current water control architectures are mostly the product of accidental biases and fashions.

Hydromentality uses Agrawal's idea of environmentality: '[Environmentality] refers to the knowledges, politics, institutions and subjectivities that come to be linked together with the emergence of the environment as a domain that requires regulation and protection' (Agrawal, 2005, p226). *Hydromentality* refers to the water engineering knowledges, consultative references, politics, and institutions that emerge in response to water control challenges as a complex domain leading to water architectures that mediate the manageability of water apportionment in river basins. Hydromentality captures the linking and co-emergence of water control challenges, cultures of control design, overlapping infrastructure experimentations, and the extant control and distribution of water.

Sufficiency and Distribution Technologies—Towards Sharing

To review supply and demand management, introduced above, and to introduce share management (Lankford, 2011), I refer to Figure 16.2, which shows a typical unit of water management that contains structures that meet

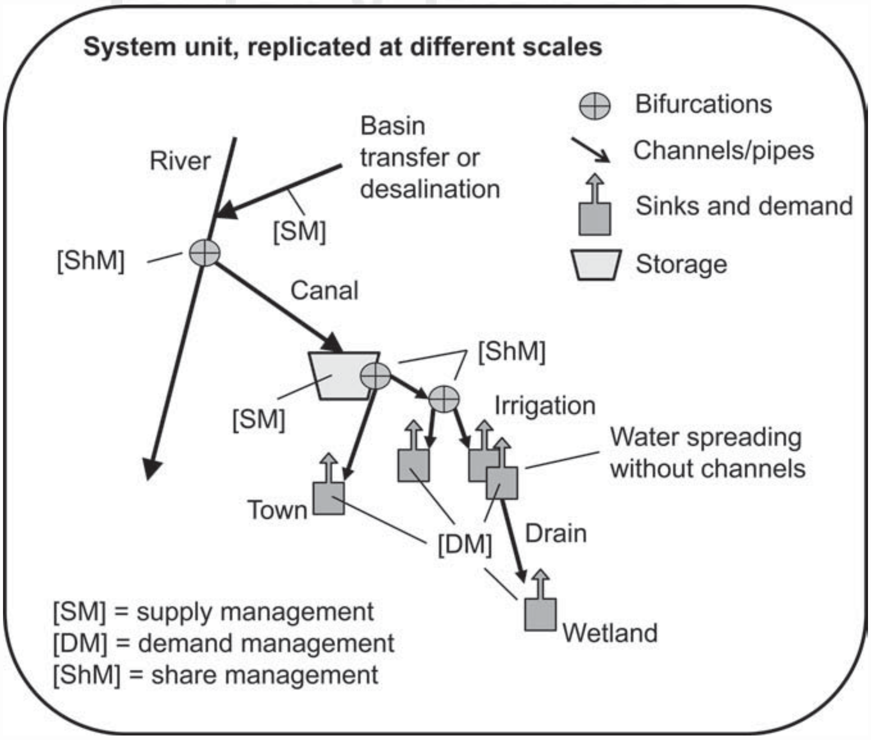

Figure 16.2 A basic model of water management and flow bifurcation

some of the functions mentioned in the previous section (water conveyance, bifurcation, storage, and depletion). Figure 16.2 shows that the distribution of water sufficiency comprises a complex mix of approaches. The meta-control framework asks: How do these different components fit together to influence the accuracy, transparency, flexibility, equity, and adequacy of water distribution in the face of variable supplies?[7]

This framework argues that structures closely associated with either supply or demand management also have 'share-type' functions. For example, a dam ostensibly acting to boost supplies also affects water sharing. It does this in two ways. First, it creates a body of water that is subject to claims over access, and therefore matters such as volume, function, and location shape those claims. (A small dam without hydropower will 'share' water differently between claimants than a large dam with hydropower installed). Second, a dam disturbs an otherwise 'natural' river regime both by storing a flood volume and by creating an area of evaporation from the lake behind the dam wall. The implicit outcome is a subtraction from an otherwise pristine environmental flow and a distribution of water away from 'the environment'. Supply and demand structures are also structures with specific 'share' functions, making three types:

- Supply-share structures are designed to augment supplies. They work over time to even out periods of deficit by storing or boosting water supplies and then sharing surpluses. Examples are storage dams, canals, or pipes that transfer water in from another basin and desalinisation plants or within basins. As explained above, the supply-side orientation also shapes the sharing of water between users and sectors. Thailand's putative water grid project (Molle and Floch, 2008), aiming to even out deficits and surpluses at a regional scale, has both supply and sharing within its ambit.
- Demand-share structures intend to reduce net or gross demand via a variety of means. Conceptually, these are more difficult to characterise than supply structures. However, the aim of such structures or modifications is fourfold: to reduce leakages and spillage, to improve the precision placement of water where required, to consider the time and timing elements of water supply, and to assist with knowledge of demand such as metering. The latter recognises the additional pressures that can be brought to bear on demand by pricing and property rights. These structures, while encouraging the reduction of demand, are clearly involved in the sharing of limited water—one follows the other.
- Share management structures aim to distribute water rather than boost or reduce water supplies. The two main types are bifurcations/connections and conveyances such as canals and pipes. They serve two main functions. The first is to divide varying flows between demands, introducing both a quantitative element but also a social issue of discerning this bifurcation and its transparency in the face of multiple competitive demands. The second is to place flows accurately for a given source and

volume of demand. The outcome of these two functions is to even out locations of deficits by dividing and moving supplies of water. Another way to think of these functions is to consider how water might be distributed in their absence; water would spread or spill across land or a landscape in a much more haphazard way.

Seeing structures in this way allows engineers and society to reconsider the various emphases and fashions that have influenced choices over structures—for example, whether to build storage or add metering. The aim of 'share' characterisation is to suggest that a focus on only demand or supply fails to deliver a coherent infrastructure that can accommodate ever-increasing complexities of distributing marginal water sufficiencies to multiple users.

Water Control and Single Structure Choices

Connected to design-management interactions (the next section) are a subset of water control complexities associated with single structures. An example is an irrigation control gate, part of a wider irrigation system. These control complexities comes from an interplay between water properties to be controlled and the structure's design parameters to control these properties. Water properties are: depth, velocity, volume, level/head/energy, flow rate, percentage division, location, timing, and duration. Physical structures control these properties by containing parameters and functions of convey, on–off, adjust/raise/lower, divide, join, maintain, clean, dispose/deplete, store, measure/be recorded, and be observed. These functions are interpreted often by 'schools of design management interactions' (below) to create user-facing and system-facing assemblages and arrays of structures throughout the river basin. However, hydromentalities apply to single structures; irrigation managers experiment or stick with structures to control water, adopting (for example) modular gates, constant-head orifices, variable orifices, and wooden sluice gates. My PhD research in Swaziland found that sugarcane estates explored gate technology within and between the estates without considering the relationships between gates, flows, and the command areas they served.

'Schools' of Design-Management Interactions

Drawing on design-management interactions, Figure 16.3 captures eight 'schools' of engineering responses to water management. A school of design-management interaction is a particular type of hydromentality that packages a sufficiency-apportionment approach under a single label heralding a protagonist's expectation that 'their' school offers the optimum way to manage water.

- *Aggrandisation*. Here the emphasis is on bold large-scale projects and structures, such as very large dams and water transfer projects. As seen in Spain and a future Mekong, large dams boost supply while 'mega grids' ideas reveal supply-side thinking (Molle and Floch, 2008).

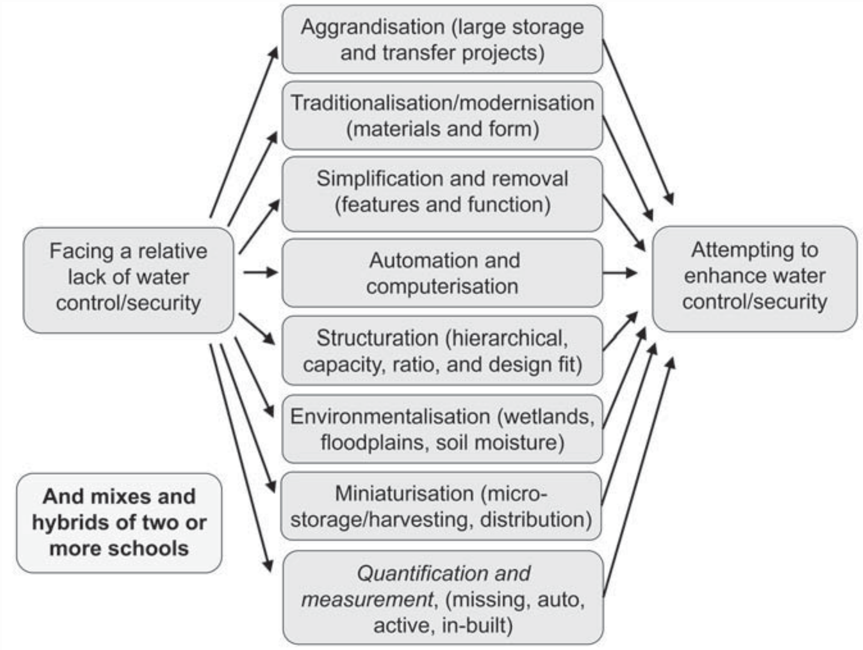

Figure 16.3 Water engineering schools of design-management interactions

- *Traditionalisation versus modernisation.* Engineers sometimes fail to distinguish that the form of, and materials used in, the structure are different to the functions contained within them. Irrigation 'modernisation' assumes that existing local artisanal structures are without merit. Modernists might mistakenly improve traditional systems when not required (Pradhan and Pradhan, 2000; Lankford, 2004a).
- *Simplification and removal.* Horst (1983) argued that one of two solutions to the problem of water control was to simplify water architectures. Examples include moving to very simple division gates that required minimal adjustment found on rotational 'warabandi' systems in Asia. While effective, the risk is such designs are unable cope with changes within those systems, such as cropping patterns, farm size, and expansion.
- *Automation and computerisation.* Horst's other water control solution was to move towards highly automated and computerised systems of control. With the advent of computers, radio control, telemetry, and remote activation in the early to mid-80s, this school was thought to represent the future of water control on large scale systems (e.g., Schuurmans et al., 1992). While this technology works well in some environments, it has not always lived up to its promise in remote semi-arid locations, also experiencing unreliable power supplies.
- *Structuration.* This mode of providing water control was missing from Horst's two-way solution and yet is seen on irrigation schemes worldwide.

Structuration offers water control by ensuring a high level of fit between upper levels of water supply (headworks, main and secondary canals) and the lower levels of supply and demand (tertiary canals, farms, fields, furrows, and earth canals). Albinson and Perry (2002) and Lankford (1992) explore a modular structured approach to water control. One criticism is that these are not flexible on-demand systems. In response, one can argue for the benefits of predictability of fixed schedules. Systems can be attuned to periods when evaporation and crop growth is at a maximum, making their operation during cooler or off-seasons feasible by on–off switching and rotating of flows.

- *Miniaturisation.* In parallel with other engineering is a trend towards micro-systems to promote local ownership and precision. Examples include micro-storage/harvesting of water on a farm, and the distribution of water to the crops using micro-systems such as drip. Miniaturisation applies to all demand, supply, and share structures, but any optimism about the ability of this approach to deliver local solutions or highly efficient control must be set against the likelihood of an increase in resources required (human, construction, energy, plastics) and a highly atomised approach to water delivery and control that might undermine precision of control at the catchment scale.
- *Environmentalisation.* This examines the role that features of the environment (wetlands, floodplains, soil moisture) play in assisting water distribution. IUCN in their 2009 report 'Environment as Infrastructure' explored this topic but could have made more of the idea by inquiring of its ability to mediate water sharing and distribution under different conditions or of how additional built infrastructure extends and intensifies environmental benefits (Pittock and Lankford, 2010).
- *Quantification and measurement.* Alongside the storage and distribution of water are fashions about how to measure water supply and distribution. Designs may be missing, or require active human measurement, automatic measurement, or deliver 'built in' measurement (Lankford, 1992), or focus on water flows, depths, or proportions.

Other than the briefest of outlines given above, one other point can be made. At any one given place or time, hybrids (these are structures that merge ideas from the eight schools within one system), mixes (where separate but coexisting structures are utilised within one system) of the above are in action. I speculate that this hybridising and mixing needs to go further; water apportionment is best served by a selection of designs from all eight schools.

Sector Emphases

The final hydromentality arises from donor and government interventions steered towards particular water sectors in response to public and advocacy influence. Typical sectors include water and sanitation (WASH), irrigation, urban-industrial, environmental works, hydropower, and flood control. I have also included IWRM (integrated water resources management) and RBM (river basin management) for their place in shaping donor agendas, and recent interest in the water–energy nexus (SEI, 2011).

The inclusion of these sector emphases in the meta-control framework provides three insights on achieving water security by water distribution. The first is that one sector promoted at the cost of others creates lopsided water infrastructure. Grobicki (2009) argues for a more comprehensive approach to all water sectors. The second is that the professions active within each sector rarely reach across these sectoral boundaries. Thus, the implications of a sectoral focus on irrigation alone for meeting downstream needs are potentially severe if declining water supplies observed during droughts and dry seasons cannot be shared fairly (Lankford, 2004b). The third insight regards the hidden costs for water control by 'omission'; that selective competition for donor and government resources by water sectors obfuscates a more purposive holistic approach to water architectures. While IWRM and RBM should have provided an integrated approach, an examination of IWRM (Biswas, 2004; Neef, 2009) shows that it has been remarkably silent about water infrastructure.

Engineering Cultures

The third part of the hydromentality framework in Figure 16.1 is concerned with engineering and other stakeholder knowledges that feed into choices over design. These knowledges struggle with solutions that appear sensible but might not meet the scalar, variability, and connectivity dimensions of water control. Because of this lack, water debates are more likely to be captured by popular yet unproven fashions outlined in Figures 16.1 and 16.3 (e.g., small scaleness, boldness, and emphasis on storage or demand management).

There can be much written here about the interplay between water engineering, existing technology, natural environmental stresses, and long-standing educational and cultural factors (e.g., Trawick, 2001). Zwarteveen (2008) argues that engineers' subjectivities, epistemic communities, and reference points 'impact on their methods and conceptualisations'. Due to space constraints, I shall argue that an architectural theory and practice of water arises from two interrelated weaknesses related to the educating and socialising of water engineering. The first is that the engineer's task of creating architectures rarely puts people at the centre of the design process in ways that communicate the scarcity of water and its bifurcating nature. Instead, I believe, process is dominated by professionalised training and norms (Chambers, 1992; Lankford, 2004b; Zwarteveen, 2008) or is skewed by the terms of commission (c.f. the role of public–private partnerships in Morocco described by Houdret, 2012). This means that during the steps of the design process, the engineer insufficiently sees the system through the system's eyes (a phenomenological approach) or through the eyes of communities expecting to voice but not fully understand their concerns over water shortages.

The second weakness arises from a poorly articulated engineering objective. This should be the result of the process chosen (above), yet aim to create operable, transparent, structured, hybrid architectures that lean towards high levels of manageability of the complex problem of water sharing and distribution. In this second aim, one 'ergonomic' factor (Chapanis, 1996) should be kept uppermost: Designs usually fail to consider 'normal' human actions such as a desire to set gates and valves at their widest or highest setting, which skews water division towards privileged groups normally at the top end of the system.

The objectives in the previous two paragraphs are not solely the engineer's responsibility. Society's failure to hold engineering to account can be blamed on a number of factors—not least a lack of recognition of the abstractness of designing physical artefacts but also a dismiss of matters 'technical' matters, leading over time to a diminution of the engineering profession[8]. In addition are sources of critical thinking over how society experiments with water and then critically examines outcomes to rephrase new approaches and objectives. Four influential communities are identified that could enliven and shape a debate on water control but which, I speculate, are largely absent or ineffectual (Table 16.1).

Table 16.1 Critical communities influencing engineering learning and knowledges

Community	*Beliefs / objectives*	*Units and ideas*
Political ecologists	An observation of the changes in narrative associated with society's experimentation with water apportionment	Tradition, modernity, 'scale-ness', cultures of learning, terms of the debates
Water users, representatives, and social scientists	Engagement with negotiation and impacts of water control by various actors, with a particular regard for communities and individuals treated (in)equitably by water technology experimentation	Community, access, equity, water poverty; water user associations.
Other water engineers	Bringing differently trained engineers into the debate might lead to reform of professional norms within sectoral protocols	Design protocols, procedures, training, qualifications
Donors funding systems and reviews	The commissioning of projects that respond to perceived problems—for example, the millennium development goals of water and sanitation, with consequences for other investments in water	Social, environmental and economic priorities—costs and benefits; investment schedules and tools