URBAN WATER PLANNING IN THE FACE OF CLIMATE CHANGE

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Abstract

Climate change is already influencing decisions in the urban water sector. However, the risks that climate change pose to the sector and how best to manage these risks remain topics of much discussion.

Introduction

This paper initially considers how the uncertainties associated with climate change might be translated into risks for water service providers and the community. It then considers the methods available for characterising climate change uncertainty and incorporating these potential impacts into yield estimations and demand forecasts.

Given the difficulties involved in resolving the risks and associated uncertainties, several potential responses from water service providers and governments are considered. The paper concludes by highlighting a number of key questions raised by the available responses.

Risk is formally characterised by a hazard with an attached likelihood of outcome. In relation to climate change and urban water supply however it is clear that for many 'risks' the probabilities of occurrence are in many regions currently unknowable. In this paper we therefore use the term 'risk' more broadly to refer to possible negative impacts and potential implications of climate change from the perspective of a water service provider and the community in general. The likelihoods of these impacts may or may not be readily estimated.

The paper draws on material currently being developed through a National Water Commission funding project on 'Integrated resource planning for urban water' (for more information see www.urbanwaterirp.net.au).

Hydrological impacts of climate change

Climate change is predicted to affect climatic and hydrological variables which could have substantial implications for urban water supply-demand planning. It is generally thought that in addition to changes in average rainfall amounts, rainfall variability will also rise, increasing the likelihood of climate extremes such as droughts and floods. However hydrological variables are complex and inter-linked and it is not fully clear how other effects such as increased evaporation due to rising temperatures and also 'catchment drying' will impact on run-off. It is also conceivable that in some situations increased rainfall intensity during storm events could contribute to greater runoff fractions entering reservoirs during these events. Whether such increases would be offset by rising temperatures reducing the amount of water that is converted into inflow is not clear. Secondary impacts could also result such as reduced surface water quality resulting from lower streamflows (Standish-Lee, Loboschefsky & Lecina 2006), and pressures on ecological flows in times of water scarcity (IWA 2008).

The impacts of climate change will be different across different regions in Australia. For example, regions such as southern Victoria and south-west Western Australia are predicted to experience a decline in winter and spring rainfall under climate change and there there is a possible drying trend on the Queensland east coast (Bureau of Meteorology 2007), whereas the eastern seaboard of New South Wales may experience only slight rainfall reduction or no change (DWE 2008). Therefore the impacts on supply-demand planning will vary from location to location.

Due to the complex nature of the climate system, climate change could lead to non-stationarity or structural shifts in climatic and hydrological patterns in some locations. Both in Perth (Water Corporation 2005) and Melbourne (DSE 2007) decreased inflows to storages have been observed in recent years (relative to historical averages)

From managing risks to managing with uncertainties.

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Conclusions

The MBR system has high buffering capacity to influent water quality changes and has high removal rates for CODcr, BOD_5, NH_3-N and total N.

The study shows that an On and Off outflow model and periodic CIP system are efficient for reducing membrane fouling and keeping a steady trans-membrane pressure.

The control of mixed liquor suspended solids (MLSS) in MBR systems is important for membrane operation. The results show that membrane filtration can be kept in a MLSS range from 4.0-12 g/L.

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Table 1. Potential negative impacts of climate change uncertainty, and implications for water service providers and the community.

Possible negative impacts	Implications for water service provider (WSP) and community
Direct supply system impacts (Level of Service failure)	
Reduced yields from surface water storages (dams and reservoirs) or river-drawn supply systems (due to decreased streamflows)	Emergence of supply-demand tensions, which could result in WSPs not meeting Level of Service objectives
Decreased reliability of water supplies & increased frequency of restrictions	
Increased customer total or seasonal demand (e.g. outdoor water use, evaporative cooling)	
Damage to coastal groundwater supplies impacted by seawater intrusion due to rising sea levels	Could lead eventually to total or partial supply system failure
Failure of a particular supply source due to prolonged low inflows	
Institutional and financial impacts	
Over-investment in large supply augmentations resulting from planning for 'worst-case' scenarios	Significantly increased cost of water services provision
Changed water access licence conditions	Potential loss of previously available supply
Increased competition for water resources	Increased cost for water or loss of previously available supply
Increased pipe breaks due to soil moisture change	An increase in non revenue water loss
Decreased revenue due to decrease in water demand or volume supplied due to restrictions	Financial pressure on WSP
Energy price increases due to emissions trading under a Carbon Pollution reduction Scheme	Exposure to higher energy prices as a result of carbon emissions charges being passed through energy tariffs
Community perceptions and expectations	
Community expectation that system reliabilities should have been maintained	Some customers have reportedly perceived continued restrictions under extended drought periods as a failure by the WSPs
Loss of trust in ability of WSP to provide a continuing water service	Movement of people or industry from areas of perceived or actual water shortages
Community perception that WSP has over-reacted to climate change uncertainties causing unnecessary costs for customers and damage to the environment	Community distress at significantly increased cost of water services. Loss of trust in WSP
Expectation that WSP must mitigate all climate impacts of any proposed supply	Community expectation means that WSP will need to ensure new sources and infrastructure are 'carbon neutral'
Perception that the WSP should be aiming to act sustainably in all their operations in the context of climate change	WSPs are expected by their communities to act responsibly with regard to sustainability issues. This is complicated by the interlinkage of water, energy and climate change issues

which have been interpreted as representing the onset of a climatic 'step change' in these regions. This implies a sudden rather than gradual structural shift in climate variables, particularly rainfall.

Uncertainties in the predicted impacts of climate change

A number of key uncertainties exist in the predictions of climate change impacts. These include:

- uncertainties introduced through the choice of climate model and emissions scenarios,
- uncertainties introduced in the climate models transformation of predicted warming into rainfall and evaporation predictions, and
- uncertainties introduced when transforming the rainfall and evaporation predictions into runoff and yield forecasts.
- uncertainties about the validity of modelled predictions where a shift in climate is perceived to have occurred,

Climate change may also affect demand forecasting, particularly for seasonal end uses such as irrigation and cooling.

These uncertainties consequently generate risks for water service providers and the community related to supply-demand planning.

Current responses to climate change in water supply-demand planning

How climate change risks have been treated in supply-demand planning varies between cities across Australia. In 2007 a working group of the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) identified a number of characteristics that distinguish between approaches including:

- reliance or rejection of the past 100 years as the best indicator of future streamflows,
- extent to which, and way that climate change modelling and predictions were incorporated into estimates of future runoff,
- levels of service objectives (with its implied restrictions regime),
- willingness to consider all options (including inter basin transfers, potable reuse etc),
- degree of reliance on demand management to achieve reductions in consumption,
- degree of integration of 'other' urban water sources (i.e. stormwater and groundwater),
- extent to which explicit and specific contingency measures to be triggered in the event of extreme and/or continued drought conditions have been identified and communicated to the population.

Some example of these differences include the following:

- supply-demand planning in Perth is based on incurring a total sprinkler ban no more than once in 200 years compared to much higher frequencies in other jurisdictions;
- Melbourne and Sydney based their supply strategies on achieving

significant reduction in per capita demand unlike elsewhere; and

- Sydney and Brisbane have dealt with drought and climate change uncertainties through publicly announcing contingency measures and trigger points for new supplies.

Reviewed in December 2008, it is evident that most utilities in Australia's major urban centres are responding cautiously to the water supply risks posed by climate change. Consequently, many have decided on significant new supply-side augmentations and the Australian water industry has begun investing $30 billion over the next 5-10 years into developing new water supplies for major urban centres (WSAA 2008).

What are the Risks?

Climate change and related uncertainties could produce a range of possible negative impacts. These negative impacts generate risks for water service providers and the community. The principal risk is that a water service provider is no longer able to meet their required level of service objectives, which describe the targeted frequency duration and severity of water restrictions that can be expected from a given supply system (Erlanger & Neal 2005). However there are also other types of risks associated with climate change including financial and institutional impacts, and potential for negative community perceptions and unmet expectations. Some of the most prominent of these possible impacts and the implications that are implied for water service providers and the community are summarised in Table 1.

Assessing the Impacts

Given the possible negative impacts and risks implied above, the next step would be to attempt to estimate the likelihoods of these outcomes. Many of these risks will hinge around the supply-demand balance and therefore techniques for assessing climate change impacts on the supply-demand balance will be critically important for managing climate change uncertainty. A range of methods have been (and continue to be) developed to incorporate climate change predictions into supply and demand forecasts. While these approaches can attempt to resolve some of the uncertainties, many still remain. This section will give a brief overview of approaches to assessing the impacts of climate change on supply and demand forecasting, and highlight the key areas of uncertainty inherent within these approaches.

Supply side

The two main approaches for assessing the impacts of climate change on urban water supply are (1) using climate models, or (2) adopting different types of hypothetical scenarios either related to future climates, future rainfall, or future yield (Ashbolt & Maheepala 2008).

Climate models

Climate models attempt to predict the climatic effects of climate change, and transform predictions of future climate data into rainfall predictions, and subsequently transform the future rainfall data into predictions of runoff and yield. Climate models are typically General Circulation Models (GCMs) which model global climate at a scale of several hundred square kilometres, although this data can be downscaled regionally using different downscaling techniques to achieve grid resolutions of around 10-20 km. A climate modelling approach provides the most comprehensive and physically-based approach to understanding the impacts of climate change on water resources. However this approach is data and time-intensive, both in terms of generating and incorporating the climate and hydrological data into water supply-demand planning. A variety of GCMs and downscaling models exist, and therefore there are questions around which models and combinations of models to use, and what may constitute 'best-practice' in this area.

A second uncertainly arises from predicting future greenhouse emissions. No one knows the level of greenhouse gases (CO_2 and ozone) and other influencing factors (e.g. aerosols) that will be present at a given time in the future. These levels will be determined by the level of global mitigation and the climate system's responses.

For these reasons, multiple emission scenarios from many models are commonly used to provide an uncertainty range in terms of rainfall and temperature changes. In some regions these ranges however diverge between increasing and decreasing runoff. In others the models converge on a prediction of decrease.

Hypothetical scenarios

Hypothetical scenarios assume various plausible trajectories of future climate or hydrological variables to examine the sensitivity and relative hydrological impact of different possible future climates, commonly in the absence of GCM-generated downscaled climate data. Hypothetical scenarios could take the form of data sourced from larger scale GCMs, extrapolations of historical trends, relationships between global and local climate, or expert judgment. Some utilities have incorporated climate change impacts directly as a hypothetical scenario at the yield forecasting stage. In these cases yields are reduced, or de-rated from the historical record by making a stepwise or linear adjustment to the baseline yield forecast (i.e. the yield forecast according to the historical record). The bases for these hypothetical scenarios are observed possible 'step changes' in streamflow records, and/or expert judgement about the possible trajectory of yield into the future in a region. However in these regions there remains substantial uncertainties about whether or not recent patterns of rainfall and runoff do indeed represent climatic non-stationarity or step changes, and what the implications are for future patterns of rainfall and runoff.

Worst case scenarios

Another critical issue for supply-demand planning is how to select and use a worst case scenario. This is, by definition, a low probability event, which traditionally has been defined by an annual exceedance probability based on the historical record. However under climate change uncertainty, the nature of extreme events could be very different as the climate data could be affected by non-stationarity. Therefore selecting worst-case scenarios under climate change uncertainty is much more difficult, and there is no clear consensus within the water industry on how to decide on, and use, worst-case scenarios in supply-demand planning in the context of climate change uncertainty. This is a key issue as different approaches to using worst-case scenarios have played a key role in driving current responses to climate change uncertainty in different parts of Australia.

Demand side

Climate change could affect future demand although the magnitude of any change will depend on many interconnected factors also affecting demand (see Figure 1). An end use based approach should be taken to best understand the impacts by understanding how climate change might affect water use behaviour in certain components of the overall urban water demand picture. For example, in the residential sector two key areas of possible increase in demand are outdoor water consumption and evaporative air conditioner use. These end uses are both strongly seasonal in nature, and therefore the sensitivity of future demand to climate change will be significantly influenced by the seasonality of demand in the region. Impacts on demand are likely to vary between different locations (e.g. impacts in inland regions will differ to impacts in coastal regions), and may depend on a combination of climatic variables including humidity, rainfall and evaporation.

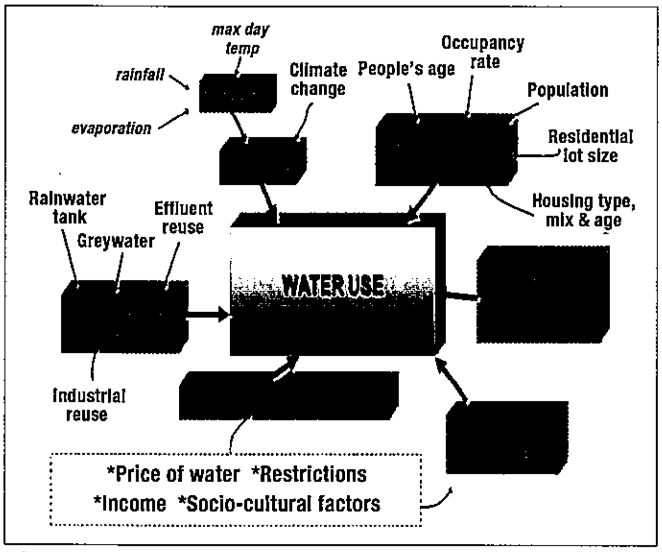

Figure 1. Factors that influence urban water demand (adapted from White *et al.* 2003).

Responding to Uncertainty

In the face of climate change uncertainty there are a number of different types of responses from water service providers and governments. The type of response taken varies with regional context and is based on differing perspectives on the risks identified in Table 1, and judgments about potential likelihoods of occurrence.

One approach that has been evident is to attempt to 'plan for certainty'. In a number of jurisdictions significant supply augmentations have been initiated based on hypothetical 'worst-case' scenarios that that use repeated drought sequences projected indefinitely into the future. To attempt to avoid further rainfall-related uncertainty, climate-independent supplies have mostly been favoured (potable and non-potable reuse, desalination). Such an approach has in most cases been a response to a perceived climatic structural shift.

This approach implies a focus on avoiding the direct supply system risks. It does however open up financial risks associated with over-investment in large supply augmentations and community expectation risks in relation to mitigation of climate impacts and perception that the water service provider has over-reacted to climate change uncertainties.

A second approach that is also evident in some jurisdictions is to 'plan for uncertainty'. This involves planning for an emerging scenario that includes a 'worst-case' but without building for it up front until certain defined trigger points are met. This approach implies the application of a form of adaptive management and requires careful planning in terms of lead times and preparatory works. For example it will take so many months to build a desalination plant but only once it has been preapproved, predesigned and the site for it has been prepared.

Such an approach has a focus on contingency measures including readiness options. Readiness options provide a level of flexibility in terms of timing and potentially also scale of implementation. In a similar way to water restrictions, readiness options are characterised by trigger points based on existing system capacities (White *et al* 2008). Real options analysis is also possible (Borison and Hamm, 2008). This is a risk analysis based approach that incorporates flexibility in decisions and accounting for new information to characterise uncertainty over time.

With such an approach there is still a focus on avoiding direct supply risks but tempered by consideration of financial risks associated with over-investment. Because it is complex and involves contingency plans and trigger points, this approach is still open to risks around community expectations related to the perception that system reliabilities should have been maintained, and could lead to possible loss of trust in the water service provider's ability to continue providing water services. If readiness measures are triggered this could result in the perception that the water service provider has over-reacted to climate change risks in relation to mitigation of climate impacts.

A third potential approach is to try to 'build for resilience' with the broad goal of creating a water sensitive city as described by Wong, Brown & Deletic (2008). This is an approach that would encourage the development of an urban water system that is resilient to climate and other changes through having a wide range of public and privately owned sources of supply at varying scales, ranging from household rain tanks or greywater systems, to local reuse, to centralised supplies. To take such an approach requires a long period of adjustment and is therefore not focused on short term supply risks. Such an approach would also be open to community expectation risks in relation the perception that system reliabilities should have been maintained and possible loss of trust in the water providers' ability to continue providing water services. As a resilient system requires some level of redundancy such an approach is not immune to the various risks associated with over-investment. Furthermore, localised supply sources will also still have energy issues that will require mitigation.

To the authors, considering alternative responses raises four questions.1) How can the potential for climatic 'step changes' that are outside the boundaries of know variability and predicted changes in the climate be accounted for in modelling and planning? 2) What are the best methods, such as real options analysis, for managing within climate change uncertainty over time? 3) To what extent should an emphasis be placed on building 'resilience' into the urban water system to climate and other changes? and 4) How can water service providers and governments respond to the challenges of climate change to supply-demand planning while also mitigating greenhouse gas though their selection of options?

Conclusions

Climate change poses major risks to urban water supplies and the associated uncertainties are a significant challenge to water planners.

A full assessment of the risks posed by climate change is currently difficult in many regions.

While methods have been and are being developed to incorporate climate change into supply and demand forecasts, much residual uncertainty remains.

The problem of responding to climate change in supply-demand planning therefore shifts from managing risks to managing with the uncertainties.

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