

# Managing complexity in Australian urban water governance: transitioning Sydney to a water sensitive city.

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## Abstract

Recognising Australia’s need for water management that better supports urban populations facing increasing socio-ecological challenges, the study on which this article is based brought together professionals from Sydney’s water sector to understand what they believe is entailed in transitioning Sydney to a water sensitive city. Participants called for new institutional arrangements requiring collaboration and leadership from various levels of government, community groups and individual community members. We adopt Tainter’s model of social complexification as an analytical framework for considering the implications of the research findings. From the perspective of this model, we argue that the proposed arrangements would involve, along with the envisioned benefits, increasing complexity and commensurate costs, with important consequences for the forms that water sensitive cities might take.

Considerations relating to the costs of complexity take on particular importance in futures for which reduced material affluence appears increasingly possible. The costs of complexity under such conditions may be more readily ameliorated via pathways that entail increased local responsibility for meeting water needs, such as decentralised rainwater harvesting. We argue that increased participation in water-related governance and responsibility for related infrastructure will follow more readily from measures to foster local enthusiasm than from mandated approaches that themselves require increased complexity.

**Keywords.** Urban water management; water sensitive cities; Joseph Tainter; decentralised water systems; enthusiasm; resilience.

## 1. Introduction

There is an urgent need for more sustainable forms of urban water management in Australia. Between 1997 and 2009, Australia experienced a severe drought known as the ‘Big Dry’, which was followed by unusually strong ‘La Nina’ conditions causing severe floods across the country, billions of dollars of property damage and the deaths of 35 people [1,2]. Due to the uncertainties attending such climatic extremes and given the growth rates of Australian cities [3, 4], future water stress is anticipated. One response by state governments has been the construction of desalination plants to boost water supplies in every capital city [4].

Requiring large amounts of energy to function, desalinisation plants have been critiqued as a ‘maladaptation’ to climate change where their functioning results in the increased output of greenhouse gas emissions [5]. Thus more needs to be done to ensure Australia’s urban centres are made resilient against a number of potential shocks associated with drivers such as climate change, population growth, natural disasters and financial crises if the well-being of Australia’s urban residents is to be maintained at a level to which they are accustomed [6]. Water sensitive cities (WSCs) are envisaged as an effective form of response to various problems associated with extreme weather, climate change and other unpredictable phenomena, as conventional forms of urban water managing do not cope with these adequately [7].

While no city was spared the consequences of the ‘Big Dry’, Sydney experienced a particularly severe water crisis from 2003 to 2007, with population growth and water consumptive lifestyles compounding the effects of drought and climate change [3]. This has highlighted the urgency of finding sustainable water supplies and a sustainable approach to water use for Australia’s largest city (population 4.6 million) and capital of the south-eastern state of New South Wales. Since Sydney’s water sources are located far from the city and in areas already suffering from water shortages, Warner [3] argues that water supplies can be bolstered by accessing the two sources of water already available in the city – rainwater and recycled water. The barriers to accessing these more sustainable water supplies are largely social and political, as the technology and expertise are well established [8]. Therefore, there is an important role for the social sciences, including Futures Studies, to play in understanding these barriers and designing strategies to overcome them.

It is in this context that transitioning to WSCs has been proposed as a pathway for ensuring urban water sustainability [9,10]. We conducted the research that forms the background to this article with a view to exploring what Sydney’s transition to a WSC might entail, via a participatory process with professionals involved in the city’s water management. A significant finding from the research is the association that participants drew between transitioning Sydney to a WSC and initiatives that we understand to entail increased social complexity. This provides the point of departure for our subsequent consideration of the research findings in terms of both the benefits *and* the costs of increased complexity, a task we regard as particularly important in light of the growing possibility of futures characterised by decreasing affluence. For this task we adopt as our analytical framework Tainter’s [11,12] model of social complexification and sustainability. Given the possible constraints suggested by Tainter’s model, in seeking viable pathways towards a WSC in Sydney we consider the prospects for ameliorating the costs of complexity through fostering enthusiasm for increased participation in water management at a local level.

## **2. Characteristics and History of Water Sensitive Cities**

The water sensitive cities concept is associated with a new urban water governance paradigm advocating the use of decentralised water systems [13]. It appears to be an Australian invention. According to several papers [14,9,15,16] the concept first appeared in 2004, in the founding document [17] of the National Water Initiative (NWI), the principal policy agreement for water management between state and federal governments in Australia. The first mention of the concept is a clause of the Intergovernmental Agreement on a National Water Initiative titled ‘Innovation and Capacity Building to Create Water Sensitive Australian Cities’ [17, p. 20]. Despite it being described as an ‘afterthought’ [18, p. 11], the concept of WSCs has become widely recognised. Evidence for this includes: the launch of the CRC for

Water Sensitive Cities with research hubs in Melbourne, Brisbane, Perth and Singapore; the inclusion of the concept in government policies, such as the Western Australian Government's *Urban Drainage Initiative* [19]; and the publication of Howe and Mitchell's [20] edited volume *Water Sensitive Cities*. There is thus widespread acknowledgement that current modes of managing water in Australian urban environments are inadequate and a transition is required [9], particularly as water is the central resource interlinking the water-food-energy nexus [21].

There are as yet no contemporary examples of WSCs [10]. They remain in the realm of the possible, and for their proponents, preferred urban futures. However, Wong and Brown [9, p. 676] have described three foundations critical to the development and functioning of WSCs, the first of these – 'Cities as Water Supply Catchments' – advocates the use of the city as a water catchment area through the use of water sensitive urban design (WSUD). At its most basic level, WSUD involves the capturing of stormwater for local use, which then limits the deterioration of creeks, streams and receiving waters associated with the influx of sediment, oil, litter and other pollutants from roads, drains and gutters (for detailed discussion of WSUD, see Wong and Brown [15]). Using the city as a water supply catchment increases the diversity of water sources, enhancing the resilience of cities to droughts, heat island effects and other shocks. The second foundation is 'Cities Providing Ecosystem Services' involving the provision of clean water for rehabilitating urban waterways, supporting carbon sinks and local wildlife habitats, and potentially, irrigating food crops. The third foundation is 'Cities Comprising Water Sensitive Communities', acknowledging that without community and political support, the development of WSCs is unlikely. Thus WSCs could be seen as types of 'flexible infrastructures' which assist in 'meeting a societal need under changed, or changing circumstances' [22, p. 922].

### 3. Research Approach

Following Author de-identified et al. [23], a major 'framing' assumption of the research leading to the findings reported in this article is that the transition to a WSC can be understood as a 'wicked problem' [24-26]. This means that it is an ever-changing, multi-faceted issue that resists resolution [27], and for which conventional responses involving the linear transfer of expertise and technology from one group to another is inadequate. Recognising Sydney's transition to a WSC as a 'wicked problem', we employed as our research approach *systemic inquiry* which 'proceeds by enacting a learning process with those who have a stake in a situation experienced as problematic' [25, p. 647]. In practice, this took the form of a series of structured conversations between Sydney water professionals working in complex and uncertain situations, for the purpose of participants learning how to act in concert with each other to bring about desired changes in their situation. The structured conversations took place during two events:

- 1) A two-day workshop with 119 participants, held in February 2009;
- 2) A one-day workshop with 8 participants, held in June 2010.

The first workshop involved interactive, table-based exercises, designed to encourage discussion, collaboration and mutual insights informed by the latest national and international research. The second workshop enabled researchers to appreciate Sydney's current water management situation from the perspectives of the participants, who developed a systems map of the Sydney water management system and a stakeholder analysis map. These are respectively depicted in Figures 1 and 2. In addition, a follow up survey was emailed to the February 2009 workshop participants, eliciting 48 responses. Each event was purposefully designed to enable new understandings and practices to emerge. The aim of the research

approach was to ‘develop a shared understanding of what a “water sensitive city” might look like and the associated barriers and opportunities for achieving this outcome’ and to ‘share views, knowledge and experience of the current situation relating to urban water management in general’ and Sydney’s situation in particular [23, p.3].

All participants in the 2009 workshop were employed by government in a variety of roles in Sydney’s water sector. Most participants were either from the areas of policy and strategy or design and operations, had backgrounds in engineering or science, had no management responsibility and worked in local government in stormwater/waterways or total water cycle management areas of the water cycle. The eight participants in the 2010 workshop were in middle or senior management positions. Data collected from the workshops and survey were allocated to the following categories: a) characteristics of WSCs; b) opportunities for transitioning to WSCs; c) priority actions and personal actions required to initiate the transition; and d) factors enabling the transition to occur.

In the next section, we present a sub-set of the overall research data, focussing specifically on findings that imply the need for increased social complexity in transitioning to WSCs (noting also that nowhere in the data did we find expectations that increased social complexity might *not* be required). Categories c and d above are the primary locus of these findings, and so it is to these that we direct attention here. We discuss these particular findings with reference to existing research on WSCs. In section 5 we extend this discussion by introducing Tainter’s model of social complexification, and explore its implications specifically for Sydney’s urban water governance context. The acronyms pertaining to this study are detailed in Appendix 1.

## **4. Results and Discussion**

### *4.1. Collaboration*

Participants believed collaboration amongst all levels of government was needed to transition Sydney to a WSC. According to participants, effective collaboration would involve ‘*communication between different types of professionals within and between organisations*’ and ‘*community participates fully in planning and implementation of a water sensitive city*’. The concern for collaboration was matched by an emphasis on shifting the ways water management in Sydney is conceptualised towards more holistic or systemic foci: ‘*responsive and flexible institutional regime that pro-actively adapts to extremes*’; ‘*gains achieved through whole of system, rather than “cherry-picking”*’; and ‘*water cycle is managed as an integrated component of the whole development*’.

The findings suggest participants were convinced that the then current mode of governing was not compatible with a WSC. Figure 1 depicts the major ‘systems’ that comprise the water sector in Sydney from the perspective of the eight participants in the 2010 workshop. A holistic perspective of water management would need to consider how these five ‘systems’ interact, while fostering interaction between the people who work within these systems is likely to require extensive research aimed at developing (i) more conducive institutional arrangements; (ii) appropriate ‘learning systems’ and (iii) new WSC communities of practice. Achieving this may involve the introduction of new institutions, with implications for overall increase in complexity if redundant institutions are not abandoned.

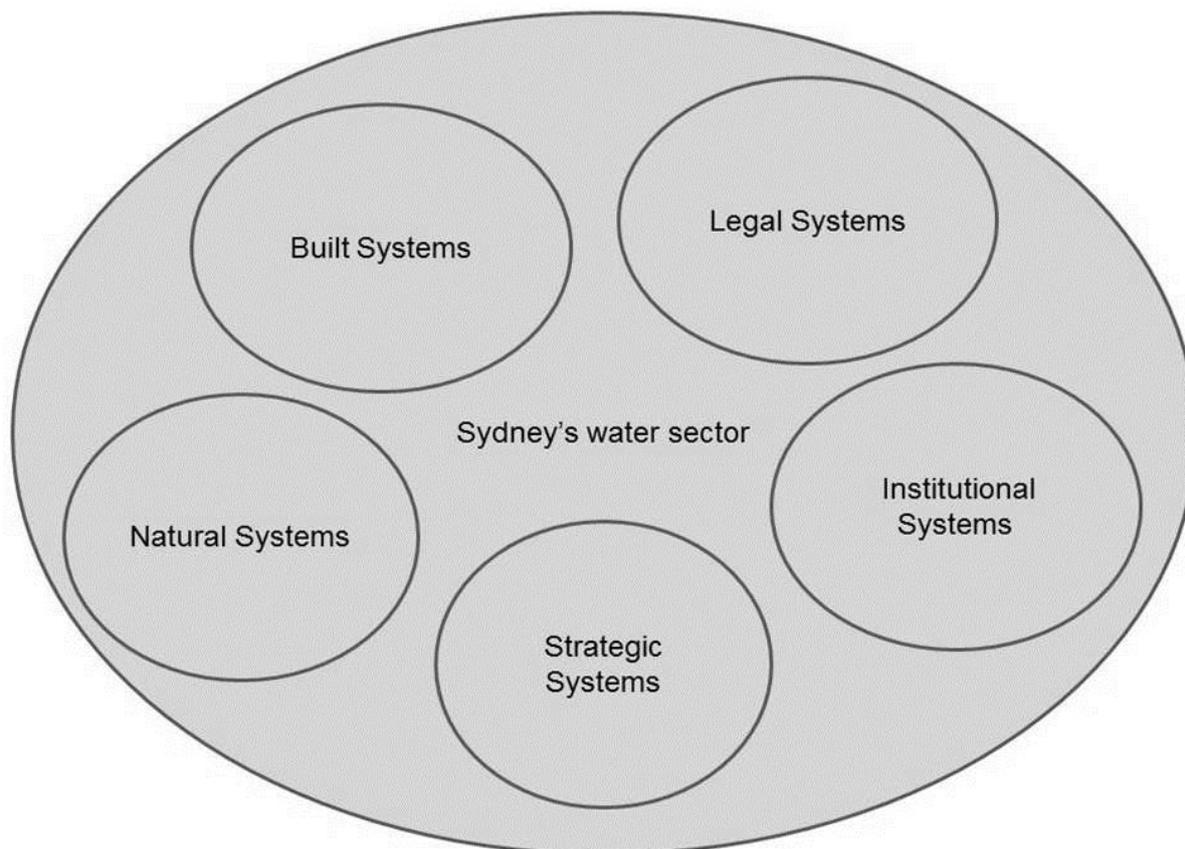


Fig. 1. Systems map – constituent systems of Sydney’s water sector.  
Source: participants in 2010 workshop.

Participants believed a diverse group of actors, such as planners, sustainability practitioners, the community<sup>a</sup>, local government councillors, catchment authorities and leaders from all levels of government, are required to collaborate to transition Sydney to a WSC. In the traditional style of urban water management, there is minimal involvement of stakeholders, with most of the decision-making and work occurring within the discipline of engineering [28]. But sustainable urban water managing regimes based on the WSC model require collaboration and cooperation between organisations [14,28]. Figure 2 depicts the stakeholders who, according to participants in the 2010 workshop, are required to collaborate to transition Sydney to a WSC. Collaboration between all ten groups in Figure 2 would change the city politically. This is similar to what Brown [29, p. 221] refers to as an ‘adaptive, participatory and integrated approach’ to sustainable urban water management, encompassing political and community commitment to sustainable urban water practices.

<sup>a</sup> We note that the category "community" on its own may not provide sufficient guidance to those seeking to diversify the group of actors involved in transitioning to WSCs. Clearly those included here would need to have some significant interest in and appreciation for WSUD, and it might be the case that an approach to "bootstrapping" this amongst citizens not accustomed to being involved in urban design or water issues could help establish this. There is also a question about how broadly this category should be extended.

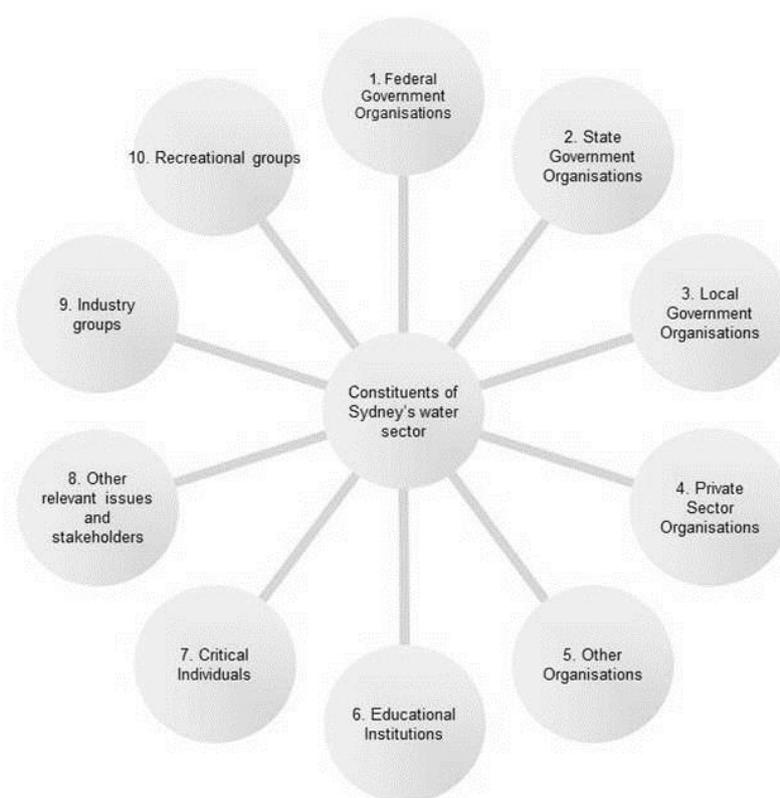


Fig. 2. Stakeholder analysis map – the ten constituents of Sydney’s water sector.  
Source: participants in 2010 workshop.

Calls for collaboration amongst participants mirror earlier studies such as that by van de Meene et al. [28] who found that transitions to sustainable urban water management systems in both Sydney and Melbourne, Australia’s two largest cities, require water professionals to have systemic appreciations of their water sector and to engage in inter-organisational and inter-disciplinary collaboration. Anticipated benefits of such collaboration include appreciation for the value of stormwater as a water source rather than regarding it as a form of waste.

#### 4.2. Leadership

Many participants believed various forms of leadership to be critical for Sydney to transition to a WSC. Participants called for leadership from higher management levels: *‘we need a high level facilitator to establish links and identify opportunities’*; and *‘need formal commitment from all stakeholders at CEO/leader level to work together’*. They also called for policy leadership – *‘state government should provide policy leadership for water sensitive cities’* and *‘form [a] community of practice to develop governance/engagement policy discussion and influence’* -- and state government funding: *‘additional funding and support for the CMA<sup>b</sup> should be given by DECC<sup>c</sup> in order to assist councils implementing water sensitive urban design’*.

<sup>b</sup> Catchment Management Authority – state government agencies responsible for natural resource management at the catchment level.

<sup>c</sup> New South Wales state government Department of Environment and Climate Change, now the office of Environment and Heritage.

Senior management support and a sound understanding of what a transition to a WSC entails were reiterated by participants as the main factors enabling such a transition to occur. The enabling power of senior management support was communicated through comments such as ‘*action through senior management and councillors*’ and ‘*commitment and support from senior management across disciplines within natural resource management, and the community*’. The call for increased senior management support was concerning because it suggests the views of more junior staff were not valued. Participants also emphasised the importance of a shift in the way local government officers are managed and trained. Several participants spoke of the need for local governments to provide their staff with training in ‘*adaptive thinking*’, and that a ‘*social learning process*’ should be initiated by councils to ‘*develop a common understanding of water related issues and the need for sustainable urban water management*’. Other quotes reinforce the importance participants placed on leadership initiatives at the government level:

- ‘a Sydney metropolitan “water sensitive city” plan guiding and coordinating councils and government should be done by New South Wales government to reduce fragmentation’
- ‘strengthen state leadership – need a champion in state government’
- ‘state government should mandate/enforce a change because local government needs stronger incentives’.

## 5. Analysis and Interpretation of Research Findings

### 5.1. Sustainability and the Costs of Complexity

Joseph Tainter is an anthropologist and historian possibly best known for his book *The Collapse of Complex Societies* [30]. His research into the mechanisms by which societies initially increase and subsequently decrease in complexity is based on the historical and archaeological records relating to past societies, perhaps most notably including the Roman Empire [31,32,11,12]. He argues that the increase in complexity of human societies observed over the past 12,000 years is not, as is commonly thought, because of an abundance of land and other resources readily available to consume [11]. Rather, complexity emerges because it is a problem-solving technique, an ‘economic function’ that people invest in, and that comes with its own costs but is pursued because of anticipated benefits [32, p. 93]. We note the implicit understanding amongst Sydney water professionals of such a relationship between problem-solving and complexity is discernible in the research findings reported here. Problem solving efforts and the increases in complexity they entail require the acceptance of various costs - in labour, time, money, energy and other resources, necessitating increased resource provision [12,32]. In other words, solving some problems can create more problems [11,32]. Thus our use of systemic inquiry, a praxis-based institution designed to engage with problem-creating problems or ‘wicked’ problems.

Despite his original research focus on the mechanisms by which past complex societies have *failed*, Tainter’s principal interest is in what this implies for the *sustainability* of contemporary complex societies. Based on the common usage of the term, he relates sustainability to the conservation of valued aspects of current ways of life [33], defining sustainability as ‘*maintaining, or fostering the development of, the systemic contexts that produce the goods, services, and amenities that people need or value, at an acceptable cost, for as long as they are needed or valued*’ [34, p. 26]. Seen in this light, sustainability requires increases in resource consumption, rather than voluntary reductions as is commonly

understood [11]. Sustainability is thus enabled by costly problem solving rather than being a ‘passive consequence of having fewer humans who consume more limited resources’ [11, p. 94].

Tainter’s focus is on complexity in an anthropological sense [12]; he draws a comparison between his use of the term and commonly-held views on the relationship between ‘civilization’ and ‘progress’ [12]. Tainter uses terms such as ‘social complexity’ [32] or ‘cultural complexity’ [11,12] to describe the differentiation in the structure and behaviour of human social systems and the degree of coordination between the differentiated parts. If the costs associated with a marginal increase in complexity are greater than a society can bear on an ongoing basis, then in the absence of appropriate intervention complexity will collapse back to an affordable level.

But an initial inability to meet the costs of complexity *does not inevitably lead to collapse*. According to Tainter [32], there are two other options – resilience via voluntarily reducing complexity, and exploitation of new resource (principally energy) subsidies. Two further options are also available. Firstly, the values of a society can change. Tainter’s focus on the costs of complexity at the *societal* level means a limitation of his work is an under emphasis on factors such as emotions, social norms and values that influence problem-response options, potential adaptations and decisions at the individual or local level, as Alexander [35] has also highlighted. Secondly, the transition to WSCs can involve transformative rather than incremental change. As Ferguson et al. [36, p. 264] explain, ‘transformation in an urban water system would involve radical changes to the way in which water servicing is planned, designed, constructed, operated, managed, governed and valued, in order to achieve more sustainable outcomes’. Transformative change can reduce complexity, if it involves abandoning any existing institutions that are redundant in the WSC context, and if new institutions are designed specifically with this intent.

### 5.2. Implications of Tainter’s model of social complexification for transitioning to WSCs

We shift focus now to discuss implications of Tainter’s model for transitioning Australian cities to WSCs, using Sydney as a case study. While the potential benefits of WSCs are well documented, the costs associated with transitions to WSCs, particularly in the context of increasing institutional complexity in the Australian water sector [37], have to date received less consideration in the literature. We think it prudent that this be given greater attention, as it is highly plausible that the development of WSCs will need to contend with general conditions of decreasing rather than increasing affluence. That is, there is a significant possibility that the task of funding development of WSCs will face a contracting resource base. While such contraction can have various proximate origins, most notably those associated with financial crises, the longer term case for treating this seriously relates to the prospect of decline in the net production rates of the conventional primary energy sources that have historically supported the expansion of industrial societies, and the limitations faced by alternatives including renewable energy sources in substituting for these [38-43].

Harvey and Pilgrim [44, p. S40] argue that ‘failure to address the demand for energy and materials, in particular to develop alternatives to counter the depletion of petro-chemical resources, will *inevitably* result in major economic and social disruption on a global scale’ (our emphasis). As others including Moriarty and Honnery [39,40], Friedrichs [45] and Trainer [46] have argued here in *Futures*, there is no substitute for oil that can meet the energy requirements for continued economic growth. On this basis, the future prospects for

current levels of rich-world material affluence must be treated at the very least as highly uncertain. The case for this is not new within futures discourse, with the *Limits to Growth* (*LtG*) [47] providing perhaps the reference point with highest profile [48]. While the perspectives presented in *LtG* have often been regarded as contentious and even controversial, recent research not only supports the contemporary relevance of the original work, but also its empirical validity [49-51]. *LtG* continues to have notable influence on thinking and scholarship within the futures field, as seen for instance in Slaughter's *The Biggest Wake up Call in History* [52] and the recent special issue of *Futures* titled 'Politics, Democracy and Degrowth' [53]. In short, the plausibility of *LtG*-related perspectives is well established within the futures field, even if their mainstream influence remains disproportionately lower than their implications warrant.

Skinner [6] acknowledges that water sensitive cities must be resilient to a range of shocks, and this would include energy constrained futures associated with declines in the production rates of highly concentrated primary energy sources. Conventional petroleum, representing over thirty percent of world total primary energy supply, over forty percent of total final energy use [54], and fuelling almost all transport, is of particular note here. This vulnerability is exacerbated by declining energy return on energy invested (EROI). An ever increasing proportion of the conventional petroleum that *is* produced is required to support the production process itself, and is therefore unavailable for other economic activity. Hall, Balogh and Murphy have estimated the minimum EROI at the wellhead that can support road transport in current industrial societies in a basic "survival mode" as 3:1 [55].

Societies with the much broader range of functions and services currently enjoyed and typically expected by rich-world citizens therefore require energy sources with minimum EROI somewhere between this figure of 3:1, and that which is currently achieved in practice. As actual EROI further reduces towards the minimum required, we can infer that the viability of an increasing range of economic functions will be compromised. In the United States, the wellhead EROI for conventional petroleum is thought to have peaked at somewhere in the order of 100:1, in the first half of the twentieth century, and is now around 20:1 [56]. Roughly speaking, this means that the amount of economic activity associated with production of a unit of petroleum in the US has increased around five-fold. Globally today, conventional petroleum typically has a wellhead EROI between 10:1 and 20:1 [57]. Popular alternative sources for the liquid fuels are well below this, for instance less than 10:1 for shale oil and less than 5:1 for tar sands and biomass ethanol [58], and also represent only a tiny fraction of conventional petroleum's production volume.

Many of the types of collaboration and leadership suggested by participants in the research described in section 4 could increase institutional complexity of the urban water sector. They call for new state government policies, additional training for local government officers and for the community to participate, as one survey respondent explained, 'fully in planning and implementation of a water sensitive city'. As Wallis and Ison [37] have discovered, increased institutional complexity has various drawbacks, with water practitioners being forced to work longer to achieve less. Following Tainter, increases in institutional complexity would likely require increased resource consumption. But in energy constrained futures, as outlined above, capacities for increase in institutional complexity would be constrained by rising energy prices and the associated detrimental impacts both for physical and financial economies and for political stability, limiting availability of the resources needed to enable complexification.

In Australia, water shortages are already driving increasing institutional complexity in the water sector. For instance, Wallis and Ison [37] explain how new institutions implemented at state and national levels intended to reduce complexity through centralisation or integration have in fact increased complexity by expanding the number of institutional arrangements. Research conducted by Byrnes [18] supports this view. Reforms implemented in the 1990s to increase competition in the water sector led to a growth in the number of institutions with water governance responsibilities. A number of institutions were then established, each with responsibility for one of the following: management of water resources such as catchments; provision of water and wastewater; setting of standards; and regulation enforcement [18]. But the combination of drought and population growth ‘challenged the capacity of the disaggregated sector to respond in a coordinated, timely and economically efficient manner’ [18, p. 17]. Table 1 provides an indication of the current complexity in Sydney’s water sector, by presenting a list of management agencies and their high-level functions, as described by Byrnes [18].

**Table 1**  
Current institutional arrangements for Sydney’s water sector.

<b>Current Water Management Agencies</b>	<b>Function</b>
Sydney Water	Provides drinking water, wastewater and stormwater services
Sydney Catchment Authority	Supplies bulk water to Sydney Water, protects water catchments and catchment infrastructure
NSW Office of Water	Policy implementation
Department of Finance and Services	Policy implementation
NSW Office of Water	Economic regulation
Independent Pricing and Regulatory Tribunal	Economic regulation
NSW Health	Health Regulation
Environmental Protection Authority	Environmental Regulation

*Source:* Byrnes [18].

We argue that implementing the additional water governance and management functions called for in the research findings reported in Section 4 would entail significant further complexification, beyond that implicit in Byrnes’ description of the current water sector. To illustrate this, in Table 2 we present a sub-set of the new functions called for by participants in the research, and propose for each of these some key implementation requirements that would involve new institutional arrangements and hence increased complexity.

**Table 2**

Projected areas requiring new institutional development.

<b>New Functions Proposed in Research Findings reported in Section 4</b>	<b>Implementation requirements involving new institutional arrangements</b>
Collaboration amongst all levels of government	Channels of communication opened between levels of government Regular forums for collaboration established Agency to oversee running of forums, to keep records and to communicate outcomes of collaborative work. Evaluation of collaboration; reporting on evaluation findings to government sponsors, participants and key beneficiaries.
Inter and intra organisation communication amongst different types of water professionals	Formalising this type of communication as part of every water professional's role. Designing, developing and maintaining of technology platform(s) for such communication. Managing communication platforms. Engaging water professionals in the communications forums, including 'selling' the benefits to time-poor professionals. Culture change programs to break down disciplinary barriers. Evaluation and reporting.
Full community participation in planning and implementation of a WSC	Establishing a community outreach agency Evaluation and reporting. Passing legislation to enshrine community's role in planning.
Champion for WSCs in state government	Establishing performance indicators for state government departments to follow. Undertaking strategic evaluations of Sydney's progress toward a WSC. Requiring all NSW government departments to report on their progress toward a WSC.
Local government training for staff in adaptive thinking	Making such training a requirement of all local government officers. Delivery of training. Training of trainers. Evaluation and reporting.

Source: Participants.

While 'developing costly institutions to solve problems is a suitable strategy as long as there is a suitable return for the investment' [31, p. 399], increased institutional complexity in the Australian water sector has placed an increasingly demanding administrative burden on environmental managers, leading to their diversion from primary responsibilities [37]. In terms of Tainter's model, there is a danger that increasing institutional complexity could push water governance systems beyond the point of diminishing *marginal* returns, into the domain of diminishing *actual* returns—there is a possibility that water system performance could be degraded rather than enhanced by complexification. At the level of whole societies, according to Tainter [31, p. 399], when investments in complexity progress 'beyond the point of diminishing returns', societies become vulnerable to collapse. We are not suggesting here that complexification of water governance systems (and the associated infrastructure managed by them) would lead directly to wholesale societal decline, but it could create increased vulnerability or fragility that undermines resilience to cope with stressors; this *could* conceivably contribute to wider declines in well-being.

### 5.3. *Costs and Benefits of Complexity in Urban Water Governance*

Advocacy for increasing infrastructural and institutional complexity as a way to solve the problems associated with Australian urban water shortages in times of climatic uncertainty is evident in the water management literature. For instance, Brown and Farrelly [59, p. 653] write ‘to conceive of urban stormwater as an environmental threat as well as a water supply source requires a substantial shift in our traditional linear supply and wastewater structures towards more hybrid and *complex* infrastructure systems’ (our emphasis). To help accomplish this, they advocate for science-policy ‘bridging organisations’, demonstration projects, community and political engagement and training programs, all of which may increase institutional complexity in the Australian water sector. But complexity is not inherently good or bad. It can be considered good if it is affordable and helps to solve problems, and considered bad if it is expensive and fails to solve problems [41]. What is important is being aware of both the potential costs and benefits of complexity. In the realm of urban water governance, attention appears to focus mostly on the anticipated benefits.

Forms of water management requiring greater collaboration, as called for by participants in the research reported here, will entail the creation of new institutional arrangements and modes of governing. This potentially entails increases in social complexity that will come with its own set of costs, such as the time required for practitioners to develop ways to cope with this complexity, to learn how to work effectively under new governance regimes, and entry and exit costs associated with the creation of new institutions and organisations, as Wallis and Ison [37] suggest. While the benefits of increased complexity were highly touted by research participants, the potential costs have so far largely evaded scrutiny. However, in a study by Bos et al. [60, p. 408] in the Cooks River catchment in Sydney, costs were apparent during their experimentation with different forms of urban water governing when ‘respondents identified that, over the first two years, they experienced *high transaction costs* while limited results were seen’ (our emphasis). These transaction costs included high levels of complexity that core actors had to negotiate in order to perform the governance experiment and the time consuming efforts required by steering committee members to get people involved at the municipal level [60]. However, the study did deliver benefits including an enhanced learning environment, greater awareness of sustainable urban water management and socio-technical system change in the urban water sector [60]. Alternatively, by not accepting and managing complexity in the early stages of stakeholder engagement the opposite effect can emerge as complexity increases over time when the ongoing failure to deal with ‘wicked’ problems unfolds.

### 5.4. *Prospects for water sensitive cities under conditions of reduced affluence*

We take collaboration and leadership to be necessary features of WSCs. Fostering these, particularly under conditions of constrained or declining affluence, will be aided significantly by cultivating sufficient enthusiasm across the spectrum of participants in water governance. We use the term *enthusiasm* here in the sense described by Ison and Russell [61], who identify it in their research as a key criterion for successfully promoting learning. They describe three different ways enthusiasm can be understood. It can act as a theory to explain motivation, it can be the driving force (with an emotional basis) that gives vitality and meaning to what people do, and it can also be a methodology for highlighting why and where people direct their zeal [61]. According to Russell and Ison [62], enthusiasm draws on people’s energy and emerges out of practices that capture people’s imaginations, engaging people to do what they most want to do. Water governance approaches responding to the calls

for collaboration and leadership that require formal institutional interventions may suffer from diminishing returns on investment in complexity. But where enthusiasm provides actors with autonomous motivation, we envisage different outcomes. As institutional form shapes complexity, institutions (as social technologies) mediate practices and understandings. When people are enthusiastic about managing their own water needs, beneficial responses can occur within the existing institutional regime, countering the apparent intractability presented by Tainter's model, as the following two examples show.

Firstly, shifts can occur in the perceived value of water, whereby people are prepared to spend more of their available resources on satisfying water needs; to modify their needs; and to accept greater inconvenience in meeting those needs. At the individual or household level, this was seen across Australian cities during the 'Big Dry': many people invested in household water infrastructure including rainwater tanks and pumps while others sought out ways to reduce consumption below per household target levels. Some also changed their behaviour to make routine those tasks previously regarded as excessively onerous – such as supplementing garden irrigation by collecting grey water by hand and using buckets to capture shower water (see Allon and Sofoulis [63]). Clearly the price mechanism also plays an important role in mediating perceptions of the value of water, as does the imposition by governments of statutory restrictions on the ways in which household water may be used. Both approaches were implemented in Australia during the 'Big Dry'.

In emphasising the role of enthusiasm, we are drawing attention to the way in which the interior social-emotional response to the exterior structural influences of prices and rules affects outcomes. Price increases and the threat of legal sanctions can motivate behaviour to conserve water with a spectrum of social-emotional co-effects ranging from resentment and disengagement through to cooperation and personal responsibility. We understand cooperation and responsibility to be complexity-attenuating, as they enhance the prospects for locally autonomous and context-appropriate responses to socio-economic challenges. Resentment and disengagement leading to social dysfunction may, on the other hand, be complexity-amplifying, if it necessitates government or other external intervention. The experience in Australia, in which a significant proportion of the population invested financial and other resources and achieved levels of conservation well beyond what might be expected on the basis of price incentive or direct regulation alone, highlights the opportunities that an appreciation for the role of enthusiasm opens up for enhancing the conventional policy toolkit, especially by ameliorating complexity-related perverse co-effects.

Secondly, shifts can occur in how the relationship between individual and collective well-being is itself appreciated, with commensurate consequences for willingness to engage in and contribute to community organising. That is, people may become more willing to bear the personal costs and inconveniences of organising with others to satisfy their needs, instead of having these met as individual consumers exclusively by central authorities. Evidence of this can be seen in the work of Ostrom [64]. Drawing on extensive fieldwork in numerous locations around the world, Ostrom showed that irrigators can sustainably manage common pool resources by collectively designing rules to govern resource extraction and enforcing penalties for over use. Thus farmers dependent on irrigation could be described as having greater 'skin in the game' with respect to water governance. They understand in a very profound way the consequences of *not* participating in this directly—farms may cease to be viable, and livelihoods and ways of life may be lost [65].

The cultivation of enthusiasm has an important enabling role to play, by supporting the shift from a principal focus on building resilient infrastructure, towards cultivating resilient people—moving the primary emphasis, in a sense, from water sensitive *cities* to water sensitive *citizens*. Fisher's [66] preference for civil defence training over the standard response of fortifying or otherwise enhancing physical infrastructure for ameliorating essential services vulnerabilities shares much in common with what we have in mind. Such training produces its envisaged benefits by preparing people for the inevitability of breakdown, rather than fostering expectation of state protection from its consequences at any cost. For Fisher, resilience, or robustness, is best built within people, and in the *social* infrastructure connecting them—namely, empathy and trust. We see a strong interdependence between this trust, and what we mean by enthusiasm.

Trust and enthusiasm can create resiliency to resource scarcity without increasing institutional complexity. In 1998, an explosion at a major gas plant in the state of Victoria, Australia disrupted Victoria's supply of natural gas for twenty days. During this time most Victorians lacked access to gas for cooking, water heating and home heating. But Fisher [66] reports that residents with solar or electrically heated hot water responded by sharing their bathrooms with neighbours, while increased body odour became temporarily socially acceptable. This shows how adaptation to resource scarcity is possible, albeit to a different resource than water, without increasing institutional complexity and without government intervention but rather through the use of self-organised local solutions. But it is preferable to act before the commencement of any shocks associated with reduced affluence as maladaptation is also a possibility [5]. For example, in Southeast Queensland, Australia, policy making under conditions of uncertainty arising from the urban water crisis of 2001-2008 curtailed opportunities for wider dialogue and concentrated the political authority of the Queensland state government [67].

#### *5.4.1 Reducing complexity through decentralised water infrastructure*

However, a focus on social infrastructure does not imply neglecting physical infrastructure. In fact, developing water sensitive citizenry can open the way to physical infrastructure options and matched governance arrangements that might offer pathways through Tainter's energy-complexity conundrum. This is not a one-way relationship though—our understanding is that enthusiasm across the spectrum of social actors for participating in water management, and the shift to infrastructure and institutions that require this, is appreciated better as co-constructive. Currently, the importance of water in urban environments such as Sydney is not readily appreciated by all residents. But rainwater harvesting systems, for instance, can connect people more intimately with the water cycle and improve adaptability to droughts through greater awareness of the amounts of water collected and consumed [68]. This can help counter perceptions of an infinite supply of water promoted by centralised systems where water is collected and stored far from its point of use [69].

Breaking down the institutional and geographical barriers that separate water users from the storage and provision of their water will help make urban water systems more democratic [69], countering 'the strong professional identities and powerful elite cultures that co-evolved with water systems and flowered in isolation from other professions and society' [70, p. 807]. Decentralised water supply systems might also help reduce institutional complexity, by bringing 'governance closer to the user and less-dependent on the international circuits of capital' [69, p. 52]. Decentralised rainwater harvesting systems would be appropriate under conditions of declining affluence as they are maintained and operated by householders

themselves, reducing the energy, maintenance and transport costs associated with centralised systems [71]. Perhaps more significantly though, while in certain contemporary industrial-capitalist contexts the aggregate capital cost of rainwater harvesting systems can far exceed that of supply solutions such as desalination plants (as Domenech et al. [69] report for Barcelona), the continued viability and availability of rainwater systems is less dependent on the extremes of institutional complexity required by their high technology counterparts. We also understand the shift from centralised water supply to decentralised rainwater harvesting to be consistent with forms of community resilience that draw on the trust engendered in informal social networks, fostering widespread community adaptability to unpredictable events [72,73].

#### 5.4.2 *Envisioning the transition: bottom-up development and regional variations*

In the case of Sydney, decentralisation could involve high levels of community collaboration but through relatively autonomous local efforts rather than city-wide coordination. One possible consequence of this is that the quality of water infrastructure and its management could be subject to significant regional variation—it might be very high where the local governance structures work well, and poor where they do not. We can perhaps see such possible futures in nascent form with the significant variation in levels of capacity for and commitment to water sensitive urban design amongst local governments in Melbourne [74]. However, increasing decentralisation is not necessarily at the expense of centralised systems. WSCs may incorporate both – with decentralised water supply technologies installed at the household to the municipal level embedded into larger centralised systems [13]. Supply diversity has potential to increase the resilience of urban residents to a wide range of shocks.

In situations where centralised infrastructure becomes less reliable and shifts to more localised water governing are enacted, transitions would likely occur in piecemeal and opportunistic ways. The emergence of effective local governance would take time, reflecting learning through trial and error, and would require governance experimentation such as that explored in recent studies [75,76]. We envisage situations in which all water-related needs for a given geographical zone would not fall under a neatly bounded governance arrangement. Certain areas of a city could advance rapidly, exhibiting effective and relatively autonomous governance, while other areas might suffer from slower learning times and poor local governance. New trans-boundary issues would then emerge where problems in one area adversely affect adjacent areas. Especially in a large city such as Sydney, the possibility of ‘patchy’ infrastructure would likely entail all citizens experiencing varying degrees of compromised amenity, even those who benefit from effective local governance.

One risk is that wealthier regions of a city see more rapid and better-resourced responses, leading to the emergence of ‘ecological enclaves’ excluding poorer areas [77]. But this also incentivises the development of local solutions that deal with those issues, as the costs, both financially but also in terms of hardship associated with the loss of amenity, would likely fall to those directly affected. Thus, decentralised systems would reduce complexity, as in principle they are able to function with less complex institutional support since they entail greater participation by citizens in meeting their own needs locally. This implies re-valuing of water services along the lines discussed earlier. We believe that initiatives oriented towards the cultivation of enthusiasm and citizen ecoliteracy in the form of water sensitive *citizens* have a central role to play here, in avoiding Tainter’s conundrum.

## 6. Conclusion

In exploring the vision of Sydney as a WSC, research participants from the city's water sector advocated for leadership in the form of vision and long term planning from local and state government, policy leadership from state government, higher management level leadership in general and funding from federal government to assist local government implement WSUD. Their calls for collaboration referred to a desire for more communication and interaction between all levels of government, industry professionals and the community; and greater responsibility for and involvement from the community and local government in decision-making. One potential outcome of such changes is an increase in socio-political complexity, which entails commensurate costs. Collaboration and leadership are essential for transitioning to WSCs, but we must be selective and cautious about how they are enacted. Increases in complexity are worthwhile if they deliver a net benefit. Ideally though, the forms of collaboration and leadership adopted would be oriented towards reducing complexity, or at least avoiding its increase.

Fostering enthusiasm for local initiatives might help to reduce or offset the costs of complexity, as people engage directly in meeting their own needs, for example via rainwater harvesting systems at the household level, or via participation in managing and maintaining neighbourhood or municipal scale infrastructure. Costs associated with the maintenance of water infrastructure and transportation of water from reservoirs to homes to sewerage systems would be reduced, while bureaucratic and administrative burdens entailed by legislating for local participation would be minimised or avoided. This would be particularly important for developing WSCs under conditions of declining affluence, as under a contracting resource base, scope is greatly reduced for expanding or even maintaining a centralised water supply system, or for mandating local participation in decentralised systems.

As Australia as a whole attempts to manage the various effects of climate change and population growth, it is not only the urban water sector that has to consider the costs of complexity. Other sectors will also be faced with problems of their own to solve. Thus findings from this study may help inform problem solving in other sectors such as transport, banking and energy. Subsequent studies could examine the costs of complexity in these and other sectors, as all will be faced with their own socio-ecological and economic challenges associated with changes in population and climate. Furthermore, all Australian citizens have a stake in how they respond to a potential contraction of their resource base, as the high standards of living enjoyed by the majority of Australians are founded on access to cheap and abundant fossil energy sources. The securing of safe water supplies for all of us is only one, amongst many, important dilemmas to manage.

## Appendix

**Table A.1**  
Explanation of acronyms

Acronym	Full name
WSC/CS	Water Sensitive City/Cities
NWI	National Water Initiative
WSUD	Water Sensitive Urban Design
CMA	Catchment Management Authority
DECC	Department of Environment and Climate Change

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