Still Waters Running Deep: Building Adaptive Capacity in the South East Queensland Water Supply Sector through Research

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Despite an exponential growth in the volume of adaptation research over the last few decades, there is still a research gap in regard to the information available to adequately inform policy makers. Contributing to this gap is a paucity of research reporting on the effectiveness of implemented adaptation strategies. This paper discusses the need for a new generation of case-study based climate change adaptation research that monitors and evaluates the effectiveness of existing adaptation actions. Examples are provided from the adaptive responses taken by the South East Queensland water sector during the Millennium Drought. The case studies demonstrate that there can be considerable disparity between anticipated and actual policy outcomes, which often result in maladaptive consequences.

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Introduction

Background

Global warming is changing the earth's climate and intensifying the hydrological cycle. Abundant evidence exists that 'freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems' (Bates et al 2008:3). Climate change projections indicate that urban water supplies will be affected through reducing water availability and water quality, and through damage to infrastructure from extreme events and sea level rise. While policies aiming to reduce these impacts through mitigation may alleviate potential risks, it is anticipated that extensive adaptation measures will still be required to reduce water stresses in urban population centres (Kundzewicz et al. 2007).

Head (2010) concluded that the design and implementation of effective adaptation policies and strategies in the urban water sector requires evidence based on rigorous scientific research. Reviews have shown that despite an exponential growth in the volume of adaptation research over the last few decades, a deficit remains in understanding the information required and used by policy makers when making decisions (Tompkins et al. 2010, Berang-Ford et al. 2011, Hoffman et al. 2011). Contributing to this lack of understanding is the paucity of research reporting the effectiveness of implemented adaptation strategies that might inform subsequent rounds of research and practice. However, an opportunity to monitor and evaluate adaptation policies in the urban water sector has now emerged in the aftermath of the unprecedented water shortages that occurred in South East Queensland (SEQ) during the Millennium Drought (the drought). This was the worst drought on record in Australia.

Aim and approach

The overarching aim of this paper is to evaluate the contention that the past and current generations of climate change adaption (CCA) research do not meet the evidenced based information needs of practitioners working in the water sector on policy formulation and analysis, program planning, on-the-ground project delivery and performance evaluation. Arguments are presented that to overcome this deficiency, a new generation of case-study based CCA project outcome analysis research should be initiated, accompanied by mechanisms to translate this material to focus on identified practitioner needs.

Five tasks help to frame the response to above contention. They are to:

- briefly examine core aspects of the past and current research responses to CCA;
- review key institutional response to the Millennium Drought in South East Queensland (SEQ);
- comment on the decentralised systems and soft adaptation measures that emerged during the drought in SEQ;
- describe the water-energy nexus in the context of maladaptive responses and energy demands; and
- briefly discuss the role of communications and public participation when seeking to introduce controversial and palatable adaptive responses.

Concluding remarks and observations are provided with the intent of indicating how the new generation of applied CCA research could be initiated based on work already undertaken by the UWSRA and others in SEQ.

Climate change adaptation: research response

A generational overview

During the early 1990s, adaptation was often viewed unfavourably as an admission that mitigation policies could not work and as such, found limited support or was even discouraged. Al Gore, for example, argued that adaptation was 'a kind of laziness' that diverted attention and resources away from the real issue: the prevention of impacts through mitigation (Gore 1993). Since then, adaptation has gained recognition as a legitimate and critical strategy for addressing the unavoidable impacts of climate change. However, despite the exponential growth in adaptation research over the past few decades, there is a strong body of opinion that there has been limited progress in developing the appropriate knowledge and tools necessary to assist policy makers design and implement sustained adaptation measures.

Climate change adaptation is an emerging as an area of study that has been embraced by a diverse community of researchers that share a common interest in addressing the problems and opportunities associated with anthropogenic climate change. Consequently, adaptation research draws on the tools, knowledge and perspectives from a diverse, and often disparate, range of biophysical and social sciences. The research has been directed primarily towards (a) impact-driven investigation (first generation), and (b) social, cultural, physical and economic characteristics that lie at the heart of a society's vulnerability (second generation). The first generation of adaptation research typically employed scenario-based modelling to identify potential impacts of climate change, with results presented as techno-engineering solutions towards reducing the level of exposure of human and natural systems to projected impacts. The second generation of adaptation research is much more social science oriented and seeks to lessen a community's vulnerability through measures that aim to reduce sensitivity to impacts and to increase adaptive capacity by transformations towards a more resilient state. Vulnerability based adaptations might still include 'hard' techno-engineering solutions, but they would also include ‘soft’ adaptations that build adaptive capacity through actions such as institutional reforms, regulatory instruments, awareness raising and education.

Translating research outputs to adaptive outcomes

While both generations of adaptation research have provided significant insights into adaptation processes, neither impact nor vulnerability research has proven to be well suited to assisting decision makers in selecting the types of adaptations that might best suite particular circumstance (Ash and Stafford-Smith 2013). The immediacy of socio-political pressures contributes to this situation and often usurps the still speculative outcomes that are underpinned by high levels of uncertainty. The uncertainty lies not in the broad climate science, but the specificity of issues to places and groups at risk that are the principal concern of policy makers. The translation of research into policy is also confounded by the fragmented nature of the adaptation research community and the disparity between disciplinary perspectives, terminologies, methodologies and evaluation criteria. This not only inhibits the generalisation of findings in a manner that allows a transfer of knowledge from one area to another, but also constrains the synthesis of knowledge into forms that address the multifaceted challenges faced by decision makers (Ash and Stafford-Smith 2013, Hofmann et al. 2011). The do nothing option often appears more attractive than proactive response because the immediate socio-economic disruption is perceived to be of more concern, when the certainty of projected impacts remains clouded in uncertainty.

The difficulty of translating adaptation research into policy suggests the need for a ‘third generation’ research agenda that integrates theory, policy and practice. The emergence of a third generation adaptation research agenda will require yet to be developed knowledge and methodologies (Patwardhan 2011). However, it will probably lie in greater use of case study methodologies, monitoring and evaluation of outcomes from adaptive actions, and hence adaptive research methods. It will require researchers to collaborate with policy makers and practitioners in a manner that allows theory and practice to co-evolve (Ash and Stafford Smith2013, Patwardan 2011, Eakin 2011). It will require approaches that critically evaluate the successes and failures of current adaptations with the aim of adjusting both practice and theory (Padwardan 2011).

Case study adaptive research: responding to an identified need

The use of case study adaptive research to enhance adaptive capacity has been constrained by the limited number of adaptations available for study. Analyses of peer reviewed literature (Berrang-Ford et al. 2011, Hoffman 2011, Arnell 2010) have found that while there is considerable research regarding the *potential* of specific adaptation measures, there are few case studies of how adaptation to climate change is actually being delivered. For example, Berrang-Ford et al. (2011) found that of 1741 adaptation documents reviewed, papers discussing actual or planned adaptations occurred in less than 5 per cent of the literature. The remainder were related to actions that developed adaptive capacity (research, planning, networking, awareness raising, training and advocacy).

However, the peer reviewed literature does not necessarily provide a comprehensive understanding of the current state of applied adaptations. Adaptations are rarely implemented solely to address climate change, and more often target sustainability issues. In many cases, adaptation benefits are delivered unintentionally, or with the rationale not made explicit for political reasons, as by-products of policies designed to address non-climate change issues such as disaster risk management, sustainable development, cost savings and efficiency measures or as a response to pressures from population growth (Tompkins et al. 2010). In some cases, adaptation actions that are climate-proofing occur through reactionary policies that aim to mitigate the impacts of extreme climatic events such as droughts, floods and heatwaves (Berrang-Ford et al. 2011).

Many climate change adaptation measures are being mainstreamed through policy that may not be recognised as such by adaptation literature reviewers, policy makers or even the researchers involved in the design, evaluation and reporting of such measures. For example, much of the research used to inform this paper comes from the 109 technical reports, 50 peer reviewed papers and six books published over the past five years by the SEQ Urban Water Security Research Alliance (the Alliance). Although not flagged as being specifically focused on climate change adaptation, this research has made a significant contribution to the adaptive capacity of the region's water sector (**Table 1**) and has provided insights that are highly relevant to other regions and sectors. Yet, a review conducted for this paper found only a single brief reference to climate change adaptation in all the literature produced by the Alliance.

The significance of this situation is illustrated and discussed in the following sections using a case study analysis of selected measures implemented in South East Queensland in response to the drought including: reducing water consumption, implementing major techno-engineering projects by way of the water grid, waste water recycling and a desalination plant, demand management and institutional reform, and seeking evidence based adaptive responses. Case study analysis of the water and energy nexus provides insights into the implications of maladaptive responses to critical water shortage conditions using desalination and other energy intensive systems. Decentralised systems such as water tanks and community roofwater harvesting are viewed as soft adaptation options and are evaluated as case examples. The importance of effective communication and public participation is examined broadly using the rejection of the proposal for a potable water recycling (PWR) plant in Toowoomba and the success of 'Target 140' in reducing demand as example cases.

Many of the adaptation strategies employed were innovative, and as such, required considerable guidance from region-specific research, much of which was provided by the Alliance. As the life of the Alliance extended beyond the drought, its considerable resources were redirected to more general research into broader water security issues. These included an assessment of some of the adaptation measures taken during the drought. Thus, the analysis and discussion explores the broad scope of actions implemented in response to the drought and then identifies examples of how 'learning by doing' has delivered insights that have facilitated the co-evolution of adaptation research, policy and practice.

Table 1. Summary of major goals and findings of Urban Water Security Research Alliance (UWSRA) research and its relevance to climate change adaptation

Goal	Key findings from projects*
Theme 1 - Reducing water grid demand	
Understand community behaviour and preferences regarding water use (Demand management and communication research).	• Provision of significant information can result in change of community attitude such as trust in Government and can result in acceptance of water options (Nancarrow et al. 2009; Russell and Fielding 2010; Price et al. 2012).
Improve understanding of water end use (Residential water end use study).	• Water efficient devices can make very large differences to demand (Beal et al. 2011). • Reduced demand for urban water has the potential to significantly delay the next major water infrastructure. • Reducing residential demand may reduce recreation, health and amenity values.
Improve understanding of rainwater	• Rainwater tanks reduce demand by as much as 30% less than anticipated

Goal	Key findings from projects*
tanks (Decentralised systems).	(Sharma et al. 2010). • Rainwater tanks harbour hazardous pathogens (Ahmed et al. 2012, Ahmed et al. 2011).
Assess the potential for stormwater harvesting (Stormwater harvesting and reuse).	• Stormwater harvesting has high potential for non-potable uses in new suburbs or developments. • Stormwater harvesting can provide environmental benefits for local creeks and receiving waters. • Pathogens and trace chemicals need to be managed in stormwater harvested in existing residential areas (Sidhu et al. 2012). • Developed areas higher than expected human contaminants. Should be treated as recycled water • Harvesting in greenfield areas has much lower risks.
Theme 2 - Water source quality	
Ensure the reliability and safety of recycled water systems (Hospital wastewater).	• SEQ hospitals contribute between 1 to 9% of overall pharmaceutical loads in municipal wastewater (Ort et al. 2010; Le Corre et al. 2012). • Hospital-specific compounds are unlikely to be present in STP effluents at levels representing a risk to humans. • Trace chemical contaminants and endocrine disrupters are effectively removed during treatment. Most pathogens in reservoirs effectively removed in storage. • New technologies developed for measuring fate of contaminants in reservoirs.

Build scientific knowledge into the management of health and safety risks in the water supply system (Multiple projects).	• Drinking water in the SEQ is well within guidelines.
	• There is low risk of NDMA formation in water supplies from SEQ catchments but a higher risk of THMs being formed and exceeding ADWG values for some waters.
	• Better understanding of
	  ○ contaminant inputs into storages and stormwater,
	  ○ formation potential of disinfection by-products in recycled and natural waters,
	  ○ DBP precursors and potential mitigation measures,
	  ○ measures to significantly reduce NDMA formation.
	• Improved detection techniques for unwanted contaminants in raw sewage.
	• Advances in the online, real-time, and monitoring of illegal discharges.
	• Research findings allow better management of new technology water treatment processes. (Farre et al. 2011).
	• Critical information for managing community concerns and reducing management costs.

Advice on infrastructure and technology for recycling wastewater and stormwater.	• Non-membrane recycled water plants produce high quality water at less cost, no brine production and less greenhouse gas production (Reungoat et al. 2010; Reungoat et al. 2012; Macova et al. 2010). • Suitable for smaller communities
Theme 3 - Total water cycle planning and management to enhance sustainability and efficiency	
Provide improved methods and analysis of water, energy and	• Quantified energy, greenhouse gas emissions and Life-Cycle Analysis from the SEQ Water Strategy and fugitive methane emissions from storages (Hall

Goal	Key findings from projects*
nutrient balances across the SEQ water system.	et al. 2011; Lane and Lant 2012). • Energy implications of water use/consumption are significant and should be considered in water strategy (Kenway et al. 2011; Kenway et al. 2012). • Externality costs better understood. • Frameworks and tools for evaluating water supply strategies now available.
Assess reuse capability of wastewater in agricultural areas.	• Better understanding of hydro-salinity and risks. Improved understanding of wastewater irrigation implications.
Institutional analysis.	• Historical information of water management in SEQ. • Improved information base to inform local and national policy regarding water reform processes and structures.

* Table 1 has been compiled from the proceedings of the Alliance's Science Forums (UWSRA 2010, 2011 and 2012). Indicative referencing is provided to key journal publications. All Alliance publications including technical reports are available at http://www.urbanwateralliance.org.au/index.html.

Responding to the millennium drought: the SEQ experience

Reducing water consumption

While crises such as droughts create great hardship, they also stimulate adaptations and generate the political will for reform (Langford and Briscoe 2011). In the water sector, droughts continue to provide stress tests for reforms and deliver valuable lessons through experience. Between 2000 and 2009, the worst Australian drought on record, the Millennium Drought, provided opportunities to stimulate reform and many learning experiences. The lessons learnt from the drought response in South East Queensland (SEQ) were particularly fruitful, not only due to the comprehensive and capital intensive nature of the response, but also the considerable body of knowledge that has become available to policy makers through the collaborative and multidisciplinary research efforts.

The response to the drought was characteristically transformative in terms of scale and innovation, and demonstrated the significant levels of adaptive capacity in the region. A broad portfolio of innovative water management strategies was implemented that drew on the three key principles of diversity, efficiency and long-term preparedness. The actions included both 'hard' and 'soft' measures that aimed to reduce vulnerabilities in the sector by: constructing robust supply sources; reducing demand through technological changes and behavioural modification; and by increasing system resilience through a portfolio of policies that emphasised flexibility and diversification (Figure 1).

The initial response was to reduce water consumption through water restrictions that imposed limitations on how water was used. This approach is a traditional and familiar practice in Australia during water shortages. Implemented at a local or regional level, restrictions generally limit the use of outdoor water. This approach has the benefits of: (a) significantly reducing water consumption, because outdoor water use can account for up to half of household consumption; (b) permitting incremental restrictions as water reserves decline; (c) making policing of restrictions relatively simple; and (d) being cheap to implement.

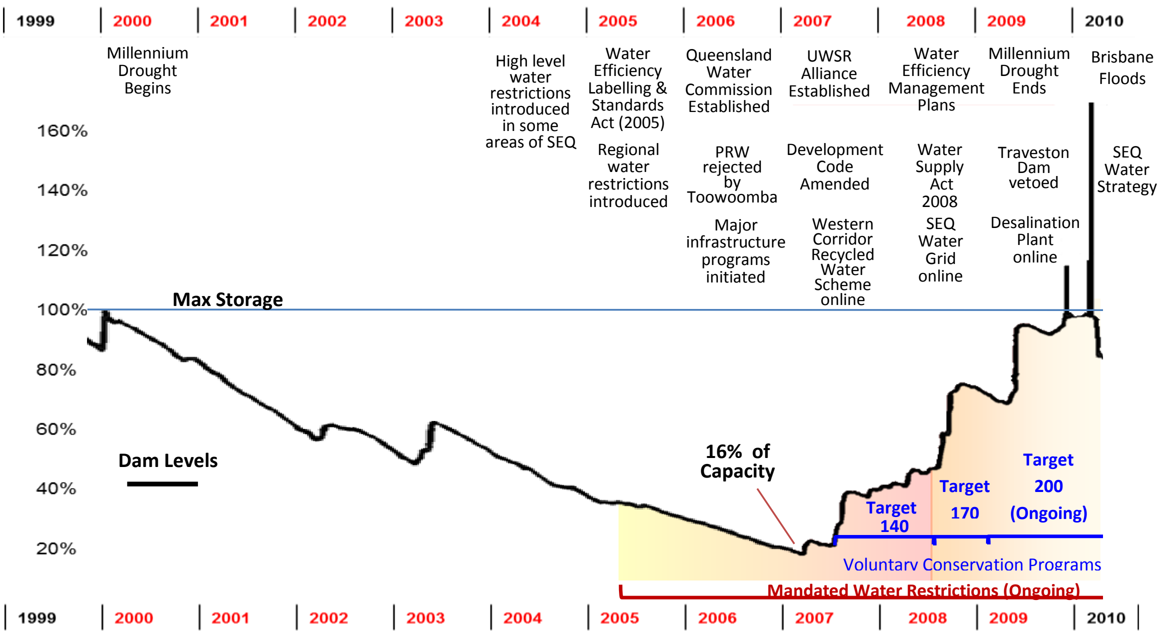

Figure 1: Timeline showing change in combined dam levels and the adaptation strategies implemented in SEQ during the Millennium Drought.

Techno-engineering projects

The key techno-engineering component of the strategy was a AUD7 billion regional water grid (the grid) designed to maximise the potential of existing water supplies by connecting the region's twelve major dams. It was estimated that the ability to transfer water between catchments could increase system yield by as much as 14 per cent during periods of drought (QWC 2010). The grid was augmented by two climate-independent water supply facilities. The seawater desalination plant at Tugun, in the south of the region, was designed with a maximum production capacity of 133 mega litres per day (ML/d) (around 10 per cent of the region's current demand for potable water from the grid). The Western Corridor Recycled Water Scheme, with the capacity to produce 232 ML of potable water a day, was the largest advanced wastewater purification scheme in Australia and the third largest in the world. Additional potential water sources investigated included stormwater harvesting, water trading schemes between rural and urban areas, and supplies from coal seam gas developments (QWC 2010).

Demand management and institutional reform

Management strategies for reducing demand were also implemented through legislation, policies and programs that encouraged voluntary adoption of 'water-wise' practices. Legislation was the key element of the demand management strategy. For example, businesses using more than 10ML per year were required to develop Water Efficiency Management Plans (WEMPs) that identified how best practice water use efficiency could be achieved. At the household level, the Queensland Development Code was altered to mandate that all new and renovated domestic dwellings install water-efficient shower heads, toilets, irrigation systems and tapware that complied with the standards set by the new (2007) national Water Efficient Labelling Scheme (WELS). To further reduce demand, the Code also prescribed that new detached dwellings supply 70 kilolitres per year (kL/yr) from local sources.

Institutional reform of the SEQ water sector was also implemented. In 2006, the Queensland Water Commission (QWC) was established to guide the water reform process, develop independent water strategies and to advise the government on water security matters. The *South East Queensland Water (Restructuring) Act 2007* facilitated the restructuring of the sector with the aim of providing a more coordinated, efficient and transparent industry through the establishment of statutory authorities to operate the region's bulk water supply and distribution facilities. Further institutional reforms, implemented in 2010, aimed to optimise costs and efficiencies by consolidating the region's 17 retail water providers into three sub-regional retail entities.

The drought response also included the development of a long-term strategy. The SEQ Water Strategy 2010 presents a blueprint for regional water management until 2056. The strategy aims to maintain water supply in the face of population growth and climate variability and change. It addresses these challenges through the general themes of: use less, be supply-ready, and manage efficiently. The strategy incorporates population growth projections, level of service requirements, the region's water resource potential, drought response plans, and also makes an allowance for climate change. The strategy addresses future uncertainties by incorporating a flexible adaptive management approach, whereby annual reviews are undertaken and the plan is revised in full every five years. It is envisaged that future supply targets will be met mostly through the construction of desalination plants.

Focused research: evidence based adaptive response

It was recognised that an effective evidence based adaptation response to the drought would require substantial and diverse research. In 2007, a collaborative and interdisciplinary research program was initiated as the Urban Water Security Research Alliance. The Alliance's task was to undertake regionally appropriate research that addressed emerging and anticipated urban water security issues, and to inform the development and implementation of the SEQ Water Strategy. This involved 17 inter-related projects delivered across the three key themes of: reducing water demand from the grid, ensuring the quality of water from a diversity of sources, and total water cycle planning and management to enhance efficiency and sustainability. A diversity of research projects was funded, some of which specifically targeted or could inform adaptation (see **Table 1**).

Decentralised systems and soft adaptation measures

Water tanks: policy goals and reality checks

Adaptation measures often draw on new and innovative approaches that may not have undergone rigorous real-world testing. Where there is a lack of pragmatic knowledge, the decision to implement a strategy may be based theoretical evidence, such as modelling, risks assessments and vulnerability studies. While this research may represent the best available information, the uncertainties associated with the data increases the potential for unforseen and undesirable outcomes. The decision to introduce rainwater tanks as a major policy measure in SEQ illustrates the importance of a 'learning by doing' approach to adaptation research.

Rainwater tanks (tanks) are a traditional water supply approach familiar to most Australians. While their use in most urban centres has been prohibited for almost five decades (primarily as a public health measure related to mosquito control), they are often the sole source of water in rural areas that do not have access to reticulated water supplies. The drought stimulated a renewed interest in tanks as an alternate supply source, particularly when modelling outcomes indicated that tanks could supply as much as a third of household demand if used for non-potable purposes such as toilet flushing, outdoor irrigation and for filling washing machines. Governments began to view tanks favourably as an adaptation strategy as they acted as a drought conservation measure that reduced demand from the grid in the short-term, and had medium-term benefits by deferring the need for major investments in supply infrastructure. The public also supported this approach because tanks provided a discretionary supply, unaffected by water restrictions. To stimulate householder voluntary uptake of tanks, partial rebates were offered as incentive by Federal, State and, in some cases, local governments.

In 2007, when water levels in dams were at their lowest, the government expanded the policy to include a mandatory requirement under the Queensland Development Code for all new detached dwellings to supply 70 kilolitres per year (kL/yr) from local sources, such as rainwater tanks, greywater treatment, or another approved alternative water substitution measure. By default, the local water provision requirements of the Code were generally met through the installation of rainwater tanks. By 2010, 43 per cent of Brisbane's houses had installed tanks at a cost of over AUD 1 billion (ABS 2012), with estimates that by 2050, local water sources could reduce water grid demand by as much as 60 Gigalitres/year; the equivalent of the annual production capacity of around three desalination plants.

Testing economic assumptions and the cost of tank water

The widespread adoption of tanks created opportunities for research organisations to conduct ex-facto monitoring and evaluation studies that were not previously possible. Results revealed adverse outcomes that had not been apparent in the modelling studies that had originally guided decision makers. Of particular concern was the finding that, on average, tanks were reducing demand from the grid by up to 40 per cent less than the policy target (Maheepala et al. 2013, Chong et al. 2011, Beal et al. 2012). In addition, water supplied from tanks was far more costly than originally predicted (Hall 2013) and initial assessments regarding energy consumption and GHG emissions associated with the use of tanks were grossly underrated (Lane and Gardner 2009). The use of rebates for tanks was also criticised in the Productivity Commission's 2011 review of urban water policies, which found that subsidies, including those for rainwater tanks, impeded the adoption of more cost effective alternatives and promoted inefficiencies.

Reassessments of the true cost of water from tanks found it to be many times more costly than that supplied from the grid. Hall (2013) calculated that the mean levelised cost of tank water was between AUD8.90/kL and AUD14.11/kL, depending on sub-regional rainfall patterns and the assumed life span of the tanks, compared with AUD0.64/kL from the grid. This represented an additional cost for tank users of between AU$350 and AU$550 a year, which had clear equity implications for marginalised sub-populations. Concerns were also raised that the high capital costs of installing tanks in new houses (approximately AU$5 000) conflicted with housing affordability policies. In 2012, a government review of the effectiveness of tanks found that the costs outweighed the benefits, and the mandated requirement for new houses to be supplied from local sources was repealed in March 2013. The implications of this decision for medium-term and long term water policy have yet to be investigated, but it will almost certainly involve a greater and earlier dependency on manufactured water facilities such as desalination and PRW plants.

The blanket decision to repeal the local water provision mandate due to issues with tanks may well be a case of "throwing the baby out with the tank water" that also removed a potentially powerful stimulus for the development of innovative and more effective methods of harvesting roofwater. In Brisbane for example, there is more runoff from rooftops of houses than is currently consumed by the people who live in them. The potential for high yields from rooftops has been demonstrated by a pilot community roofwater harvesting scheme in Warrnambool Victoria, where houses delivering roofwater to the town reservoir contributed 49 per cent more water to the system than they consumed.

Another innovative community roofwater scheme was planned for construction at Coolum Ridges Estate at Peregian Springs in SEQ. The planned approach was to collect roofwater from around 1 500 houses, treat it to a potable standard and then export the high quality water to the grid. Preliminary assessments (Parsons Brinkerhoff PB 2010; Laves et al. 2010; Coombes and Cullen 2010) have indicated that this approach:

- may produce on average about 140 kL/hh/yr - twice the policy goal;
- would be more cost effective than water tanks;
- would require far less energy (291 (kWh)/ML) for the treatment and delivery of water than the SEQ Water Grid (500 kWh/ML), traditional water tanks (1500 kWh/ML) or desalination plants (3600 kWh/ML); and
- might be a resilient water source capable of producing 124 kL/hh/yr under a much drier climate change scenario where mean annual rainfall declines by 33 per cent.

This scheme, with several others proposed in the region, have not progressed, with developers citing a downturn in the housing market and government red tape as the primary causes. Without further incentives, it is likely that commercial interest in following up on this approach will be limited, and an opportunity to gain real-world insights to alternate roofwater schemes will be lost.

Adaptation and the water energy nexus: maladaptation and energy demands

Maladaptive responses

In general, adaptations aim to reduce vulnerabilities and/or increase system resilience to disturbances and changing conditions. However, vulnerability and resilience are dynamic system traits that can also be impacted negatively as a consequence of adaptation attempts. Maladaptations are actions taken ostensibly to reduce vulnerability to the impacts of increased climate variability and change but result in adverse impacts that increase the vulnerability of other systems, sectors or groups (Barnett and O'Neill 2009).

Barnett and O'Neill (2009:2011) have argued that the potential to implement maladaptive strategies in the water sector is very high. They characterise maladaptations in the water sector as actions that, '*relative to alternative options, increase emissions of greenhouse gases, disproportionately burden the most vulnerable, have high opportunity costs, reduce incentives to adapt, and set paths that limit the choices available to future generations*'. In the case of the water sector, 'increasing the likelihood of public health risks' and 'creating conflict between water users', could be added to the list (Reyer et al. 2011). The promotion of rain water tanks embodied most of these characteristics.

While the hard SEQ adaptive strategies endow the supply system with the positive adaptive characteristics of diversity, flexibility and resilience, they also reflect many of the dimensions of maladaptation. This highlights the importance of research to monitor and evaluate applied adaptations so that further inappropriate actions can be avoided or their consequences mitigated. Considerable research effort has been directed to identify and understand these issues in SEQ, including investigations of: the energy implications of water supply alternatives including decentralised systems (Sharma et al. 2010); life-cycle implications of the water supply strategy (Lane et al. 2011); and the cost of related externalities (Daniels and Porter 2011).

Energy intensive systems

Of particular concern is the overall regime shift in water supply source-mix towards "climate resilient supplies", which has led to a more energy intensive and GHG emitting system. Many new water sources (such as desalination, PRW and household rainwater tanks) require far more energy than traditional water sources operating under normal conditions (Table 2). For example, in SEQ it is estimated that by 2020, desalinated water will consume 44 per cent of the water supply energy budget to produce 9 per cent of the region's water, while dams will provide 84 per cent of the water but account for only 40 per cent of the energy (QWC 2010).

Table 2. Typical energy demands for water supply options in SEQ.

Water Source	kWh/kL	Reference
Mains water, Australian capital cities	0.09-1.92	Kenway et al. 2011
Desalination, Australian Capital Cities	4.0-5.7	Gregory 2012
Purified Recycled Water	2.5-3.0	Knights 2006, ARUP 2012
Rainwater tanks in SEQ	0.4-2.1	(Gardner et al. 2006, Beal et al. 2008, Hood et al. 2010)

Estimates from systems analysis and modelling (Hall 2011) indicate that greenhouse gas emissions in the SEQ urban water system will rise at a faster rate than population growth and may at least double between 2008 and 2050 (Kenway et al. 2008). To develop a better understanding of water supply related GHG emissions, the Alliance initiated studies that included: the development of conceptual frameworks and methods (Baynes et al. 2009); modelling and measuring components of the system including wastewater (de Haas et al. 2011); and reservoir greenhouse gas emissions (Sherman 2010).

However, research undertaken by the Alliance and elsewhere has indicated that from a holistic perspective, the energy required to supply and transport water is far less than that required to use water. The inclusion of end use energy is largely ignored in the overall energy budget of water initiatives (Marsh 2008), despite evidence that energy associated with water end use was dominant in the urban water cycle (Arpke and Hutzler 2006). Kenway (2011) demonstrated that over nine times more energy is consumed during water usage, than in the supply and removal process. This represents 8 per cent of total national greenhouse gas emissions. The research has demonstrated that the potential for reducing energy demand in the water sector could be addressed through demand management initiatives, providing a valuable and cost effective approach to reduce GHGs.

Communication and public participation

Harnessing community support

During the drought, community support was demonstrated to be an important element in determining the degree of success experienced by certain adaptation measures. At one end of the spectrum was the rejection of the policy to augment potable water supplies with PRW, while at the other was the extraordinary level of public commitment for the 'Target 140' campaign (140 litres/person/day (L/p/d)) that challenged the community to achieve a 50 per cent reduction in water consumption.

Impact of public concerns: rejection of the potable water recycling (PWR) proposal

While there is confidence within the water industry that augmenting drinking supplies with PRW is a safe and reliable process, experience has shown that the public does not necessarily have the same confidence. The plan to augment dams with recycled wastewater treated to a potable level, met with significant opposition from the public. The City of Toowoomba was earmarked as the first to be augmented from the scheme, because the city was precariously close to running out of water. Yet the opposition to drinking recycled water was so great that a plebiscite was held on the issue in 2006, resulting in the rejection of the proposal by 62 per cent of the city's population.

The broader political implications of the rejection were clear, and plans to augment other dams in the region with PRW were dropped. A portion of the potential output from the scheme still makes a valuable contribution to meeting the region's water needs, but is limited to supplying water to power stations, industry, agriculture and the environment. Nevertheless, there is provision in the SEQ Water Strategy for augmentation of dams during periods of extreme shortages (e.g., when combined dam levels fall to less than 40 per cent). Whether the public will accept this provision or adopt the position taken by Toowoomba residents is unlikely to be known until this policy provision is triggered. If however, public confidence in PRW can be achieved, its potential contribution to regional water security is significant.

The rejection of PRW by Toowoomba residents highlights the need for policy makers to gain community confidence before applying this adaptation measure. This requires considerably more research into the potential health risks if public perception is to be changed and fears allayed (Le Corre 2012, Farre et al. 2011, Ahmed et al. 2011, Poulsen et al. 2011). Attitudes towards PRW have also been investigated to develop effective approaches to garner public acceptance and support (Price et al. 2012, Green et al. 2012, Tucker et al. 2010). While the research has found a relatively high level of support for the PRW, it is also clear that, given a choice, the majority of respondents would prefer not to drink water that contained PRW, with support dropping if a viable alternative to PRW were available. The research also finds that while there may be initial public support for PRW, it declines as the possibility of augmenting supplies becomes closer to being implemented.

An emerging priority area for researchers in this field is communication. Public opposition to recycling projects is often perceived by authorities as being due to a lack of understanding of high levels of quality control and the low levels of health risks associated with advanced water treatment technologies and practices. In SEQ, as in many other areas that have attempted to introduce indirect augmentation, the typical approach has been to alleviate concerns through the delivery of awareness and education initiatives. However, Kandulu et al. (2010) report that the use of science 'facts' to reassure the lay person is ineffective, and heigtened awareness of recycling schemes does not necessarily lead to changes in behaviour or attitude. Conversley, this approach is more likely to entrench opposition, intensify extremes of opinion, and politicise and polarise debate.

Understanding the reluctance of communities to accept PRW is a complex challenge that needs to overcome a range of issues related to perceptions, emotions and trust (Kandulu et al. 2010). The 'Yuk-factor' has been put forward as a key emotional barrier to the acceptance of drinking recycled sewerage, while the low levels of trust placed in authorities and scientists to ensure the safety of PRW has been identified as a critical barrier to public acceptance (Kaercher et al., 2003; Nancarrow, 2007; Hurlimann et al, 2008). An alternative that has demonstrated some success in other areas is through a participatory approach that engages the community in a way that issues, questions, and goals can be discussed and debated within a co-management approach. However, while the participatory approach to policy development might, to some extent, legitimise policy decisions, Burton and Mustelin (2013) suggest that public interest in participation is more likely to be apparent when policies begin to tangibly affect individuals and communities rather than during the policy development process itself.

Reducing domestic demand: the success of 'Target 140'

By 2007, the combined dam levels were at 19 per cent capacity. With rainfall over the previous two years being only 10 per cent of the long term mean, projections indicated that without significant rainfall, capacity would fall below 6 per cent. Despite the highest level of water restrictions in place and the AUD9 billion dollar commitment for expanding supply infrastructure, no new sources were due for completion until 2008. In the hope of maintaining supplies above 10 per cent, the QWC launched the 'Target 140' campaign (140 litres/person/day (L/p/d)).

Restrictions had already reduced average household consumption to 180 L/p/d, but to maintain supply it would be necessary to achieve reductions within the inner household. The program developers, recognising the challenges, undertook a multidiscipinary research program that provided key insights for the strategy including that:

- public understanding of the critical nature of the problem, who was using the water, and awareness that an individual could make a difference was low (QWC, 2008; McCann Erickson, 2009);
- residents had grown "restriction weary" after several years of severe restrictions;
- options to restrict outdoor water use were fully exploited and that the most significant use of water in the home was the "7 minute" shower, which accounted for 33 per cent of internal consumption;
- the benefits of personalising the problem by encouraging individuals to self-regulate consumption were likely to be high; and
- choosing a water use target that was not only measurable and tangible but also meaningful to the individual consumer was essential for altering behaviour.

The campaign was based on the three key messages: the crisis is real and very serious; householders consume 70 per cent of the region's water; and small changes can make a difference through cumulative effects. Showers were heavily targeted in campaign promotions, which encouraged residents to limit the time spent in the shower to four minutes.

Extensive advertising and public education programs were structured to progress the public through the desired behavioural changes and repetitively promoted the themes of 'water wise' behaviour and community solidarity. The multi-media promotion was also backed up by more tangible actions that empowered people to implement and maintain the desired behavioural changes. These included:

- four minute shower timers and booklets of water saving tips were mailed to households in the region;
- the provision of weekly feedback to residents regarding their performance against the 140 target via television news reporting and daily newspapers;
- the introduction of the Water Efficiency Labelling and Standards (WELS), which required household appliances to include water saving technologies and to make available the information necessary to enable consumers to make water wise purchases;
- a rebate program to encourage the voluntary uptake of water efficient appliances, greywater recycling units and to retrofit existing dwellings with household water tanks; and
- the availability of water efficiency and leakage reduction consultants to evaluate household performance and to replace inefficient shower heads and repair leaking taps.

The program was extremely successful with demand falling as low as 126 L/p/d. This dramatic change in behaviour persisted beyond the drought. Apart from a particularly hot and dry spell in 2010, domestic water consumption has remained at around 160 L/p/d since the drought, compared to almost 300 L/p/d before the drought (QWC 2010), suggesting the campaign has had some success in embedding sustained behavioural changes.

As successful as the demand reduction strategies have been, they have not been without unanticipated and undesirable consequences. Instilled 'water wise' behaviours in consumers have resulted in a significant decrease in demand for water at a time when dams are full and water utilities are facing higher costs associated with the major investments in advanced supply. Currently, the combined output from the desalination and PRW facilities represents only 8.7 per cent of production capacity and 3.6 per cent of water supplied from the grid. This situation is causing considerable hardship within the SEQ water industry. Financial reports for the 2011-12 period indicate that the three major organisations responsible for the supply and delivery of bulk water in the region, the SEQ Water Grid Manager, SEQwater and Linkwater, reported operational losses of around AUD434 million, AUD64 million and AUD21 million respectively. Consequentially, there is pressure on regulators to approve a substantial increase for bulk water charges in a system that has already seen approved price increases that exceed 2008 prices by more than 400 per cent.

Conclusions

This paper has challenged the policy and action influence of projection-based research that generates hypothetical outcomes, scenarios and potential adaptation strategies. It has argued that the product of such research may not adequately meet the needs of planners and policy makers when designing and implementing effective adaptation strategies. Specifically, to date there has been little attempt by researchers to apply adaptive research principles to inform adaptive management practice through comprehensive evaluation of adaptation responses and outcomes to climate change threats. Selected outcomes of adaptation actions to the SEQ water crisis demonstrate the gaps between research products, practitioner needs and policy outcomes. Arguably, by closing this gap policy makers would benefit from a broader research agenda that includes a 'learning by doing' approach that focuses on the evaluation of applied adaptation measures.

'Learning by doing' provides a crucible in which adaptation theory can be tested and refined. In the case of the SEQ experience, the evaluation of applied adaptations provided ample evidence of frequent disparities between anticipated and actual outcomes. It was also shown that even when actions successfully meet policy objectives, such as the Target 140 initiative, unanticipated and undesirable implications may still occur in untargeted areas. Further, adaptation policy is strongly influenced by public and political perceptions of vulnerability and the efficacy of potential adaption actions, as in the case of PRW. Predictive vulnerability assessment, through analysis of potential harm (exposure x sensitivity) and adaptive capacity (IPPC 2001), is inadequate for identification of potential adaptations because it does not include public and political perceptions of each of the elements of the model or the adaptation strategies themselves.

The importance of communications and public participation was clearly identified also as both an agent of and a barrier to change. The outcome of ineffective communication of the rationale for crisis-driven adaptations is confounded by failure to place actions within the climate change perspective. Without explicit commitment to climate change adaptation and acknowledgement of it as the underlying driver of crises and the need for adaptation, climate proofing is not possible, because when the pressure to adapt is removed, so too is the immediate need for the adaptations.

Applied adaptations provide a common ground from which policy makers, practitioners and researchers may more effectively relate to each other's needs and capacities. Pragmatic lessons, regarding both successes and failures, generate a more practical discourse and awareness of the challenges being faced and the knowledge required to address them. In SEQ, there were a number instances, the case of water tanks for example, where insights gained from evaluations led to co-evolutionary adjustments in policy and provided direction for further research. In this respect, adaptation is seen not as a one-off action or suite of actions, but a progression of cumulative and progressive actions, the efficacy and consequences of which need to be evaluated within an adaptive learning framework. That is, further adaptation of the adaptations may be necessary.

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