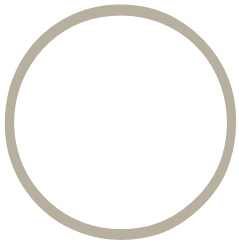




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Review of operating regime for Sydney Water's desalination plant



Prepared for

Sydney Water Corporation



*Centre for International Economics
Canberra & Sydney*

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Disclaimer

The analysis for this report has been conducted over the past two years. A report was initially provided to Sydney Water in February 2009. The report was then modified to remove commercial-in-confidence information and circulated to NSW Government agencies to check for factual errors prior to being completed in July 2010.

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Summary

In 2009 the Government announced the construction of a 250ML/day desalination plant that can be increased to 500ML/day in the future if the need arises. The plant provides a significant additional source of water for Sydney, the Illawarra and the Blue Mountains that is independent of rainfall. Construction of the plant and associated pipelines has commenced and is anticipated to be completed by late 2009 or early 2010. Under the contract with the plant operators, the plant will be operated at full capacity for the first two years while it remains under warranty. The operating rules for the plant after this initial warranty period have yet to be determined. The plant could be operated only during drought periods or throughout the year, similar to a baseload electricity generation plant.

The CIE has been engaged by Sydney Water to provide advice on the benefits and costs to the community of alternative operating rules for the plant. In measuring these impacts we have taken account of the impact of different operating rules for the desalination plant on:

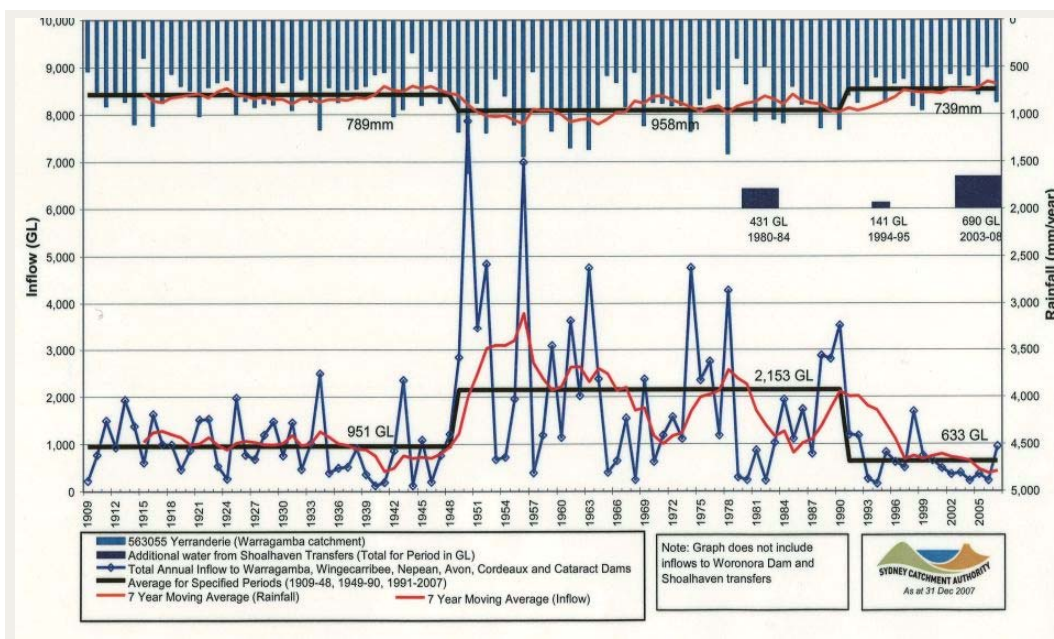
- the operating costs and start-up and shut-down costs of the plant;
- the operating costs of the Shoalhaven pumping scheme and associated changes in CO2 emissions;
- the length and severity of water restrictions during drought and the value that the community places on avoiding these restrictions;
- deferring the next augmentation to the water supply;
- the potential to support the environmental flow releases to downstream rivers; and
- the volume of water being released to the environment due to more frequent 'spills' from dams.

Overview

The catchment areas that supply Sydney's dams predominantly receive higher rainfall in the summer months, although the city of Sydney itself has relatively uniform rainfall. Sydney and its catchment area are subject to infrequent but severe droughts. Because of this Sydney has much larger water storages than most other cities throughout the world.

The volatile nature of rainfall patterns in Sydney is reflected in Sydney's dam levels (chart 1). From 1909 to 1948, inflows into dams were relatively low. However, from

1 Sydney's dam levels from 1909 to 2007



Data source: Sydney Catchment Authority.

1948 to the early 1990s there were substantially higher inflows into dams compared with the preceding 50 year period, although the rainfall pattern was highly volatile with some years experiencing low rainfall similar to earlier part of the century. Since the early 1990s the rainfall pattern appears to have changed and is following a similar pattern to the early part of the century.

In the past the NSW Government and governments throughout Australia have relied on quantitative water restrictions as a key policy instrument for dealing with drought. Restrictions have been critical as the water supply for communities relied on large rainfall dependent dams located on the outskirts of the cities or towns. Restrictions have ensured that communities could withstand periods of drought without running out of water and enabled governments to defer the need to undertake additional investments in water infrastructure.

Even with Sydney's large storage capacity, the NSW Government has used water restrictions during drought periods. Mandatory water restrictions have been in place in Sydney since 1 October 2003, with voluntary water restrictions in place for approximately one year before this.

Water restrictions have also been in place in a number of other major cities (and townships) throughout Australia over the last few years. This has prompted some debate about the costs that water restrictions impose on the community versus the benefits of lower investment in storage.

Non-rainfall dependent measures, such as desalination plants, provide governments with an alternative to quantitative restrictions. Governments can now, for example, choose between drawing water from the desalination plant more often and imposing

water restrictions less frequently than they have in the past. Whether this is a good idea will depend on the cost of water from the desalination plant and the cost of restrictions to the community. Whether governments choose to run desalination plants infrequently or all the time will largely depend on whether the additional benefits from running the plant more often outweigh the additional costs of doing so.

Recent history

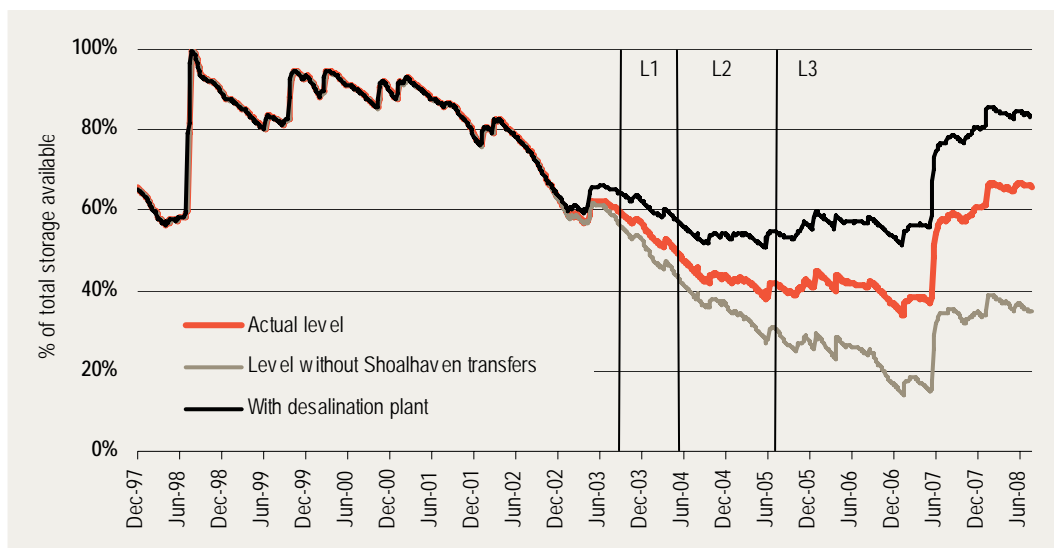
Recent history provides an example of a sequence of low rainfall events in Sydney's catchment, leading to the imposition of restrictions. In the most recent drought the following dam level triggers were applied for restrictions:

- Level 1 restrictions were introduced in 1 October 2003 when dam levels dropped below 60 per cent.
- Level 2 restrictions were introduced on 1 June 2004 when dam levels dropped below 50 per cent.
- Level 3 restrictions were introduced on 1 June 2005 when dam levels dropped below 40 per cent.

The imposition of these restrictions and the corresponding dam levels is shown in chart 2, from 1997 to 2008.

We can assess the impact that a desalination plant would have had on dam levels and hence restrictions over this period, had one been available. In chart 2 we show dam levels if the desalination plant were operated almost continuously from June 2002. The desalination plant would have allowed Sydney's dam levels to be maintained above 50 per cent, thereby avoiding the need to apply Level 2 and Level 3 restrictions.

2 Available water storage in total system



^a All levels include the impacts of restrictions.

We also show the impact that pumping water from the Shoalhaven had on dam levels. Without this facility, dam levels would have reached close to 15 per cent of capacity in February 2007, instead of their actual low point of 33.8 per cent.

A role in supporting environmental flows

Since Warragamba dam was constructed, the dam operator (now the Sydney Catchment Authority) has been required to release a steady 43.3 ML a day from the dam. This flow is for river health and irrigation purposes.

Since 2000, the NSW Government has been introducing environmental flows to all NSW rivers affected by major dams. Environmental flows are water released from dams and reservoirs to downstream rivers to mimic natural flows and improve river health. Environmental flows are important to support native fish and aquatic wildlife. They also reduce algal blooms and the growth of aquatic weeds.

The Sydney Catchment Authority will be required to make environmental flow releases from its storages as specified in its Water Management Licence.¹ Environmental flow regimes have been determined for the upper Nepean System, the Shoalhaven system and the Woronora system (appendix G). Environmental flows from Avon dam have commenced. To ensure the environmental flows from other Upper Nepean dams can have the greatest benefit, a series of capital works is required on instream weirs. Flows from these dams will therefore commence in early 2010. Flows from Tallowa dam will commence when restrictions are lifted and new outlet works are completed. The new works are expected to be completed in mid 2009.

As set out in the 2004 Metropolitan Water Plan, in periods of extreme drought, the Government maintains the power through the *Water Management Act 2000* to change priorities to reduce environmental flows to protect the community. For example, in the current drought, environmental flows have been modified or ceased on most major rivers across NSW. In the Sydney basin, the 43.3 ML a day the Sydney Catchment Authority is required to release from Warragamba dam was halved when Level 3 restrictions were introduced in Sydney Water's area of operations.

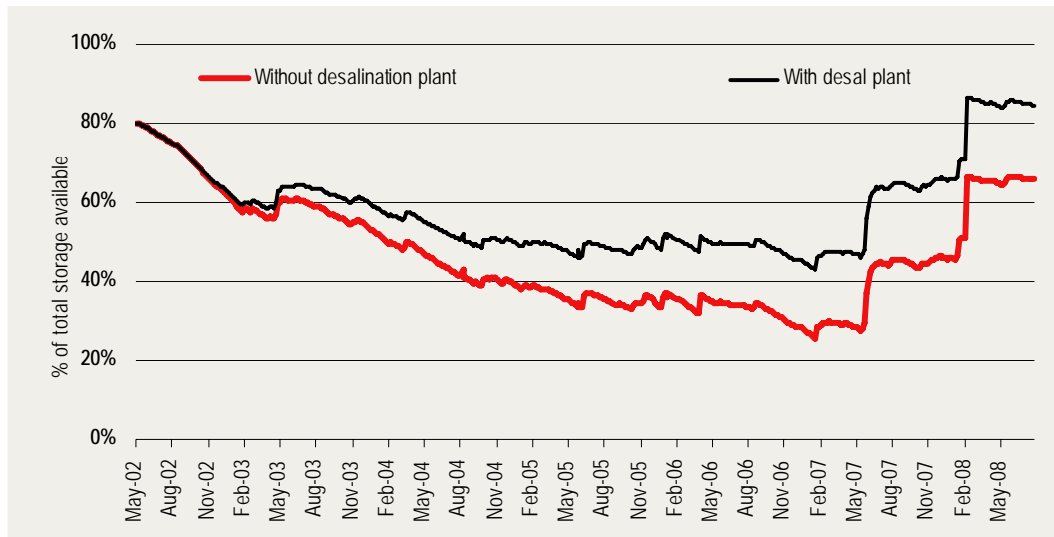
The desalination plant can play a role in supporting the environmental flow regimes from storages. Operating the desalination plant reduces the water drawn from the dams for human consumption and means that more water is available for environmental flows.

The NSW Government is considering what environmental flow regime should apply for the Warragamba System which is expected to be decided around 2015. One environmental flow regime being considered is a 95/20 environmental flow rule. We

¹ The environmental flow releases are specified in section 3 of the SCA's Licence (see http://www.dnr.nsw.gov.au/water/pdf/clu_sca_licence.pdf).

have used this flow regime and the inflows over the last drought to illustrate the contribution desalination could make. We have modelled an approximation of how dam levels would have changed if this 95/20 environmental flows regime had been in place since May 2002. This is presented in chart 3.

3 Water storage levels in total system, with modified environmental flows regime for Warragamba Dam



Data source: TheCIE.

Note: This reflects total storage levels across all storages in the system. It assumes that the modified environmental flows regime for Warragamba applies irrespective of drought conditions, consistent with a transparent and translucent flow regime.

Without the desalination plant, if the 95/20 regime had operated for Warragamba dam, storage levels would have fallen to 25.5 per cent in February 2007, compared with 33.8 per cent which actually occurred under the existing environmental flow regime for Warragamba Dam. However, with the desalination plant operating dam levels would have only reached a low of 43.3 per cent of capacity in February 2007. As dams deplete to low levels, there is likely to be mounting pressure to suspend or reduce environmental flow releases. In this context, operating the desalination plant could, therefore, reduce the demand on water from storages and provide for an environmental flows regime that is sustainable in droughts. Further, the operation of the desalination plant would have also avoided the need to introduce Level 3 restrictions, although Level 2 restrictions would have been needed under the new environmental flows regimes.

The benefit to the environment of additional flows from Warragamba dam made possible by operating the desalination plant has not been incorporated in the benefit-cost analysis because government policy is still being developed in this area. Nevertheless, previous studies have estimated the total environmental benefit from environmental flows of between \$1 million and \$3 million (in net present value

terms) of an extra gigalitre of water for the environment each year.² Therefore, there is likely to be significant value in operating the plant to support and enable environmental flows during dry periods.

The future

Desalination capacity would have made a substantial difference to dam levels under historical rainfall patterns. It will make a similar difference in the future if similar rainfall patterns occur. While dam levels are now approximately 65 per cent, levels can drop significantly as the recent past indicates – dam levels fell from 80.2 per cent in June 2002 to 33.8 per cent in February 2007.

While the recent past provides a useful basis to illustrate the potential benefits from operating a desalination plant, future rainfall patterns could be much higher or lower than those experienced in the past eight years. Using a longer history, the last 100 years, Sydney Catchment Authority has constructed 2000 possible rainfall scenarios.³ These scenarios capture rainfall sequences that are more extreme than the drought of the past eight years, although on average they reflect higher rainfall than the average rainfall experienced over the past two decades. Assessing the operation of the desalination plant under these 2000 scenarios provides a better guide as to the likely benefits and costs given climatic uncertainty and how these costs differ across different climatic conditions.

In using these rainfall scenarios, it is important to recognise that in the future the rate at which dam levels fall may be greater reflecting population growth and to meet environmental needs. These factors will be considered when assessing appropriate operating rules for the desalination plant.

Approach to evaluating alternative operating rules

The challenge for the policy maker in establishing the operating rules for the plant is to recognise the highly variable rainfall patterns in the catchment and the potential for more extreme events in the future. In many ways, the problem is one of insurance. Operating the plant more of the time is costly, but when future rainfall events are small then the accumulated water savings from running desalination are valuable. If rainfall events are large then the dams may fill anyway and the accumulated water savings from desalination will wash through the river system. The problem reflects:

² BDA and Gillespie Economics 2004.

³ Strictly speaking these scenarios are *inflow* scenarios. Rainfall is only a subset of total inflows that enters storage. Nevertheless, in this report we generally use the term *rainfall* which is more commonly understood by a general audience.

- maintaining storages with sufficient capacity to enable the capture of large rainfall events that is a characteristic of Sydney's hydrology; but
- maintaining sufficient dam levels so as to minimise the chances of dam levels falling to critical levels if future rainfall events are small.⁴

Whether the insurance for small rainfall events is worth buying depends on how much the insurance costs, how likely are these rainfall events and how big are the benefits if these rainfall events occur. The likelihood of rainfall events is derived from historical variability and persistence of rainfall, with sensitivity testing to climate change scenarios. The costs are the variable operating costs of the desalination plant, such as energy. The avoided costs include, for example, reductions in the time spent at different levels of restrictions – calculated as the economic losses to consumers and producers of reducing demand for water.

We have also taken account of the indirect benefits of operating the plant, such as the reduction in greenhouse emissions if less water is required to be pumped from the Shoalhaven River and the value of additional spills to river health.

The choice of which operating rule to choose becomes a tradeoff between the expected benefits and costs of each rule. The rule with the largest net benefits is viewed as the optimal operating rule. We also test whether the choice of optimal operating rule changes under plausible alternative assumptions about the key parameters in our analysis.

There are limits on the number of operating rules that can be considered. We have considered three alternative operating rules for the plant, as well as a baseline of not operating the plant at all.

- **30/40 rule.** The plant is switched on when dam levels fall below 30 per cent of total storage capacity and is switched off when dam levels return above 40 per cent capacity.
- **70/80 rule.** The plant is switched on when dam levels fall below 70 per cent of total storage capacity and is switched off when dam levels return above 80 per cent capacity.
- **80/90 rule.** The plant is switched on when dam levels fall below 80 per cent of total storage capacity and is switched off when dam levels return above 90 per cent capacity. This is similar to the 70/80 rule, except that is switched on at slightly higher dam levels.

⁴ We assume that storage levels are 'critical' when the volume of water in storages is around 5 per cent to 10 per cent of total capacity.

The results

Recent history of rainfall

Using the recent history of dam levels as presented in chart 2 we can approximate the net benefits resulting from the operation of the plant according to the 70/80 rule and the 80/90 rule.⁵ The results show a net benefit of approximately \$125 million per annum to the community of operating the plant according to a 70/80 rule or an 80/90 rule over the last 10 years. These results provide a useful illustration of the potential net benefits that could have occurred. However, the operating rules for the desalination plant should be set with reference to potential future events.

Future rainfall

The main analysis uses the last 100 years of rainfall data to simulate potential future rainfall events that may occur. This analysis indicates that without the desalination plant (the base case), on average it is expected that water restrictions will apply for approximately 6 per cent of the time in the future (table 4). Operating the desalination plant in accordance with the 70/80 rule reduces the time in restrictions to about 3.7 per cent. Importantly there are significant reductions in the time at higher level restrictions.

4 Average time in restrictions

<i>Restrictions regime</i>	<i>Base case</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
	%	%	%	%
No Restrictions	94.03	94.27	96.33	96.93
Level 1	3.16	3.08	2.37	1.98
Level 2	0.86	0.84	0.56	0.48
Level 3	1.94	1.81	0.74	0.61

Source: TheCIE.

A plant operating in accordance with the 80/90 rule further reduces the time in restrictions, particularly at higher level restrictions. For example, the average time in Level 3 restrictions under the 80/90 rule is almost one third that which can be anticipated without the desalination plant operating.

Operating the desalination plant in accordance with the 30/40 rule only makes a minor change to the average time in restrictions, as restrictions are triggered before the desalination plant.

⁵ As dam levels did not go below 30 per cent over this historical period, the operation of the plant according to the 30/40 rule cannot be evaluated.

Under the full range of possible climatic events, the largest expected net benefits occur running the plant using the 70/80 rule (table 5). The reduction in time in restrictions is valuable enough that it is worth running the desalination plant according to these triggers – some insurance is worth buying. Operating the plant using this rule provides net benefits of \$424 000 per month, compared with \$5000 net costs per month for the 80/90 rule and \$69 000 net benefits per month for the 30/40 rule.⁶

5 Net benefits (\$'000 per month)

<i>Restrictions regime</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
Expected	69	424	-5
Lowest quartile	-2	-337	-954
Highest quartile	19	631	386

Source: TheCIE.

When the desalination plant is triggered at relatively high dam levels it has a much greater benefit in reducing the chance of dam levels falling into low levels, triggering restrictions and augmentation of the supply system. This is highlighted by the large net benefits in low rainfall events (the highest quartile). On the other hand, when subsequent rain pushes dam levels higher, running the desalination plant earlier typically has net costs (the lowest quartile).

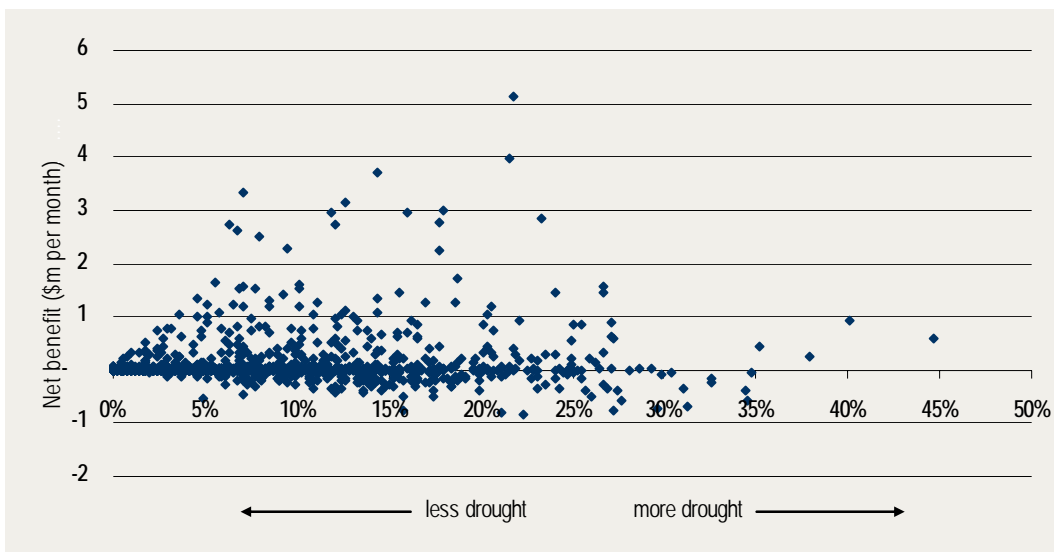
The distribution of net benefits across different climatic events is large (charts 6 and 6). Broadly speaking the distributions of future rainfall patterns can be separated into those scenarios where drought is not a prevalent feature, compared with those where droughts are more frequent.⁷

Chart 6 illustrates the case for the 30/40 Operating Rule. The chart highlights that operating the plant in this way delivers relatively low net benefits across a wide distribution of rainfall patterns. Where there are more frequent drought scenarios (to the right of the chart) the 30/40 rule does not deliver high net benefits. This highlights the fact that operating the plant in this way does not offer substantial benefits in reducing the amount of time spent in restrictions or the chance of needing new investments to augment supply.

⁶ Under the 80/90 rule the plant runs for longer periods compared to the 70/80 rule, but does not significantly reduce time in restrictions or the probability of falling into low dam levels compared to the 70/80 rule.

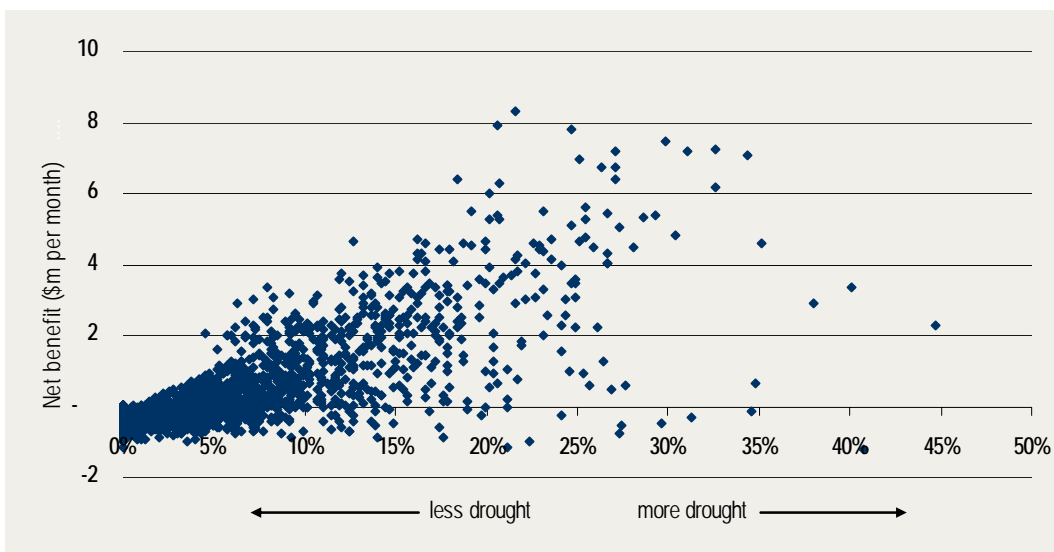
⁷ Further explanation of these scenarios is presented in chapter 6 of the report and appendix E.

6 Distribution of net benefits — 30/40 Operating Rule



Data source: TheCIE.

7 Distribution of net benefits — 70/80 Operating Rule



Data source: TheCIE.

Chart 7 presents the distribution of net benefits under a 70/80 Operating Rule for the desalination plant. This clearly shows that for a large number of alternative rainfall scenarios that operating the plant in this way only delivers minimal net benefits. But where droughts are likely to be a more frequent part of future climatic conditions operating the plant according to a 70/80 Rule can deliver substantial net benefits. The net benefits associated with operating the plant according to the 70/80 Rule (or the 80/90 Rule) is significantly higher than the 30/40 Rule in extreme events.

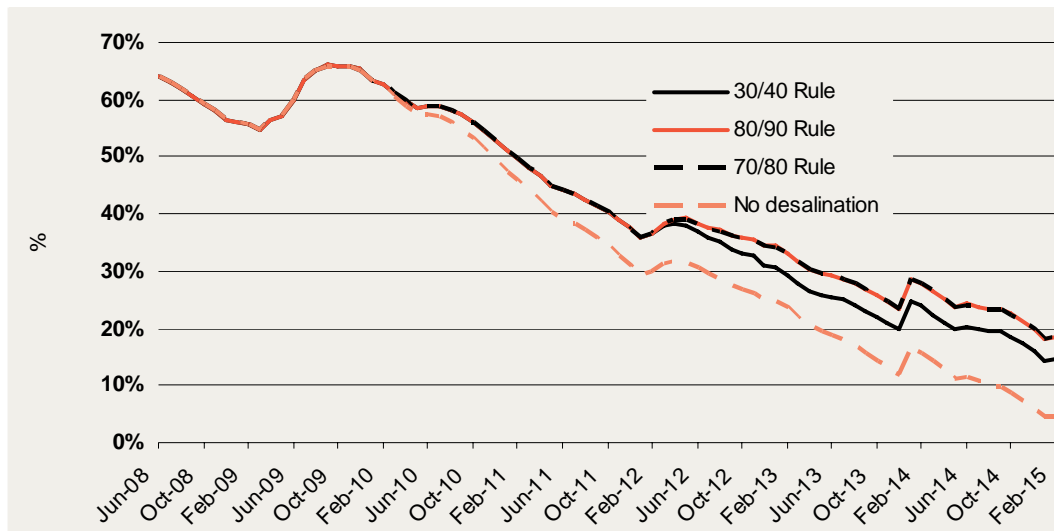
Extreme events

As noted above, the desalination plant has greater benefits in periods of low rainfall. As an illustrative example, we have chosen one scenario from the SCA's hydrological model under extremely low rainfall from 2008 to 2015. This scenario is drawn from a similar pattern of rainfall for the Sydney region that has occurred in the past. Therefore, while not a forecast, it reflects a possible rainfall pattern that should be taken account of when setting policy.⁸

The resulting dam levels under this rainfall scenario for the different operating rules considered are presented in chart 8. At the start of this period (1 June 2008) storage levels are at 63.5 per cent. The results in the chart also take account of the fact that the desalination plant will be operating at full capacity for the first two years from the point of construction. Different operating rules can significantly reduce the chances of falling into extremely low dam levels in the advent of adverse climatic conditions over the next few years.

In the example rainfall scenario there is no difference between operating rule 70/80 and 80/90 because dam levels are always below 70 per cent over this period. By early 2015, without a desalination plant operating, dams would have reached approximately 5 per cent of capacity. However, with the desalination plant operating in accordance with the 30/40 rule dam levels would have reached approximately 15 per cent and 18 per cent if the 70/80 or 80/90 rule had been adopted.

8 Storage levels (% of total capacity) in 'extreme' events from 2008 to 2015



^a In the first two years, the plant is operating at full capacity.

⁸ It is important, however, to recognise that these events have a very low chance of occurring.

Risks

The results above make a number of key assumptions. The most important of these is that future climatic conditions can be approximated by those of the past. That is, even though there is uncertainty about future rainfall patterns, the main analysis assumes that on average it is the same as it has been in the past 100 years. With the possibility that climate change will impact on rainfall patterns this may not be the case.

Our analysis shows that even under different assumptions about future climatic conditions the 70/80 rule has the highest net benefits of the rules evaluated. If average rainfall is 15 per cent lower, running the desalination plant more often (the 80/90 rule) does not provide higher net benefit. If average rainfall is 15 per cent higher, running the desalination plant less often (the 30/40 rule) does not provide higher net benefit. The 70/80 rule is also robust to changing the volatility and persistence of rainfall events.

We also test the robustness of the 70/80 rule to assumptions about:

- costs of restrictions;
- environmental value of spills;
- level of demand; and
- risk preferences of government and community.

Our finding that the 70/80 rule performs better than the other rules is robust to these assumptions.

Conclusions

Operating the desalination plant in the midst of a drought, when dam levels are low, has limited benefit either in providing greater security or in terms of reducing time in restrictions. The value of the desalination plant comes from its ability to reduce the demand from surface water supplies which results in higher storage levels prior to droughts occurring or in anticipation of droughts. By operating the desalination plant when dam levels reach 70 per cent, the expected time spent in restrictions falls and severe restrictions may be avoided. Additional infrastructure spending may also be avoided.

But operating the plant well in advance of a drought is more costly. We find that these costs are worth incurring under a 70/80 operating rule but not a 80/90 operating rule.

If climate change leads to more severe droughts there may be additional benefits to running the desalination plant using an 80/90 rule. For example, if climatic conditions were expected to be the same as occurred over the past eight years, but under most rainfall patterns, this operating rule provides little additional insurance

and much of the water saved from desalination ends up as environmental spills, with lower environmental value than the cost of producing the water.

While the 70/80 rule for the desalination plant performs better than the other rules under a range of alternative assumptions, the rules should remain flexible to new information. This is consistent with the principles of adaptive management. There may be scope to pursue a better strategy by incorporating information from medium term climate forecasts, as well as adjusting the rule as our understanding of possible climate change improves.

The rule for the desalination plant should also be subject to review as other parts of Sydney's water portfolio change. For instance, changes to the environmental flow rules for the dams or unanticipated changes in demand may require refinements of the operating rules to extract maximum benefits.

1 Introduction

Sydney Water supplies more than 1.4 billion litres of water to more than 1.7 million homes and businesses each day in the Sydney metropolitan area as well as the Illawarra and the Blue Mountains. Sydney Water buys untreated water from the Sydney Catchment Authority (SCA), the organisation responsible for bulk water supply in the Greater Sydney region.

In the past Sydney's water supply needs were met primarily through large dams constructed on the outskirts of the city and managed by the SCA.⁹ To deal with the variable rainfall runoff patterns, the extended operating storage capacity of the Sydney system of dams is approximately 2600 billion litres which is very large relative to the population it serves. The largest of these storages is Warragamba dam which supplies approximately 80 per cent of Sydney's water. In recent times, however, the NSW Government has been gradually diversifying its sources of water so as to provide a secure and sustainable water supply now and in the future. The system, however, remains an interconnected system so as to be able to meet supply needs of all parts of all customers in the system.

1.1 Who benefits from the desalination plant?

The desalination plant will provide up to 15 per cent of the water supply needs of Sydney Water's customers. The direct recipients are customers in parts of metropolitan Sydney and the eastern suburbs, who will receive desalinated water in their homes. However, all Sydney Water customers benefit because 15 per cent more water remains in the dams, available for use by other customers.

Customers in Sydney, the Illawarra and the Blue Mountains rely on a water supply system made up of 10 major dams. Warragamba is by far the largest, supplying around 80 per cent of Sydney's water, but the system forms an interconnected network. Various dams are linked to enable top up during drought conditions, including the Illawarra. For example, a significant amount of water is transferred from Tallowa and Nepean Dams to Warragamba, and Avon Dam in the Illawarra is used to top up Nepean. A schematic of the water supply system is presented in appendix F.

⁹ A schematic representation of the water supply system is presented in appendix 8F.

In 2009 the Government announced the construction of a 250ML/day desalination plant that can be increased to 500ML/day. The plant provides a significant additional source of water that is independent of rainfall. Construction of the plant and associated pipelines has commenced and is anticipated to be completed by early 2010. Under the contract with the plant operators, the plant will be operated at full capacity for the first two years while it remains under warranty. Following this, the operating rules for the plant have yet to be specified.

In deciding on the operating rules, it is important to consider how to maximise the net benefits from the desalination plant. This requires taking account of the costs of operating the plant and the benefits of operating the plant, such as reduced time in restrictions and less need for new water infrastructure. Options for operating the plant range from treating the plant as a 'base-load' to treating it as an insurance policy. If operated as an insurance policy, the plant could be operated only in droughts or more often in anticipation of droughts.

Operating the plant only when dam levels reach relatively low levels may not recognise the full potential of the plant in reducing the impacts of droughts, given that the plant (on its own) does not have the capacity to meet Sydney's water needs. Therefore, there is likely to be benefit in operating the plant in advance of a drought, so as to minimise the chance of the drought leading to much reduced dam levels (where additional investments may be required). It can also have the added benefit of reducing the need to draw on the Shoalhaven system, which is likely to be beneficial for river health in this system.¹⁰ However, operating the plant too much can be costly and would reduce the 'airspace' in the dams to capture significant rainfall events that characterise Sydney's catchments.

Establishing the optimal rules for the plant is therefore a balancing act. The optimal rules of the plant will be dependent on a wide range of factors including the hydrological characteristics of the Sydney catchment, as well as the value the community places on having a secure supply of water and avoiding restrictions.

This project

The purpose of this project is to establish the appropriate operating regime for the desalination plant. The most appropriate points to switch the plant on and to switch it off depend on the costs and benefits of operating the plant.

In measuring the costs and benefits we have taken account of factors such as the impact that operating the plant has on:

- the operating costs and start-up and shut-down costs of the plant;

¹⁰ Transfers from the Shoalhaven system complement the operation of the desalination plant in reducing the demand for water stored in the dams.

- the operating costs of the Shoalhaven pumping scheme;
- the length and severity of water restrictions during drought and the value that the community places on avoiding these restrictions;
- deferring the next augmentation to the water supply; and
- social and environmental benefits and costs arising from greenhouse emissions and spills.

It is envisaged that the operation of the plant will, in general terms, be linked to total dam levels. Therefore, the operating rules will need to specify at what dam levels should the plant commence and cease operation. However, there are other factors (eg short and medium term weather forecasts) that may allow the plant to achieve higher benefits.

The findings of this report will assist Sydney Water in formulating its proposed operating regime which will be submitted to the NSW Government.

Report structure

The structure of this report is as follows.

- Chapter 2 explains the approach used to compare alternative operating rules for the desalination plant and presents an overview of the key changes resulting from the operation of the desalination plant under different operating rules, compared with the base case.
- Chapter 3 sets out the costs of operating the desalination plant under each scenario.
- Chapter 4 discusses our methodology for, and estimates of, the cost of restrictions.
- Chapter 5 explains the calculation of other costs, such as environmental, operation of the Shoalhaven scheme and security benefits.
- Chapter 6 brings together the estimates from the previous chapters to present results on the net benefits under each operating rule.
- Chapter 7 tests the robustness of the findings to key risks such as climate change.
- Chapter 8 discusses our conclusions.

2 *The approach*

Each alternative operating regime will result in different operating costs but will also have implications for the amount of water available for supply at different points in time. Choosing the best operating rule for the desalination plant requires the development of a measure to compare these different impacts across operating rules. The measure we use is the expected net benefit. The benefit cost framework that we use and the alternative operating rules that we assess are discussed in more detail in this chapter.

Analytical framework

The broad outline of the analytical framework that we use to evaluate the costs and benefits of different operating rules for the desalination plant is shown in chart 2.1. The left stream on the chart shows the components that go together to evaluate the benefits of the option, while the right hand stream illustrates how the costs of the option are estimated. Below we describe each of the steps in this approach in more detail.

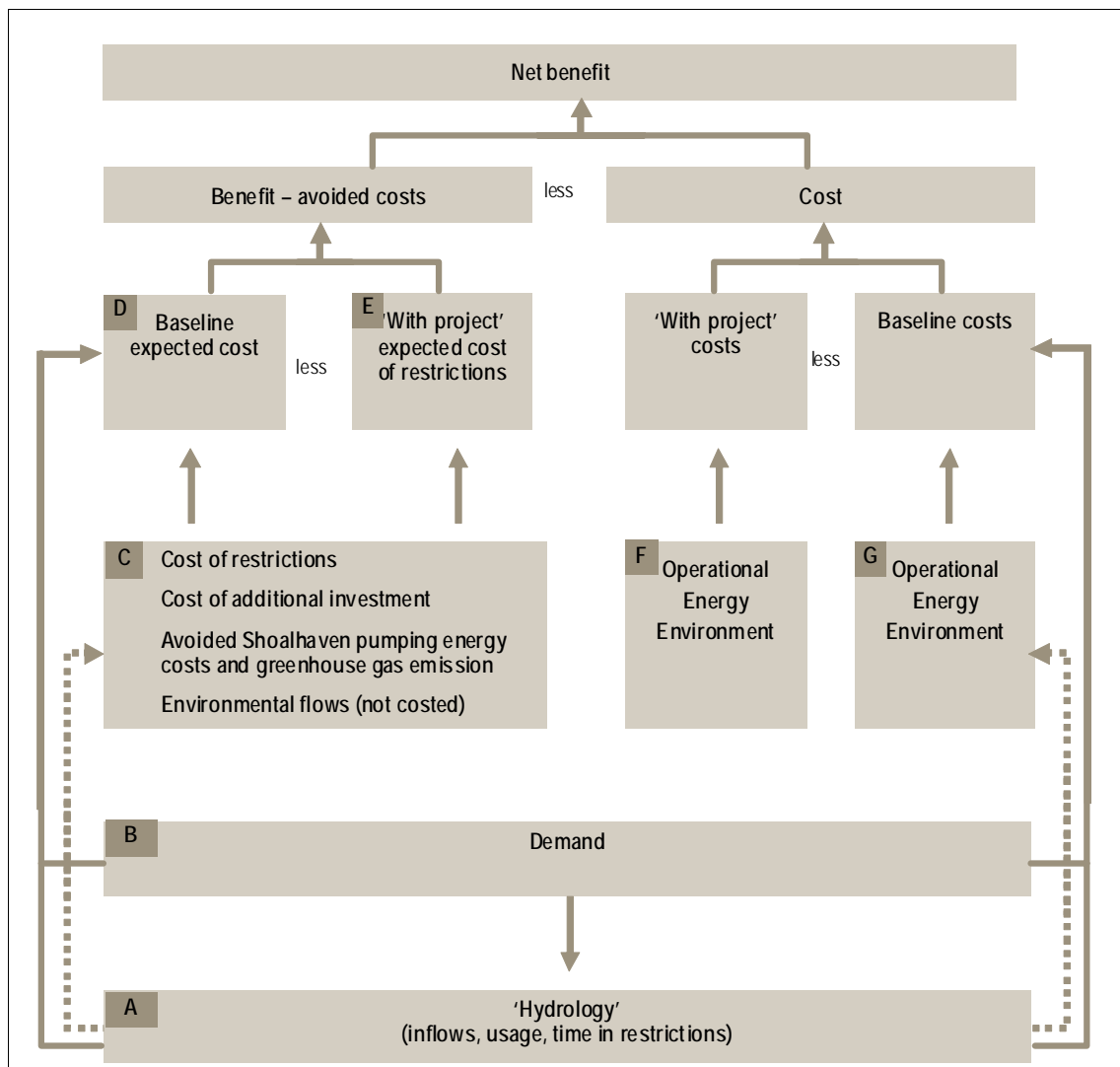
Hydrology and demand

Elements A and B provide the basic information required to generate hydrological outcomes – data on expected inflows which given expected usage patterns can be used to produce estimates of the how often and for how long restrictions are imposed (or the expected time in restrictions) and dam levels and spills over a given time frame. We apply a demand figure of 519 GL per year as set out in more detail below.

The hydrology is worked out using the Water Headworks Network model (WATHNET) applied to the baseline and for different operating regimes for the desalination plant. It provides information on:

- the time in restrictions;
- dam levels;
- the volume of water pumped from the Shoalhaven scheme in each month; and
- the volume of water produced by the desalination plant in each month.

2.1 Illustration of the evaluation approach



The benefits

The benefits or avoided costs of running the desalination plant include a more reliable and secure source of supply into the future. In order to capture these benefits we calculate the:

- incremental improvements to the reliability of supply, measured by the changes in the time in and severity of water restrictions under different operating rules. We can then place a value on the marginal changes in time in restrictions; and
- incremental improvements to the security of supply, measured by the change in the time spent below defined dam levels. We can then place a value on the marginal changes at these low dam levels.

This approach recognises that the community would seek additional investments to boost supply, rather than face the punitive costs of extremely low dam levels.

These benefits are built up by combining hydrology and demand data with value and cost data.

Element C is the avoided costs from operating the desalination plant. These include the reductions in total cost of restrictions for a given level at a given point in time and the costs of additional investment if it is incurred. These costs will themselves be made up of a number of components. Other cost items avoided include:

- the reduction in pumping costs from the Shoalhaven scheme due to the reduced volume of water needed to be pumped from the Shoalhaven river throughout the year, resulting from additional desalination water;¹¹
- the reduction in greenhouse gas emissions from the Shoalhaven scheme due to a reduction in the volume of water needed to be pumped from the Shoalhaven system;¹²
- reductions to the cost of administering the restrictions regimes;
- reduction in the losses in revenue for Sydney Water; and
- value of additional water available for the environment through increased spills from dams.

Elements D and E are derived directly from the information provided by the other elements.

The cost side

The major cost of operating the plant is power costs. Sydney Water advises that there are minimal environmental costs from operating the plant. For example, there has been some discussion of the impact of concentrated seawater discharge on receiving waters. However, the seawater concentrate beyond the mixing zone has no effect as it has been diluted to background levels. Similarly, studies in Perth have shown that there is no discernible effect beyond the mixing zone of the Kwinana desalination plant. The mixing zone is not large – 50–75 metres from the discharge point.

¹¹ Extracting water from the Shoalhaven system will remain an important component of Sydney's water supply system. However, with the desalination plant operating there is likely to be less reliance on water from the Shoalhaven system, particularly in the short term. In the longer term demand is anticipated to increase and there is likely to be greater extractions from the Shoalhaven system into the future (holding other factors constant).

¹² The SCA could undertake actions to reduce the greenhouse gas emissions, such as purchasing 'green energy'. Although, this would result in higher direct pumping costs (assuming that green energy is more expensive).

Alternative operating rules considered

In undertaking the analysis, we have considered three alternative operating rules for the plant, as well as a scenario with no desalination plant.

- **30/40 rule.** The plant is switched on when dam levels fall below 30 per cent of total storage capacity and is switched off when dam levels return above 40 per cent capacity.
- **70/80 rule.** The plant is switched on when dam levels fall below 70 per cent of total storage capacity and is switched off when dam levels return above 80 per cent capacity.
- **80/90 rule.** The plant is switched on when dam levels fall below 80 per cent of total storage capacity and is switched off when dam levels return above 90 per cent capacity. This is similar to the 70/80 rule, except that is switched on at slightly higher dam levels.

These three alternatives rules allow us to test the degree to which the plant can contribute to reducing time in restrictions and reducing the chances of dam levels falling to a point where additional infrastructure investments are required.

The different rules represent different trade-offs between incurring the costs associated with restrictions and augmentation of supply versus the cost of operating the desalination plant. They can be considered as different levels of insurance. The more frequently the desalination plant is run, the higher the operating costs (the insurance premium) and the higher the payoffs when climatic conditions are not favourable (reduced costs of restrictions and supply augmentation). The decision is then how much insurance is worth purchasing, if any.

The WATHNET model

In order to evaluate how the plant contributes to reducing the time in restrictions and the likelihood of low dam levels, we use the results from a complex hydrology model, the WATHNET model. This model is used by the Sydney Catchment Authority to optimise the use of its infrastructure and to calculate the impact on system yield of specific changes to the supply system.

The model allows historical inflow data to be replicated by stochastic modelling to provide 2000 simulated inflow sequences.¹³ The WATHNET model takes the inflow data and estimate dam levels, spills and operation of different parts of the system depending on triggers (restrictions, Shoalhaven pumping, desalination).

¹³ The WATHNET model allows the user to specify the number of simulated inflow sequences to be generated. The SCA commonly uses 2 000 simulated inflow sequences in its modeling.

The assumptions and inputs underlying the WATHNET model include the physical infrastructure of the system,¹⁴ the operating regime for this infrastructure, the demand and other release requirements (for example environmental flow releases, riparian releases) and the hydrologic behaviour of the catchment.

For this project, the assumptions incorporated in the WATHNET modelling regarding how Sydney's water supply system will operate in the future include:

- new environmental flows (80/20 release rules) commencing from Tallowa Dam when all water restrictions are lifted (assumed to be in January 2009);¹⁵
- revised Shoalhaven Scheme pumpmark, with pumping commencing when dam levels fall below 75 per cent of the SCA total system storage level and ceasing when storage levels return above 80 per cent;
- Tallowa Dam minimum operating level of 1.0 metre;
- Upper Nepean dams environmental flows (80/20 release rules) in 2010. For Avon Dam the new environmental flow releases began in March 2008. New environmental releases from the other dams and weirs will start in 2010 when new outlet works are completed;
- current Warragamba environmental flows and riparian flows replace with Western Sydney Recycled Water (anticipated in 2009/2010); and
- a 95/20 rule for Warragamba environmental flows is imposed in 2015, with 1000ML of the flows supplied through the Western Sydney Recycling Initiative.¹⁶

It should be noted that the modelling is undertaken based on the current storage levels (as at May 2008) as the starting point. This gives a base level of probability of triggering restrictions from current levels of dam storage.

The WATHNET model produced a range of output to assist in examining how the operation of desalination plant impacts on the supply system. Key pieces of information produced by the modelling include:

- the amount of time in restrictions;
- storage levels over time and storage behaviour (that is, depletion curves);
- the volume of water pumped from the Shoalhaven scheme in each month – the pumping from the Shoalhaven system is triggered by overall dam levels;
- the volume of water produced by the desalination plant in each month; and
- the volume of water that spills from dams into the downstream rivers.

¹⁴ All water recycling initiatives are treated by the model as 'negative demands'.

¹⁵ Sydney Catchment Authority correspondence.

¹⁶ The decision regarding a revised environmental flow regime for Warragamba dam and commencement on this regime has not been made. Therefore, these assumptions were used as a 'best estimate' at this point in time.

Assumed restrictions regime

The modelling also requires a water restrictions regime to be specified. The restrictions regimes currently assumed in the WATHNET model and used for the purposes of this study are presented in table 2.2. This broadly reflects the restrictions regime applied in Sydney over the past years, although it reflects slightly lower triggers than applied in the recent drought.

2.2 Modelled restrictions regime

<i>Restrictions policy</i>	<i>Trigger level (ON)</i>	<i>Trigger level (OFF)</i>	<i>Assumed total reduction in Demand</i>
	%	%	%
Level 1	55	70	7
Level 2	45	65	11
Level 3	40	65	12

Note: Trigger levels are defined in terms of the percentage volume in the seven major storages at a point in time. The reduction in demand at each level is in reference to a base case. Once Stage 2 and 3 restrictions are removed it is assumed that Stage 1 restrictions are maintained until dam levels reach 70 per cent.

Source: SCA (25 August 2008), personal communication.

Projected demand

The WATHNET model requires assumptions regarding the level of demand to be specified. For this study, rather than a variable demand profile, we have assumed a constant demand at projected 2014-15 levels of 519 GL per year (table 2.3).¹⁷ We conduct sensitivity analysis using demand of 570 GL per year, which is the level forecast at 2019-20 (incorporating population growth as well as the reduction in per capita demand due to Sydney Water's demand management programs).

Calculations based on monthly average

A benefit-cost analysis typically sets out the present value of future costs and the present value of future benefits. This discounts future cash streams by the NSW Government discount rate of 7 per cent. The difference between the benefits and costs is the net present value of the particular operating regime. When ranking different options, the net present value decision rule suggests that the option with the highest net present value would be preferred.

¹⁷ This figure is based on forecasts as at May 2008. It excludes the demand from the North Richmond System which draws water directly from Hawkesbury-Nepean river and is not part of SCA's supply system

2.3 Projected demand at 2014-15 levels

<i>Month</i>	<i>Demand (ML)</i>
January	48 804
February	44 132
March	44 651
April	39 978
May	39 978
June	37 382
July	38 940
August	41 016
September	42 055
October	45 689
November	46 208
December	50 362
Total	519 195

Note: In the WATHNET model the monthly demand is assumed to be constant and does not vary with the prevailing climatic conditions.

Source: SCA (27 August 2008), personal communication.

For this project, instead of using the net present value we generate an average cost and average benefit over the period of analysis. The reason for this is that the WATHNET model was not designed as a forecasting tool. Although it produces results for the next 506 periods into the future – these are scenarios rather than forecasts. Further, for this project we have assumed a constant demand level into the future.¹⁸

We have calculated the net benefits using an average monthly figure, rather than using a net present value. All dollar figures presented in this report are in 2008–09 dollars unless otherwise specified.

¹⁸ This provides a good basis to establish the initial operating rules of the plant. As demand levels change into the future or if there are significant policy changes in the future then the optimal operating regime could be reviewed at that point in time.

3 Costs of operating the desalination plant

A key factor in developing the optimal operating rule for the plant is to understand how the costs of operating the plant vary according to the different trigger levels. Electricity use is a major cost related to the plant. However, there are a range of other complexities that must be accounted for. These are provided for in the contract between Sydney Water and the provider of this service, the Blue Water Consortium.

This chapter provides an overview of the key cost elements and examines how these costs change as a result of operating the plant.

Overview of operating costs

The desalination project's main infrastructure comprises:

- a desalination plant on the Kurnell peninsula with capacity to produce 250ML of water a day, which can be scaled to the ultimate capacity of 500ML/day;
- seawater intake and concentrated seawater outlet connections for the ultimate capacity of 500ML/day but also suitable to operate at lower capacity levels;
- water pipeline infrastructure across Botany Bay and a connection with Sydney Water's pipeline network sized for the ultimate capacity of 500ML/day but also suitable for lower capacities; and
- a pumping station with an initial capacity of 250ML/day.

For the purposes of this analysis we treat the capital costs of the first stage of the desalination plant (the 250ML per day plant) and its associated infrastructure as sunk costs. This is appropriate as these costs are incurred no matter which operating rule is chosen for the desalination plant.

There are also indirect costs of pumping water if the desalination plant is required to supply water to residents in the western parts of Sydney and the potentially reduced payments to filtration plant operators for the reduced cost of filtration. These cost differences have not been incorporated into our analysis due to limited information, although these are not expected to be large enough to make a difference to the results.

Our primary concern is with changes in operating costs of the plant under different operating regimes. The main operating expenditure categories include:

- costs paid to the Blue Water Consortium (the operator of the plant) for operation and maintenance of the desalination plant and associated infrastructure, as specified in the contract;
- electricity costs – payments for electricity supply and renewable energy credits (as the plant will use 100 per cent renewable electricity). These payments will vary significantly depending on the levels of production of the plant and the level of plant efficiency; and
- other expenditures – this includes all of the operating and maintenance costs borne by Sydney Desalination Plant Pty Ltd and not the operator. These costs may include, amongst other things, insurance costs (for example relating to property, business interruption, products and public liability, professional indemnity) and contract management costs.

The costs that are affected by the extent to which the plant is operated are smaller and include:

- variable operating costs – these include electricity costs and the costs of the Renewable Energy Certificates for amounts above a minimum;
- costs of shutdown – these include the costs of shutting down the plant, the standby costs and the costs of restarting the plant. The magnitude of these costs depends on the duration of the shutdown period; and
- costs avoided by shutdown – these can include maintenance costs and costs of replacing membranes that change depending on the amount the plant is operated.

The expected variable costs associated with the plant in the future are dependent on the future rainfall patterns and storage levels. For example, where storage levels are high for long periods of time the desalination plant is generally switched off, unless the trigger for the operation of the plant is at high dam levels.

The current modelling of the desalination plant in the WATHNET model assumes that the plant is either at full capacity or at zero capacity and that the plant can be switched on or off without a notification period. In practice, however, a notification period is required before the plant can be switched on or off. The notification period may vary depending on how long the plant has been out of operation. This is likely to make little difference to the result, particularly if short-term climate forecasts can partially offset the impacts of a notification period.

The total annual cost of operating the plant at full capacity is currently estimated to be approximately \$70 million per annum, which includes some costs which do not vary according to the volume of water produced.¹⁹

¹⁹ Detailed information on the costs items included in our modelling have not been reported due to the confidential nature of this information.

Expected costs of the desalination plant

The actual operating costs will depend on the cost per kL of approximately \$0.60, start-up and shut-down costs and the amount that the plant is operated. This in turn, will depend on the operating rule and the rainfall events that occur.

The expected operating costs for each of the rules, assessed using the 2000 possible rainfall scenarios from WATHNET are shown in table 3.1. The average operating cost for the 30/40 operating rule is \$37 000 per month. This compares to \$830 000 per month for the 70/80 rule and \$1.6 million for the 80/90 rule.

3.1 Desalination plant and water pumping station costs

\$000 monthly average	No Desalination Plant	30/40 rule	70/80 rule	80/90 rule
Expected	0	37	829	1 576
Lower 2.5 per cent	0	3	3	510
Lower quartile	0	3	468	1 164
Upper quartile	0	3	1 111	1 948
Upper 2.5 per cent	0	417	1 941	2 765

Source: TheCIE.

The distribution of operating costs across different rainfall sequences (replicates) can also be assessed. For many sequences the costs are low. For instance the costs of the 30/40 rule under three quarters of the replicates are \$3000 per month, reflecting standby costs. For other sequences the costs are high. For example, the highest 2.5 per cent of operating costs are above \$2.8 million for the 80/90 operating rule. Although this is still well below the cost of operating the desalination plant all the time.

The extent of standby, shut-down and start-up costs can be determined by the average cost per kL (table 3.2). These costs add between 18 cents per kL and 38 cents per kL depending on how often the desalination plant is run. There may be scope to avoid some of these costs through adjusting the way the plant is run.

3.2 Desalination plant and water pumping station costs per kL

Item	30/40 rule	70/80 rule	80/90 rule
Expected water from desalination (ML/month)	37.7	988.7	2 009.8
Expected cost (\$000 per month)	37	829	1 576
Cost per kL	0.98	0.84	0.78

Source: TheCIE.

Note: The relatively high average volume of desalinated water produced under the 80/90 rule compared with the 70/80 rule reflects the fact the hydrology model indicates that dam levels are expected to be below 80 per cent capacity (on average) for 20 per cent of the time.

Conclusions

Triggering the operation of the desalination plant at higher dam levels results in a higher level of operating costs being incurred. The 30/40 rule results in expected costs of \$37 000 per month, which is less than 5 per cent of the \$0.8 million average monthly costs under the 70/80 rule. The 80/90 rule results in costs that are almost twice those of the 70/80 rule.

The expected variable costs associated with the plant in the future are dependent on the future rainfall patterns and storage levels. For example, where storage levels are high for long periods of time the desalination plant is generally switched off, with the exception of the 80/90 operating rule.

The current modelling of the desalination plant in the WATHNET model assumes that the plant is either at full capacity or at zero capacity and that the plant can be switched on or off without a notification period. In practice, however, a notification period is required before the plant can be switched on or off. The notification period may vary depending on how long the plant has been out of operation. This is likely to make little difference to the result, particularly if short-term climate forecasts can partially offset the impacts of a notification period.

4 *Cost of restrictions*

Water restrictions are limits on how and when people can use water. They aim to reduce the amount of water demanded, allowing the water system to continue to be viable in drought periods. These restrictions do not put a strict quota on water use but rather impact on water use by affecting how and when water can be used. This involves additional time costs for water users or less amenity from using water in particular ways. Restrictions are an important policy instrument that have been successful in deferring costly infrastructure investments, But like other policy instruments they have costs that should be explicitly accounted for in the analysis.

There are currently three levels of restrictions applying in Sydney, with Level 1 being the least restrictive and Level 3 the most restrictive. The restrictions policy has a direct impact on consumers (and businesses). Restrictions also partly reduce the return that Sydney Water earns on its fixed assets because of lower water sales.²⁰

This chapter discusses the approaches to calculating the loss in welfare if restrictions occur and estimates these costs.

Change in consumption as a result of restrictions

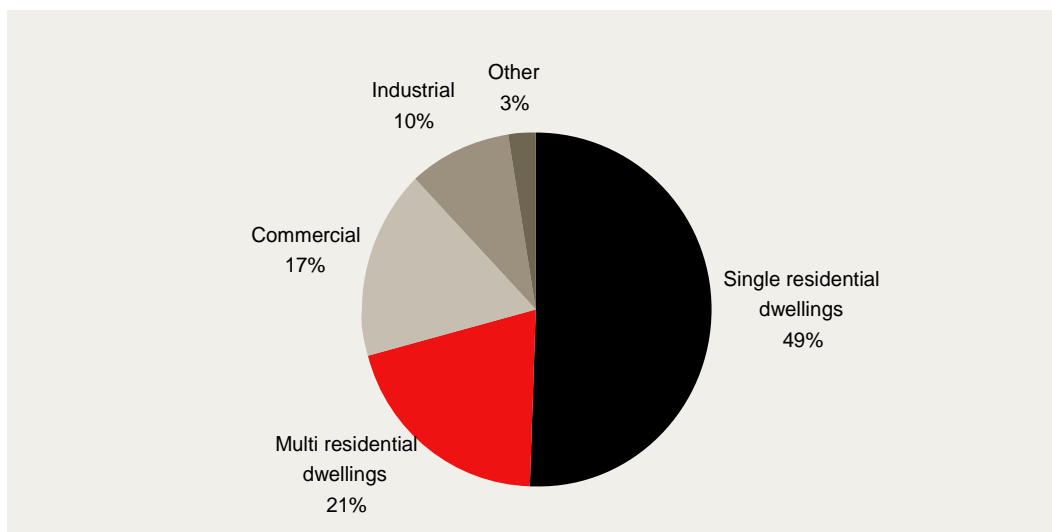
Sydney Water has estimated the impact of the recent restrictions as presented in the table below. In the most recent drought the following restrictions applied:

- Level 1 restrictions were introduced in 1 October 2003 when dam levels dropped below 60 per cent.
- Level 2 restrictions were introduced on 1 June 2004 when dam levels dropped below 50 per cent.
- Level 3 restrictions were introduced on 1 June 2005 when dam levels dropped below 40 per cent.

The group most affected by restrictions is the single dwelling residential customers, reflecting the large component of outdoor use. Single dwelling customers comprise about half of water use in 2006-07 (chart 4.1). Commercial and other customers are

²⁰ A typical household in Sydney uses approximately 200 kilolitres of water per annum and faces a fixed charge of \$75.70 per annum and volumetric charge of \$1.61 per kilolitre of water consumed.

4.1 Consumption by sector (2006-07)



Data source: Sydney Water.

also impacted by restrictions to some extent due to the significant outdoor usage of certain groups within this category such as sporting facilities and clubs.

Understanding the impact of restrictions on industrial customers is more difficult, particularly given that the restrictions policy does not directly impact on these customers. These customers have also reduced their consumption in recent years, so it is more difficult to isolate the changes in demand purely due to the introduction of water restrictions.

Table 4.2 below presents the estimated changes in consumption as a result of restrictions since 2003-04. Single dwelling residential and commercial properties have had the largest reduction in consumption since the introduction of restrictions. This is consistent with their usage patterns which includes a substantial proportion of outdoor usage.

4.2 Assessed impact of restrictions (percentage on restricted consumption)

Property type	2003-04	2004-05	2005-06	2006-07
	%	%	%	%
Single residential dwellings	12.0	21.6	23.5	26.7
Multi residential dwellings	5.9	9.4	9.2	9.3
Commercial/other	7.4	14.2	15.0	14.5
Industrial	4.1	7.9	9.3	8.4

Source: Sydney Water, correspondence (11 September 2008).

Estimating the lost welfare from restrictions

The costs of restrictions potentially accrue to a number of different groups within the community, including consumers (for example households, businesses, community groups) governments and water utilities.

Costs of water restrictions include:

- time and inconvenience costs – for example, hand watering of gardens at specific times;
- investment in high cost water sources – for example, rainwater tanks, domestic recycling systems;
- flow on effects to businesses as a result of reduced demand for services – for example, garden centres; and
- costs of administering water restrictions – for example, advertising and compliance costs.²¹

The elements of the costs of restrictions that could be considered under the analytical framework are summarised in table 4.3. The table also lists the potential range of data sources to estimate the cost of restrictions to different groups.

The most important of these groups is likely to be households. They incur the costs of restrictions both because of their use of water around the house and because of their reduced recreational options. The costs of restrictions will vary by household type and by location within the Sydney metropolitan area. For example, the coastal regions of Sydney generally receive substantially higher rainfall than inland regions and have more moderate temperatures. Therefore, water restrictions are likely to have low impacts in these areas, compared with inland areas, as gardens receive more natural rainfall.

Other impacts are also likely to differ by region. For example, sporting facilities in the inland areas of Sydney are likely to be more affected by drought conditions compared with the same facilities located in coastal areas. The diversity of impacts of restrictions is also likely to be significant for the business sector which is typically a heterogeneous group according to different levels and types of water use.

Estimating the costs of restrictions to consumers

Restrictions reduce the quantity of water consumed by Sydney's households and businesses. They do not put a strict quota on water use but rather impact on water

²¹ Further discussion on the cost of restrictions can be found in Allen Consulting Group (2007), ACIL Tasman and ISF (2007).

4.3 Elements of the cost of water restrictions

<i>Group affected</i>	<i>Aspect of activity affected</i>	<i>Description</i>	<i>Potential data sources</i>
Households	Activities around the home	Mostly related to outside activities such as gardening and swimming pools.	Statistical estimation of demand curve Targeted surveys (for example WTP or Choice Modelling) Combination survey and behavioural modelling
	Activities elsewhere (sport and recreation)	Cost of changes in recreation options	Estimates based on time use Surveys (choice modelling)
Business	Water dependent activities	Business cost arise through increased water costs or through reduced sales of products that require water (eg plants or swimming pools)	Statistical estimation of demand curve Choice modelling Economywide modelling
	Tourism		Economywide modelling
Community facilities	Street trees	Death of street trees leading to a loss of amenity	Replacement cost Surveys
Government	Other costs	Other costs incurred by government	Can be directly estimated
Water utility	Monitoring and enforcement costs	Cost of advertising restrictions, cost of enforcing restrictions	Can be directly estimated
	Lost producer surplus		

use by affecting how and when water can be used. This involves additional time costs for water users or less amenity from using water in particular ways.

The cost of restrictions to households and businesses can be conceptually understood in two ways:

1. as increasing the total cost of water for a given demand; and
2. as reducing the demand for water at a given price.

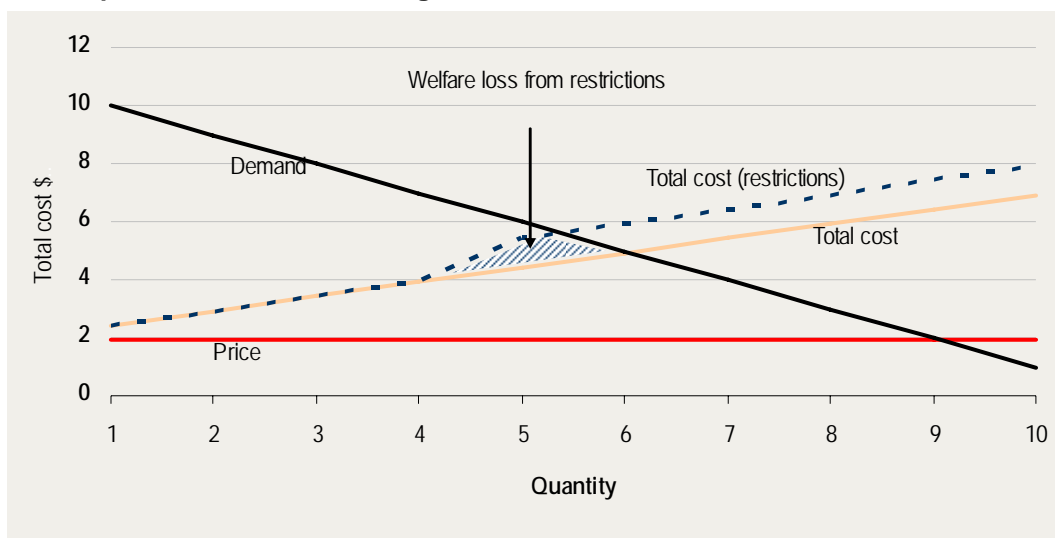
These two methods should arrive at the same conclusions. Each is discussed below.

Total cost

The cost to a household of using water can be thought of as greater than just the price of the water used. There are time costs in watering your garden for example. These costs can be reasonably thought to rise for some types of water use if restrictions are in place.

This situation is set out in chart 4.4. The variable price for water is just under \$2 per kL. On top of this are other costs, giving an upward sloping total cost curve. The quantity consumed is where total cost equals demand.

4.4 Impact of restrictions through total costs



Data source: TheCIE.

The impact of restrictions is to increase total costs. This reflects additional time and inconvenience costs in undertaking activities involving water. The increase is only for a portion of water use, assumed here to be the water uses that had the least value of those for which water is purchased. The quantity of water consumed falls, as it is now where the total cost (restrictions) line meets the demand curve.

The loss in utility from restrictions is a dead weight loss from lowering water use and the loss from higher total costs for undertaking some water uses. It is the shaded area in the chart.

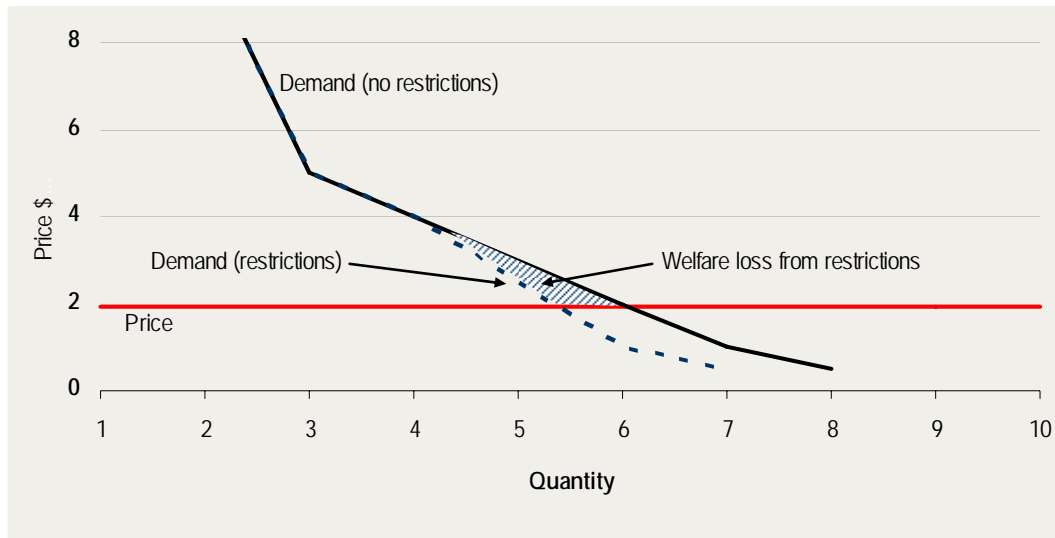
There is an assumption embedded in the above analysis that the restrictions policy is reasonably well targeted. That is, restrictions only increase the total cost for activities that had fairly low value to consumers and fairly high total costs. This means that utility loss in the shaded blue area is a minimum estimate. In fact, some people would be willing to pay more to use water to fill their pool or water their gardens, meaning that there would be higher valued demand that is actually being lost.

Lower demand

A different method of conceptualizing restrictions is that used in Grafton and Ward (2008). In this case, the price of restrictions remains the same, but the change in what can be done with water lowers the demand for water. This is set out in chart 4.5.

Restrictions shifts demand down for some part of the demand curve. The quantity of water demanded falls. The loss in utility is represented by the shaded area.

4.5 Impact of restrictions through demand



Data source: TheCIE.

The two methods appear conceptually very different but are actually very similar. They plot the same economic impacts, just using different y axes. In the second, the demand curve incorporates the lower value that users may get from watering their garden in a different way, while in the first, this is incorporated as a cost to the consumer.

Another alternative method of modelling would be to create a number of sub-markets for water, reflecting its different uses and impose restrictions in each of the different markets. The methods above instead present an aggregated water demand and cost curve that incorporates the adjustment in the sub-markets.

Evaluating the cost of restrictions to consumers

The conceptual framework above suggests that the cost of restrictions can be estimated if we have information about the demand curves or total cost of particular water activities. This is one method for estimating the cost of restrictions and is used in this study.

A preferable method is to measure the loss in welfare directly through consumer surveys of willingness to pay, willingness to avoid or choice modelling. There are no studies of this kind for Sydney. We benchmark our results based on the demand method to the findings of willingness to pay studies in other jurisdictions. A detailed discussion of willingness to pay is contained in appendix B.

A key parameter for estimating the loss in consumer surplus is the extent to which demand falls as the price rises – the price elasticity of demand. For our analysis we use a price elasticity of demand of -0.17 as estimated by Grafton and Ward (2008) for Sydney. This means that for a 1 per cent increase in price, we expect the quantity of water consumed to fall by 0.17 per cent. This is the most recent study undertaken for

consumers in Sydney and it is an approximate mid-range of the information currently available on price elasticity of demand (see appendix C for other estimates of the price elasticity of demand).

This estimate of the price elasticity of demand is broadly consistent with recent surveys by Sydney Water and IPART that indicate that price is not a major issue for consumers.²² This is also consistent with Sydney Water's observations that consumers do not change their consumption significantly to changes in prices.

We use an estimate of 30 per cent of water use (without restrictions) is allocated to activities that are affected by restrictions, such as outdoor water uses.²³ We can then calculate the shaded figure in chart 4.5.

We do not rely overly on our estimates of the price elasticity of demand and extent of demand impacted by restrictions. The estimates of the cost of water restrictions are benchmarked against a range of studies. The results are robust to alternative estimates of the cost of restrictions, as explored in chapter 7.

We estimate that the cost of restrictions to households is \$122 per household for Level 1 restrictions, rising to \$210 for Level 3 restrictions (table 4.6). The total cost of restrictions in Sydney is estimated at \$202 million for Level 1 restrictions and \$347 million for Level 3 restrictions.

4.6 Estimated cost of restrictions for consumers (2011-12 prices)

	<i>\$ per household</i>	<i>Total (\$m)</i>
Level 1	122	202
Level 2	192	318
Level 3	210	347

Note: These results are not additive.

Source: TheCIE.

In comparison, Grafton and Ward (2008) estimate costs of restrictions of \$209 per household (adjusted to 2011-12 prices). This is not specific to a particular level of restrictions and applies to total costs to households, rather than just costs of restrictions on residential water use – it incorporates costs to businesses passed on to consumers and costs on recreational activities. The estimates used in this report are broadly in line with theirs.

²² IPART (2007), *Residential energy and water use in Sydney, the Blue Mountains and Illawarra*, November, pp. 45-48.

²³ Early estimates from Sydney Water's end-use model suggest that outdoor use for single dwelling residential properties is 38 per cent of total use and 32 per cent for multiple dwelling residential properties.

We also consider how our estimates relate to estimates of the cost of restrictions in Canberra. Hensher, Shore and Train (2006) estimate per household costs of Level 3 restrictions at \$309 in the ACT (adjusted to 2011-12 prices). Our estimates align reasonably well with this, as we would expect the cost of restrictions in Sydney would be lower than in Canberra as Sydney gardens and lawns get more rainfall even in drought. The ACT study finds no cost to lower levels of restrictions. We discuss the sensitivity of results to such an assumption in chapter 7.

For the non-residential sector, the number of studies estimating the elasticity of demand is relatively small. However, there are a range of studies from overseas that can be used.²⁴ We have used a price elasticity of demand of -0.3 based on a median elasticity for Canadian industries as an approximation.²⁵

Using this generates a welfare cost of imposing restrictions for a year of:

- Level 1 – \$33m for commercial, \$11m for industrial;
- Level 2 – \$52m for commercial, \$17m for industrial; and
- Level 3 – \$57m for commercial, \$18m for industrial.

The cost to the water utility of restrictions

The cost to the water utility of restrictions includes the loss in producer surplus as well as increased costs of monitoring and enforcements of particular restrictions regimes. The cost to the producer largely occurs because its variable costs are well below the price of water, which is set taking into consideration the long run marginal cost of additional water. The loss in producer surplus and monitoring costs are discussed in turn below.

Producer surplus

Producer surplus is the difference between the price of water and the marginal cost of producing each unit of water. For Sydney's water, the marginal cost of producing much of the water is approximately 30 cents per kL which includes the costs of purchasing water from the SCA and the costs of filtration. The infrastructure costs, such as the building of dams, have mostly been incurred, so these costs are not

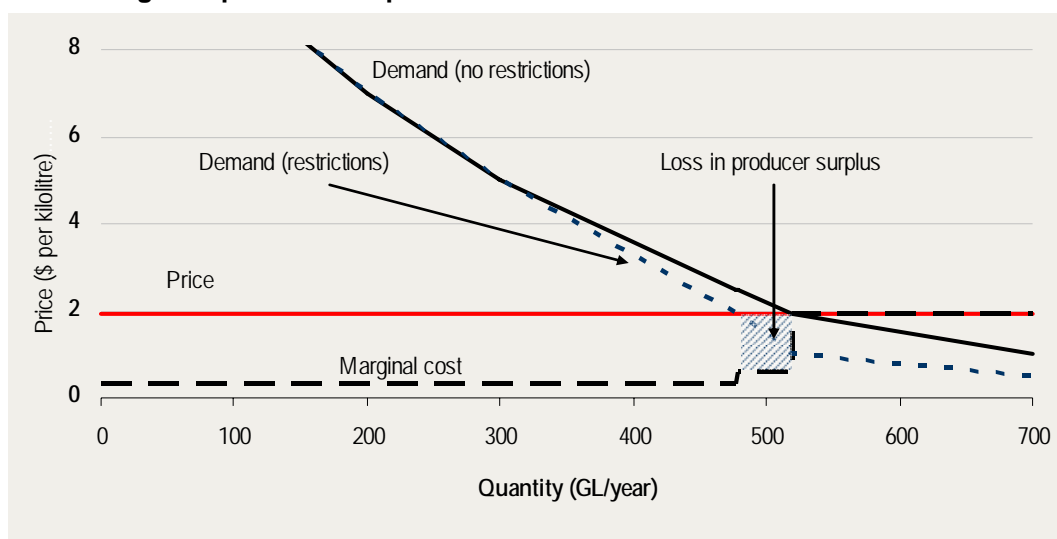
²⁴ Industrial firms use water for a variety of purposes – for cooling intermediate inputs, producing high pressure steam, moving intermediate inputs, sanitation, and as a direct input. The major issue affecting accurate elasticity estimates for industry as a sector is its heterogenous composition and the uneven distribution of water use across industries. Therefore, there are limitations of using a single elasticity figure. Nevertheless, in the absence of more detailed information we have relied on a single elasticity figure but recognize its potential limitations.

²⁵ CIE (2003), *Literature review of the price elasticity of urban water demand*, prepared for the Sydney Catchment Authority, p. 21.

included as part of the marginal cost of producing water. The desalination plant, once constructed, produces water at a marginal cost of in the order of 60 cents per kL as discussed in chapter 3 (excluding start-up and shutdown costs).

A supply curve (or marginal cost curve) for Sydney's water is shown in chart 4.7. The marginal cost (including filtration costs) of producing water from the dams is currently approximately 30 cents per kL and additional water is produced by desalination at approximately 60 cents per kL.²⁶ The 30 cents per kL costs apply to approximately 470 GL of water, which is based on a sustainable yield of 530 GL prior to the desalination plant and adjusted for system losses of 10 per cent.

4.7 Changes in producer surplus from restrictions



Data source: TheCIE.

Producing water beyond the current demand level has much greater marginal costs, as this requires building additional infrastructure. The price of water set by IPART measures this cost using a long run marginal cost of water concept (IPART 2008).²⁷ For 2011-12 the volumetric price is set at 1.93 per kL (in 2008-09 dollars).

The loss in producer surplus from restrictions is the shaded area in chart 4.7. It can be calculated as the difference between the price and marginal cost of existing water options multiplied by the change in the quantity of water.

²⁶ Sydney Water can buy water from the Sydney Catchment Authority for 22 cents per kL in 2008-09 (Sydney Catchment Authority 2008, *Submission to IPART's Review of Prices for the Sydney Catchment Authority*, September, p. 41). Sydney Water estimates that it faces additional costs of 8 cents per litre for filtration.

²⁷ IPART (2008), *Review of prices for Sydney Water Corporation's water, sewerage, stormwater and other services*, June.

The marginal cost curve may not be below the current price if demand is higher than currently forecast. In this case, the loss in producer surplus from imposing restrictions would be much smaller, as restrictions would reduce the need for supply augmentation rather than lowering the return on current supply infrastructure.

Note that producer surplus is not profit. It is required to cover fixed costs of operating the water system and provide a return to previous investment.

Based on the above assumptions, the loss in producer surplus from each level of restrictions is:

- Level 1 – \$70 million;
- Level 2 – \$110 million; and
- Level 3 – \$120 million.

Monitoring and enforcement costs

There are a range of costs incurred by Sydney Water in relation to administering the restrictions regime. This includes the costs of advertising the restrictions that apply at a given point in time and the cost of enforcing the restrictions. Sydney Water estimates the following costs for administering restrictions:

- Level 1 \$5.4 million per annum;
- Level 2 \$7.5 million per annum; and
- Level 3 \$10 million per annum.

Where infringement notices have been issued the utility can gain some additional revenue. Therefore, these additional revenues should be 'netted off' the costs. Sydney Water currently estimates the revenue from fines of between \$0.4 million to \$1 million per annum.

Expected cost of restrictions

The calculations in the previous section provide information on the estimated welfare losses if restrictions occur. Applying these figures to hydrological outcomes gives estimates of the expected cost of restrictions under each of the operating rules.

Hydrological outcomes indicate that without desalination capacity restrictions of some form would apply about 6 per cent of the time (table 4.8). About 2 per cent of the time these would be the relatively severe Level 3 restrictions. The 30/40 rule makes little difference to these outcomes, as desalination kicks in too late to stop restrictions occurring.

The 70/80 rule and 80/90 rule substantially impact on the expected time in restrictions. Under the 70/80 rule restrictions are expected to apply for 3.7 per cent of the time, with relatively severe restrictions applying less than half of the time

4.8 Expected time in restrictions

<i>Restrictions regime</i>	<i>No desalination</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
No Restrictions	94.03%	94.27%	96.33%	96.93%
Level 1	3.16%	3.08%	2.37%	1.98%
Level 2	0.86%	0.84%	0.56%	0.48%
Level 3	1.94%	1.81%	0.74%	0.61%

Sources: Sydney Catchment Authority modelling and TheCIE calculations.

expected with no desalination plant. The 80/90 rule reduces time in restrictions to about 3 per cent, with 0.6 per cent for relatively severe restrictions.

For some rainfall sequences much more time is spent in restrictions than others. For more than a quarter of replicates, restrictions would not apply regardless of the operating rule for the desalination plant. Restrictions would apply more than 9 per cent of the time for another quarter of the replicates, under the base case. Operating the desalination plant at the 80/90 rule, restrictions would apply more than 5 per cent of the time for the quarter of replicates that have the most time in restrictions.

4.9 Time which restrictions do not apply, by distribution

	<i>No desalination</i>	<i>30/40</i>	<i>70/80</i>	<i>80/90</i>
	%	%	%	%
Bottom quartile	91	92	94	95
Average	94	94	96	97
Median	96	96	98	99
Top quartile	100	100	100	100

Source: Sydney Catchment Authority modelling and TheCIE calculations.

The results in charts 4.8 and 4.9 above assume that history repeats itself, at least in a probabilistic way. If the climate is drier in the future than it has been over the past 100 years then restrictions will be imposed more frequently and operating the desalination plant more would have a greater impact on the cost of restrictions.

The expected costs of restrictions under each scenario and for each category of costs are shown in table 4.10. The costs are smaller as the desalination plant is operated closer to capacity. If there is no desalination plant, the expected cost of restrictions is over \$2 million per month, with about three quarters of the costs imposed on households and businesses. The 30/40 rule changes these costs very little.

Under the 70/80 rule, expected total costs of restrictions fall to about \$1.2 million per month. Under the 80/90 rule the expected total costs falls to less than \$1 million per month. These rules have substantial expected cost savings. This reflects that even though restrictions are rare, when they occur they impose substantial costs on households, businesses and Sydney Water.

4.10 Expected costs under each operating rule

<i>\$000 monthly average</i>	<i>No desalination</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
Costs to households and businesses	1 631	1 572	887	719
Costs of administering the restrictions regime	33	32	18	14
Producer surplus loss	456	439	248	201
Total restrictions cost	2 120	2 043	1 153	934

Source: TheCIE.

The restrictions costs can also be considered for those replicates where restrictions have higher and lower costs. For the highest quartile of replicates, arranged by cost of restrictions, the cost of restrictions are about 50 per cent higher than the expected costs (table 4.11). The restrictions costs of even more extreme outcomes is more than four times that of the average (table 4.12), taking the costs of the replicate at the 2.5 per cent band.

4.11 Costs under each operating rule under highest quartile

<i>\$000 monthly average</i>	<i>No desalination</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
Costs to households and businesses	2 347	2 315	1 202	907
Costs of administering the restrictions regime	47	46	23	18
Producer surplus loss	656	647	336	254

Source: TheCIE.

4.12 Costs under each operating rule under highest 2.5 per cent

<i>\$000 monthly average</i>	<i>No desalination</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
Costs to households and businesses	7 705	7 316	4 933	4 478
Costs of administering the restrictions regime	162	157	102	89
Producer surplus loss	2 155	2 046	1 379	1 252

Source: TheCIE.

Conclusions

Water restrictions have been an important policy instrument used to manage water scarce water supplies during drought situations. Amongst other things, the use of water restrictions have allowed costly infrastructure to be deferred into the future. Nevertheless, it is important to recognise that restrictions have a cost which should be factored into the analysis of alternative operating rules for the desalination plant.

We have estimated the expected cost of restrictions using available information on the price elasticity of demand for water in Sydney, benchmarked to willingness to pay studies in other regions. We estimate significant costs imposed on households, businesses and Sydney Water from a restrictions regime.

Even though restrictions are fairly rare, their expected costs are not negligible. Without desalination, the expected total cost of restrictions is over \$2 million per month. Operating the desalination plant at high capacity can more than halve these costs. The impact of the desalination plant on restrictions costs is greatest when rainfall outcomes are bad.

The figures presented are based on an assumed level of demand at 2014–15. Future demand could be substantially higher than that at 2014–15. Therefore, the results in these tables are likely to underestimate the expected costs of restrictions. Likewise the potential impacts of climate change have not been incorporated into this analysis. If the future climate is expected to be drier or more variable then water restrictions are likely to apply more frequently in the future. This is considered in the sensitivity analysis in chapter 7.

5 *Calculating other costs and benefits*

A number of additional costs and avoided costs have been flagged in the discussion in chapters 1 and 2. Operating the desalination plant more frequently may reduce the need for (or delay) additional investment in the water supply system that would be triggered in the event of low and falling dam levels. It could also reduce the costs of pumping water from the Shoalhaven and provide additional water for the environment. This chapter sets out the estimation of these factors.

Security benefits of the desalination plant

The operation of the desalination plant substantially reduces the expected time in restrictions where the desalination plant commences operation before water restrictions are triggered. But more than this, the plant can provide security benefits as it can reduce the likelihood that dams reach critically low levels. However, given that the first stage of the desalination plant only has capacity to meet a proportion of Sydney's monthly water needs, we assume that (at low dam levels) additional capacity for the desalination plant would be commissioned, in order to avoid running out of water.²⁸

Before turning to the estimation of security benefits, extreme hydrological outcomes that might compromise water security are discussed.

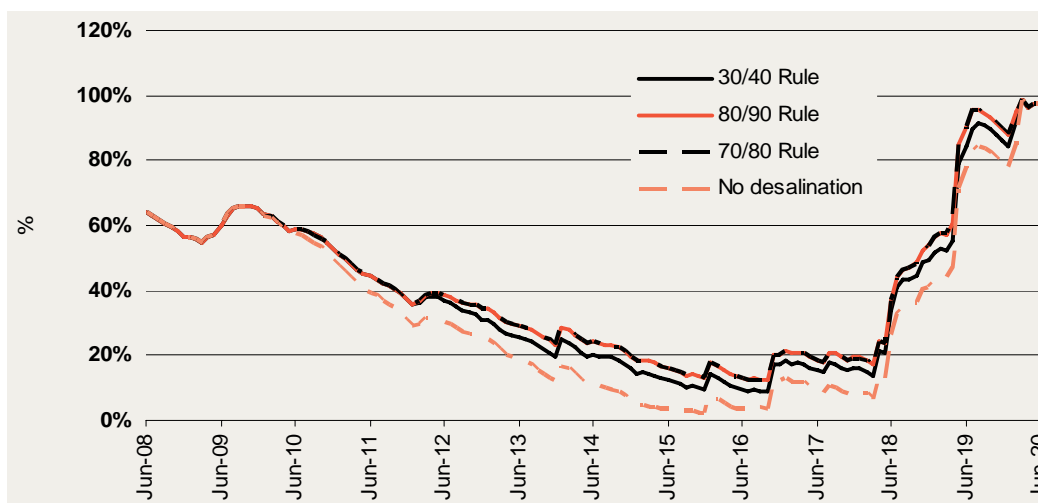
Extreme hydrological outcomes

Extreme hydrological outcomes highlight the value of the desalination plant under particular circumstances. While the probability that these circumstance occur is clearly crucial, analysis of particular scenarios indicates the difference that a desalination plant can make to water security.

To illustrate this point consider an extreme sequence of rainfall outcomes captured by one of the scenarios (replicate 1772). Under this sequence of rainfall outcomes, dam levels reach 2.3 per cent of capacity in 2020 without desalination capacity (chart 5.1). If desalination is operating, say using the 70/80 triggers, then dam levels

²⁸ There are also some limitations in the ability of the desalination plant to service certain parts of Sydney that are further away from the coast. This has not been incorporated into the modeling.

5.1 Total storage levels from 2008 to 2020, replicate 1772 (% of capacity)

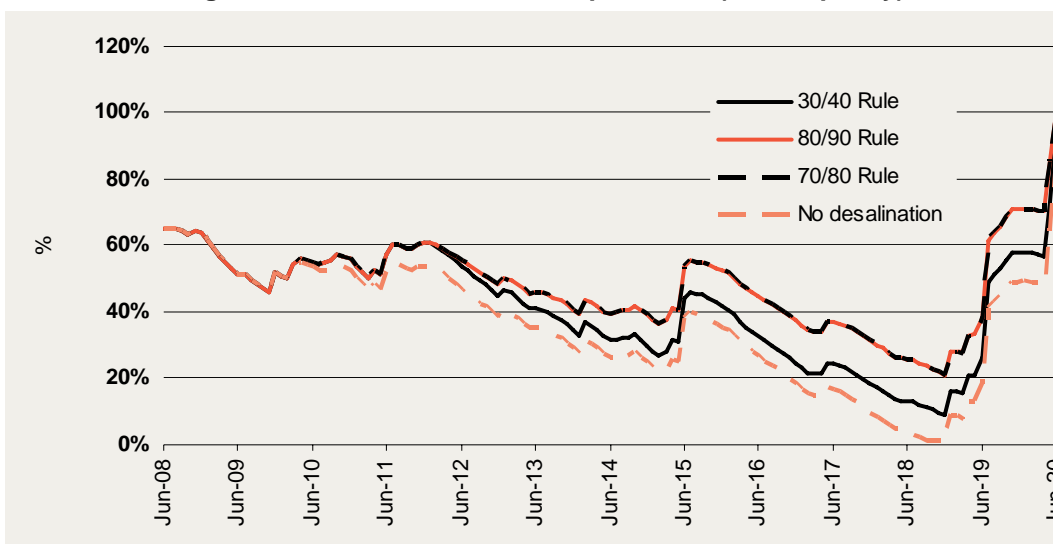


Data source: SCA WATHNET model.

reach 12.3 per cent of capacity in 2020 or 12.4 per cent under an 80/90 operating rule. Under a 30/40 operating rule, however, dam levels 8.9 per cent over this period.

Similar impacts on extreme outcomes can also be observed in other scenarios. In replicate 19 in the SCA’s WATHNET model (chart 5.2), dam levels reach 1.3 per cent in 2018 with no desalination but with desalination operating under a 70/80 Rule or 80/90 Rule storage levels would be approximately 21.1 per cent. However, a 30/40 Rule only raises storage levels to 8.7 per cent in 2018.

5.2 Total storage levels from 2008 to 2020, replicate 19 (% of capacity)



Data source: SCA WATHNET model.

The charts above illustrate how the alternative operating rules for the desalination plant can avoid dam levels reaching critically low levels. The 70/80 and 80/90 Operating Rules have significant ability to avoid these situations – there appears to

be limited difference between these two rules in terms of the security benefits achieved. The 30/40 rule still has a security benefit, however, it is substantially less than the alternative rules considered in this project. This highlights the fact that, given the current capacity of the desalination plant, that it needs to be triggered prior to a drought to be able to have significant impact on providing greater security. When the operation of the plant is triggered within a drought sequence then the security benefit of the plant is significantly reduced.

Distribution of storage levels

The likelihood that events such as those discussed above occur can be considered through analysis of all hydrological outcomes in the WATHNET replicates. But bear in mind that this makes the strong assumption that future climatic conditions will be the same (in average, volatility and persistence) as those in the past 100 years.

Table 5.3 below illustrates this by examining the number of replicates (of the 2000 in the WATHNET model) where dams fall below certain levels. This illustrates the fact that reaching low dam levels are a feature of a relatively large number of alternative rainfall scenarios in the WATHNET model. Therefore, in a relatively large number of the 2000 alternative scenarios modelled by the SCA, dam levels reach below 30 per cent at some point in the future.

5.3 Number of replicates where dams fall to low levels

<i>Dam level</i>	<i>No desalination</i>	<i>30/40 Rule</i>	<i>70/80 Rule</i>	<i>80/90 Rule</i>
	No.	No.	No.	No.
Below 5 per cent	14	6	5	5
5 to 15 per cent	45	24	7	7
15 to 30 per cent	249	233	63	63

Sources: SCA WATHNET model, TheCIE analysis.

In 14 separate replicates, or 0.7 per cent, dam levels would fall to below 5 per cent at some stage between 2010 and 2050, without running the desalination plant. However, if the desalination plant is operated according to the 70/80 Rule or 80/90 Rule then dam levels fall below 5 per cent in only 5 separate replicates.

Similarly, dam levels are expected to reach between 5 to 15 per cent in 45 separate replicates (or 2.25 per cent of the replicates) without the desalination plant operating. However, with the desalination plant operating under a 70/80 or 80/90 Rule this reduces to 7 separate replicates (0.35 per cent of the replicates). Similarly, operating the desalination plant under a 30/40 Rule does also reduce the number of replicates where dam levels fall between 5 to 15 per cent, however, this is substantially less than that achieved when the operation of the desalination plant is triggered at higher levels.

In the near future, up to 2015, the potential distribution of storage levels is likely to be higher than that discussed above. The reason for this is that dam levels are currently at reasonable levels and the desalination plant will be operating for the first two years from commencement, irrespective of the operating rule. Table 5.4 presents the potential range of dam levels at 2015 that can be anticipated from each replicate we have analysed the 2000 alternative scenarios of dam levels.

5.4 Distribution of potential storage levels as at 2015

	<i>No desalination</i>	<i>30/40 Rule</i>	<i>70/80 Rule</i>	<i>80/90 Rule</i>
	%	%	%	%
Minimum	4.7	14.6	18.3	18.4
5th percentile	62.4	63.6	66.0	68.5
Average	87.5	87.8	88.2	88.7
Median	91.6	91.7	91.8	91.9
95th percentile	99.7	99.7	99.7	99.7
Maximum	100	100	100	100

Source: TheCIE.

The table indicates that if 'average' climatic conditions prevailed until 2015 then dam levels are expected to be over 85 per cent, even without the construction of the desalination plant. Even at the lowest 5th percentile of outcomes, storages levels remain above 60 per cent. However, in the worst case scenarios the still is a chance of dam levels falling to critical levels. In these circumstances the existence of the desalination plant has substantial benefit in avoiding being in these critical levels.

It should be noted that under the modelling presented above, demand is held constant at 519 GL per annum as currently projected for 2014-15. The extent to which demand is higher than this projection will substantially increase the probability of falling into low dam levels, even with the operation of the desalination plant.

Benefits of water security

The hydrological outcomes discussed above show that the desalination plant does have benefits for water security. These benefits could be valued either by considering the value that the community places on water, imposition of severe restrictions or the alternative investments that would have to be made to avoid running out of water. Of these options, additional investments are the most likely response to critically low dam levels.

The actual dam level at which new infrastructure is triggered is open for debate and analysis and will largely relate to the time taken until the new infrastructure was producing water. It would be subject to a similar evaluation to this one, to determine the costs and benefits of different trigger points for new infrastructure. We do not

attempt to estimate it here. Instead we impose a trigger level of 30 per cent, which is the level at which the 2006 Water Metro Plan suggested the original desalination plant should be triggered.

The analysis assumes that the second module of the desalination plant is assumed to be the next available infrastructure and this would cost of \$1 billion if this cost is incurred.

Avoided energy costs related to the Shoalhaven Pumping Scheme

The Shoalhaven pumping scheme will still remain an important source of water into the future, even with the desalination plant operating. The desalination plant expands the portfolio of options available to the Government to provide a secure and sustainable water supply system into the future.

The energy costs related to operating the desalination plant have been included in our analysis in chapter 3. However, the operation of the desalination plant will also result in less water being required to be pumped from the Shoalhaven system. This is because the desalination plant will enable (on average) higher dam levels to be maintained, thereby reducing the need to draw on water from the Shoalhaven river.

In this section we estimate the changes in energy costs for the Shoalhaven pumping scheme. This involves considering the cost per unit of water pumped and changes in the volume of water pumped.

Cost of water pumped from the Shoalhaven

The SCA has indicated that the marginal pumping costs for the Shoalhaven system are \$0.07 per kL.²⁹

The energy used for pumping water from the Shoalhaven has additional environmental costs, through greenhouse emissions. We base estimates of these costs on:

- changes in the energy use from Shoalhaven pumping – a combination of the volume of water extracted from the Shoalhaven (from WATHNET), with an average energy use of 1.89 MWH per ML of water pumped;³⁰

²⁹ SCA (2008), *Submission to IPART's review of prices for the Sydney Catchment Authority*, September, p. 40.

³⁰ This is based on SCA's reported volume of extraction from the Shoalhaven of 150,475ML in 2005-06 and 175,115ML in 2006-07 (SCA website). The SCA's annual report 2006-07 (p. 71) also reports energy use of 294 200MWH in 2005-06 and 331 500MWH in 2006-07.

- emissions intensity – an emissions intensity of 0.9645 tonnes of CO₂ emissions per MWH, based on the average forecast by IPART for 2012 of between 0.946 to 0.983 tonnes of CO₂ emissions per MWH;³¹ and
- a price of carbon of \$35 per tonne of CO₂-e.³²

The calculation of the costs of carbon emissions is likely to be more contentious given that there is not a carbon market in place at the moment and the price of carbon is required to be estimated based on existing modelling. If the SCA, at a later stage, reduced these emissions by, for example, purchasing green energy then an explicit carbon price would not be required to be factored into the analysis. However, this would result in higher pumping costs (assuming there is a higher cost of green energy) which would need to be factored into the analysis.

Operation of the Shoalhaven Transfer Scheme

The operation of the Shoalhaven under each of the operating rules for the desalination plant is assessed under the WATHNET model.

On average, without the desalination plant, an additional 264 ML of water is required to be pumped from the Shoalhaven Scheme per month. (In approximately 5 per cent of replicates, over 730ML of water per month is required to be pumped from the Shoalhaven Scheme.)³³

5.5 Operation of Shoalhaven transfer scheme

<i>Item</i>	<i>No desalination</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
Expected water pumped from the Shoalhaven (ML per month)	2 053	2 021	1 780	1 444
Expected costs of pumping (\$000 per month)	144	141	125	101
Expected cost of greenhouse emissions (\$000 per month)	135	133	117	95

Source: TheCIE.

³¹ BDA and Gillespie Economics (2006) use an emissions intensity factor of 0.835 tonnes per MWH in its study of the Shoalhaven transfer scheme.

³² This is the average price of emissions from Australian Treasury modelling of various emissions trading scenarios in *Australia's low pollution future*, Canberra, November, p. xii.

³³ Note that our analysis assume the Shoalhaven Scheme operates as per the triggers set out in chapter 2. An announcement by the Minister for Water on the 7th of November indicated that there would be a three year period over which transfers from the Shoalhaven would be capped at 100ML per day. This has not been incorporated into the modelling.

Environmental impacts

The operation of Sydney's desalination plant may impact on the environment in four ways:

- by changing the amount of energy and therefore the greenhouse gas emissions required to supply Sydney's water (as considered above for the Shoalhaven transfer scheme);
- by changing the amount of water flow to the environment by increasing the volume of spills from dams;
- by impacting on the ecosystems around the desalination plant and its attendant infrastructure; and
- by changing the water transfers through the Southern Highlands river systems.

In some cases it is difficult to assess the biophysical changes that result from different operating regimes. Where possible impacts are quantified and valued.

Greenhouse emissions

Sydney's water system uses energy in a number of ways, some of which will change depending on how much the desalination plant is operated. Here we principally consider energy use by the desalination plant and the Shoalhaven pumping scheme. In some cases, the energy used by these schemes will generate greenhouse emissions.

Sydney's desalination plant will be run from energy from the national grid. The construction of the plant occurred in conjunction with a wind farm, which is contracted to provide renewable (wind) energy into the grid at least equal to that required by the plant. In this sense, as a bundled project, the desalination plant and wind farm are not expected to increase greenhouse gas emissions for NSW. It is possible that changing the way the desalination plant is run will generate positive greenhouse impacts. This would depend on whether the wind farm continues at full capacity even if the desalination plant is switched off and not using all the power produced by the plant. For this analysis we assume there are no changes in greenhouse emissions regardless of the operating rule chosen.

Offsetting the additional energy use by the desalination plant is that less energy would be required to pump water from the Shoalhaven.³⁴ The energy used in these pumping activities is not specifically sourced from renewable energy providers, although this could change into the future. Therefore, there is a net reduction in greenhouse emissions from any reduction in energy use from these activities due to

³⁴ Note that there is also a hydro-electric scheme on the Shoalhaven. There are unlikely to be significant emission effects from changes in water flow to this system as it is primarily used to smooth demand by pumping water upriver during off-peak times and sending water downstream during peak times.

the operation of the desalination plant. This has been quantified in the previous chapter regarding the pumping from the Shoalhaven system. There is limited information available to estimate the pumping activities from groundwater sources and this saving in energy and emissions is likely to be trivial.

River flows

The desalination plant can play a role in supporting the environmental flow regimes from storages. That is, operating the desalination plant reduces the water drawn from the dams for human consumption and means that more water is available for environmental flows. For example, due to the drought conditions over the period 1 June 2005 to 4 March 2008, only 50 per cent of the specified environmental flow releases in the Hawkesbury-Nepean system were made. However, new environmental flow regimes will be in place for the majority of storages in 2010, with a new regime for Warragamba Dam expected to be announced in 2015. Given this, we have not taken account of the potential benefit that the desalination plant can have in supporting future environmental flow regimes.

However, we have taken account of the impact of the plant on river health by increasing the volume of 'spills' when dams reach and exceed capacity. The potential increase in river flows resulting from spills is not well understood but the value is believed to be at the estuaries where spills will result in increased flushing.

Using the WATHNET modelling, for each replicate, we can derive the change in the volume of spills across all Sydney's dams under different operational rules of the desalination plan.

There is little concrete evidence linking the amount and timing of spills to river attributes that can be valued. Environmental benefits of increased water flow are likely to be highly non-linear and the links between water flows and the environment are not well understood.

For the Shoalhaven river system, the environmental impact of different environmental flow rules has been evaluated. Changing the transfer volume from the Shoalhaven from 33–45 GL/ year to 18 GL/ year is expected to have very small environmental benefits as identified benefits relate primarily to an additional species of fish above Talowa dam. This is not sensitive to the lower transfer volume (BDA and Gillespie Economics 2006).

For the Hawkesbury and Nepean rivers, an evaluation has also been conducted of different flow rules (BDA and Gillespie Economics 2004). This evaluation valued additional environmental flows through using expert opinions of physical changes and benefit transfer to value these changes. In order to quantify the environmental benefits of spills we use the results from this study. They analysed the impact of spills in the Hawkesbury and Nepean on:

- commercial fishing operations (for example in Hawkesbury and Nepean);
- swimming options;
- boating; and
- native fish stocks and variety.

On this basis, an extra GL of water for the environment each year could be expected to have environmental benefits of between \$1 million and \$3 million (in net present value terms). Their assessment of a number of different flow rules is shown in table 5.6.

The 80/20 environmental flow rule is the one imposed in the WATHNET hydrological modelling.³⁵ Given that these environmental flows have already been allowed for, the benefits of additional spills resulting from the desalination plant may be lower.

The figures from BDA and Gillespie (2004) can be represented as equivalent dollars per KL of water for the environment. The figures range from \$0.09 cents per kL to \$0.21 cents per kL.

Note that no allowance has been made for the timing of spills. If environmental flow rules are optimally set then the benefits from spills would be expected to be lower than the benefits from the same volume of water released through changing environmental flow rules. The BDA and Gillespie figures should therefore be seen as a maximum. We use a figure of \$1m net present value per GL, equivalent to \$0.07 cents per kL of water for the environment from additional spills.³⁶

5.6 Hawkesbury and Nepean environmental flow rule options

<i>Option</i>	<i>Water volume from baseline (GL/year)</i>	<i>Benefits from baseline (\$m net present value)</i>	<i>\$m per GL (NPV)</i>	<i>Equivalent \$ per KL</i>
Forum (no AER) ^a	86	114	1.3	0.09
20/80	113	184	1.6	0.11
20/95	52	112	2.1	0.15
10/95	25	76	3.0	0.21

^a Forum includes a range of other measures unrelated to water flow.

Sources: BDA and Gillespie (2004), TheCIE calculations.

The average monthly spills under the different operating rules for Warragamba, Tallowa and Nepean dams are shown in table 5.7. Operating the desalination plant

³⁵ 80/20 means that 20 per cent of the inflows over a low flow benchmark (the 80th percentile). These are in addition to releasing low volume flows and contingent flows.

³⁶ We recognise that the benefits from spills are likely to vary between the different river systems depending on, for example, the physical characteristics of the river system. The information to compare impacts across river systems is not available.

5.7 Average monthly releases and spills (ML)

Scenario	30/40 rule	70/80 rule	80/90 rule
Additional spills to base case (ML per month)	127	695	1 375
Additional value of spills over base case (\$000 per month)	9	47	93

Sources: Sydney Catchment Authority modelling, TheCIE calculations.

more raises average dam levels and leads to greater spills. The additional environmental benefits could be as large as \$93 000 per month under the 80/90 rule.

Impact on immediate surroundings

The impact of the desalination plant on its immediate surroundings can be understood through the Environmental Assessment process that the project had to undergo (table 5.8). Many of the environmental impacts were related to the construction of the plant rather than the level at which it is operated. There are impacts from operating the plant on fish larvae and the reef related to the input and output pipes. Changing the operating rules is unlikely to change these environmental impacts.

5.8 Environmental assessment

Area specified in environmental assessment	Related to amount of operation of plant	Impact from operation
Water quality impacts		
▪ Erosion and sedimentation during construction	Construction	
▪ Stormwater and surface water run off from dry land components	Construction	
▪ Construction of cross-Bay pipeline and intake/discharge infrastructure	Construction	
Impacts on aquatic ecology		
▪ Sea grass beds	Construction	
▪ Specific species	Operation and construction	No
▪ Fish larvae from input pipe	Operation	Yes, 2 per cent in adjacent area
▪ Impact of output pipe emissions	Operation	0.05 per cent of reef
Terrestrial ecology		
	Construction	

Source: Major Project Assessment: Kurnell Desalination Plant and Associated Infrastructure, Director General's Environmental Assessment Report, Department of Planning, (September 2006).

Another environmental impact that has been raised is the potential impact of concentrated seawater discharge on receiving waters. Sydney Water advises that the seawater concentrate beyond the mixing zone has no effect as it has been diluted to background levels. This is consistent with the detailed studies examining the impact of the discharge from the Perth desalination plant on Cockburn Sound which have

indicated limited impact on the surrounding environment. The results indicate that the

saline discharge is diluted to such an extent by the action of the diffuser and natural environmental mixing processes that the Perth Seawater Desalination Plant has not measurable impact on the oxygen levels in Cockburn Sound.³⁷

Given these findings we have not incorporated the potential impact of concentrated seawater discharge on the environment in our analysis.

Impact on Southern Highlands river systems

The volume of water transferred from the Shoalhaven through run-of-river systems in the Southern Highlands can be affected by the operating rules of the desalination plant. These transfers can cause environmental and social issues such as loss of use of farmland, increased difficulty of access to land, scouring and erosion of river banks, and impacts on plant and animal habitats. The 2006 Metropolitan Water Plan discusses options to mitigate these issues. The extent of the avoided environmental costs from a high level of operation of the desalination plant will depend on which of these options is put in place. If the high cost option is put in place then the operating rules of the desalination plant will have no environmental impact on the Southern Highlands. If there is no additional infrastructure put in place then the transfer volume may have additional impacts.

At this stage, there is no biophysical or community survey information available to assist in quantifying the potential impacts of reducing the run-of-river flows. The SCA has also indicated that the impact of run of river transfers under alternative operating rules for the desalination plant is expected to be minimal.

Other factors

It should be noted that we have not include a number of items in the analysis.

- The social impacts of alternative operating regimes. The main social impact of alternative operating regimes is likely to be through customers' bills. However, the construction costs and operating costs associated with an assumed operating regime have already been incorporated into the price of water. Therefore, marginal changes to the operating rules for the plant are not likely to significantly change customers' bills.
- The impact on groundwater pumping. We recognise that, in a similar way to the Shoalhaven Transfer Scheme that the operation of the desalination plant will change the amount of water required to be pumped from groundwater sources.

³⁷ Centre for Water Research (2007), *The impact of the Perth Seawater Desalination Plant discharge on Cockburn Sound*, University of Western Australia.

However, there is limited information available to examine the impact on groundwater pumping costs. Further these costs are likely to be insignificant compared with the pumping costs associated with the Shoalhaven Transfer Scheme.

Conclusions

In analysing the alternative operating rules for the desalination plant there are a range of indirect impacts that need to be considered. We have incorporated the following in our analysis:

- the financial and environmental costs arising the volume of water pumped from the Shoalhaven river. The alternative operating rules will have different impacts on the volume of water needed to be pumped from the Shoalhaven river and, therefore, the pumping costs under each rule. The expected reduction in Shoalhaven pumping costs and associated CO2 emissions vary from \$5000 per month under the 30/40 to as much as \$83 000 per month under the 80/90 rule.
- the environmental value of the additional volume of water that spills from dams under each operating rule. We have estimated that on average the 30/40 rule generates an additional environmental benefit of \$9000 per month and up to \$93 000 per month for the 80/90 rule.
- The reduced risk of having to augment supply at critical dam levels has been taken into account. We have assumed that such augmentation would occur at a 30 per cent dam level and involve a cost of \$1 billion (the approximate cost of upscaling the desalination plant). While this is a high cost if it was incurred, the probability of incurring this cost is low thereby resulting in a low risk weighted cost.

There are other potential impacts that have not been able to be quantified. Based on the evidence above, we expect that these impacts would not make a substantive difference to the conclusions drawn from our analysis.

6 *Estimated net benefits*

The costs and benefits have been individually set out in the previous chapters. This chapter brings these estimates together to indicate which of the different operating rules has the highest net benefits. We present results both for the expected net benefits and for the benefits across the distribution of replicates. We highlight the different components of costs across the different operating regimes.

Expected net benefits

The 70/80 rule has the highest expected net benefits of the three rules and base case considered in this evaluation (table 6.1). The net benefits of operating the desalination plant using this trigger system, compared with not operating it at all, are more than \$420 000 per month. The 30/40 operating rules also has net benefits relative to the base case (\$69 000 per month). The 80/90 operating rule has expected net costs relative to not operating the plant of \$5000 per month.

6.1 **Expected net benefits**

<i>\$ monthly average</i>	<i>No desalination</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
Costs				
Desalination plant and water pumping station costs	0	37	829	1 576
Benefits/avoided costs				
Cost of restrictions to consumers	1 631	1572	887	719
Costs of administering the restrictions regime	33	32	18	14
Producer surplus loss from restrictions	456	439	248	201
Energy costs of Shoalhaven pumping	144	141	125	101
Cost of greenhouse emissions from Shoalhaven pumping	135	133	117	95
Cost of security	264	248	63	54
Environmental value from additional spills	0	-9	-47	-93
Net benefits relative to base case	NA	69	424	-5

Source: TheCIE.

The 70/80 rule performs better than the other rules because it provides a better balance between the cost of restrictions and the operating costs of the desalination plant. It has higher restrictions costs than the 80/90 rule and higher operating costs than the 30/40 rule. Additional reductions in time in restrictions from running the plant more (such as the 80/90 rule) cost a lot in terms of additional operating costs. This is because much of the water saved in the dams ends up spilling when rainfall

occurs – producing desalination water for the environment does not provide value as the water costs \$0.60 cents per kL to produce (plus shut-down and start-up costs) and provides benefits of slightly under \$0.07 cents per kL in the environment.

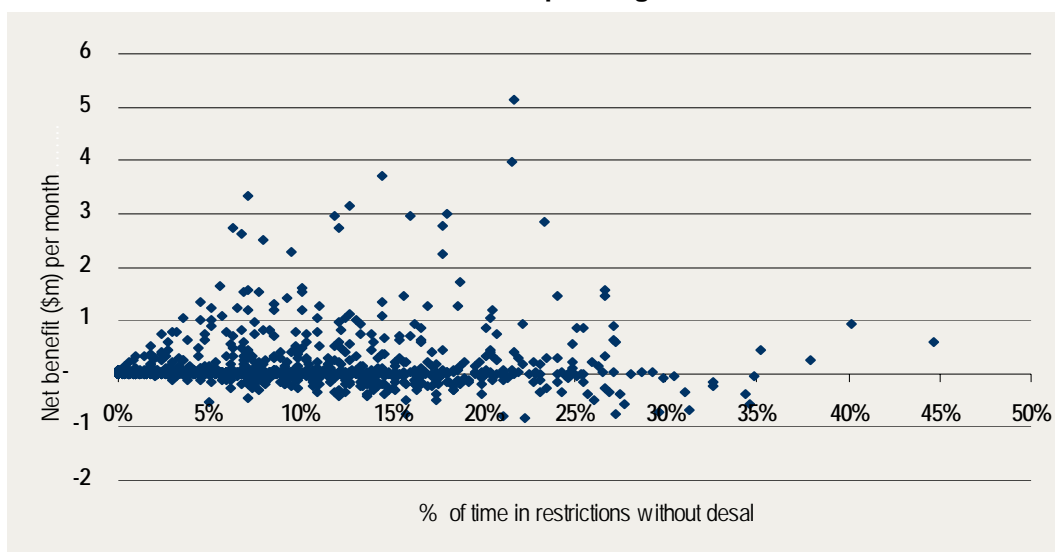
Distribution of net benefits across rainfall scenarios

An assessment of the net benefits across the various replicates confirms the insurance proposition discussed in earlier chapters. The distribution of net benefits across different climatic events can be illustrated using scatter diagrams which plot the net benefits under each of the 2000 replicates produced through the WATHNET model. In the charts below, each replicate is ranked according to the percentage of time where restrictions do not apply without the desalination plant. This can broadly be interpreted as a ranking of replicates according to the frequency of drought – replicates on the left handside of the chart have a lower frequency of drought compared those replicates at the right handside of the charts.

Chart 6.2 illustrates the case for the 30/40 Operating Rule. The chart highlights that operating the plant in this way delivers relatively low net benefits across a wide distribution of rainfall patterns. There are several conclusions that can be drawn:

- the net benefits are generally small for a large number of replicates;
- there is limited correlation between the net benefits and the percentage of time in restrictions, highlighting the fact that operating the plant in this way does not substantially reduce the amount of time in restrictions; and
- the net benefits are high for a small number of replicates, where operating the plant avoids the chance of dam levels falling to levels that would trigger an augmentation of supply.

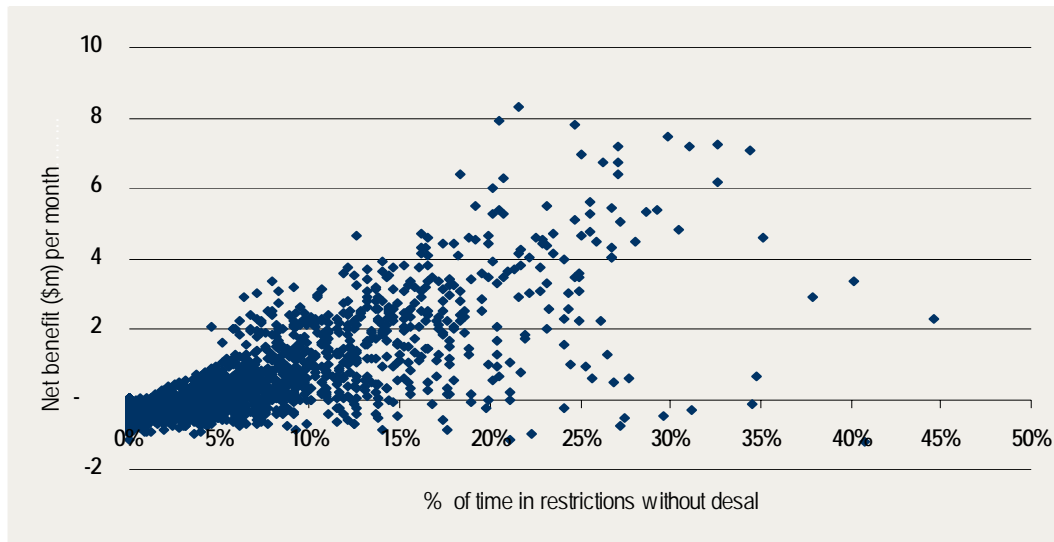
6.2 Distribution of net benefits — 30/40 Operating Rule



Data source: TheCIE.

Chart 6.3 presents the distribution of net benefits under a 70/80 Operating Rule for the desalination plant. It shows a clear relationship between the net benefits and the percentage of time in restrictions without the desalination plant – operating the plant in this way can substantially reduce the amount of time spent in restrictions, delivering larger net benefits. It also shows that, compared with the 30/40 Rule, there are substantially higher net benefits for more replicates, although there are more replicates with negative net benefits.

6.3 Distribution of net benefits — 70/80 Operating Rule



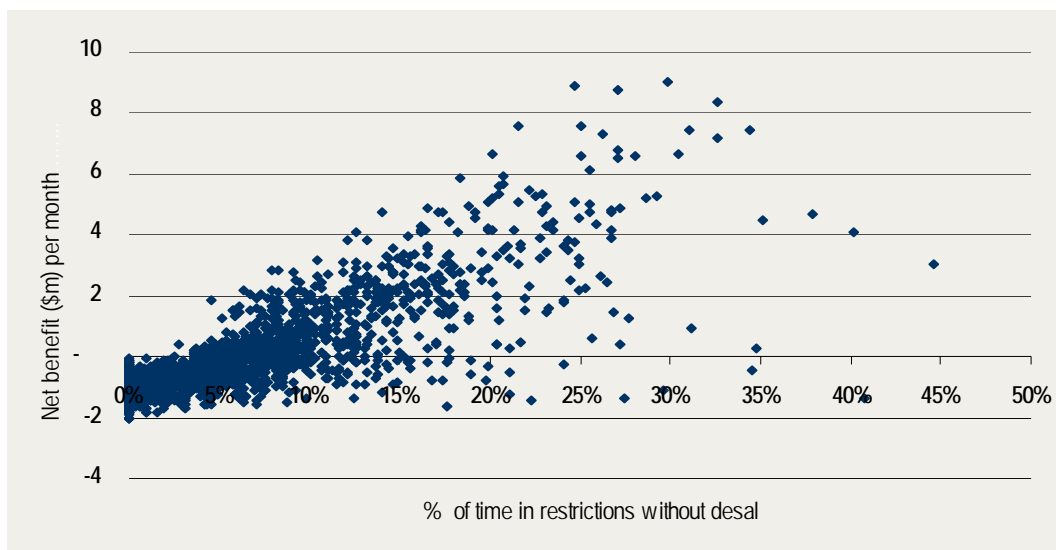
Data source: TheCIE.

Chart 6.4 illustrates the case of for the 80/90 Operating Rule. It shows a similar pattern of net benefits as the 70/80 Rule, except that the net benefits are 'magnified'. So, for example, there are four separate replicates where the monthly net benefits are greater than \$8 million, compared with only one replicate for the 70/80 Rule. On the other hand, in those replicates where there is less time in restrictions, operating the desalination plant in this way results in larger negative net benefits compared with 70/80 Rule.

As noted above, the net benefits for the 70/80 rule and 80/90 rule are often negative. For both rules there are net costs for more than half of the rainfall sequences. This is similar to an insurance premium – payments are made on the chance that events will not turn out well. For much of the time events turn out well and the costs of running the desalination plant accrue no benefits. But for poor rainfall outcomes, the insurance pays out, with large positive net benefits.

The net benefits at the high end of the distribution are up to \$4.3 million per month from running the desalination plant at either a 70/80 or 80/90 rule (table 6.5). In comparison, the net benefits of the 30/40 rule are much lower at the top end of its distribution at \$1 million per month.

6.4 Distribution of net benefits — 80/90 Operating Rule



Data source: TheCIE.

6.5 Net benefits across the different replicates

\$ monthly average	30/40 rule	70/80 rule	80/90 rule
Lowest 2.5%	-239	-747	-1 528
Lowest quartile	-2	-337	-954
Median	3	-83	-531
Highest quartile	19	631	386
Highest 2.5%	981	4 287	4 321

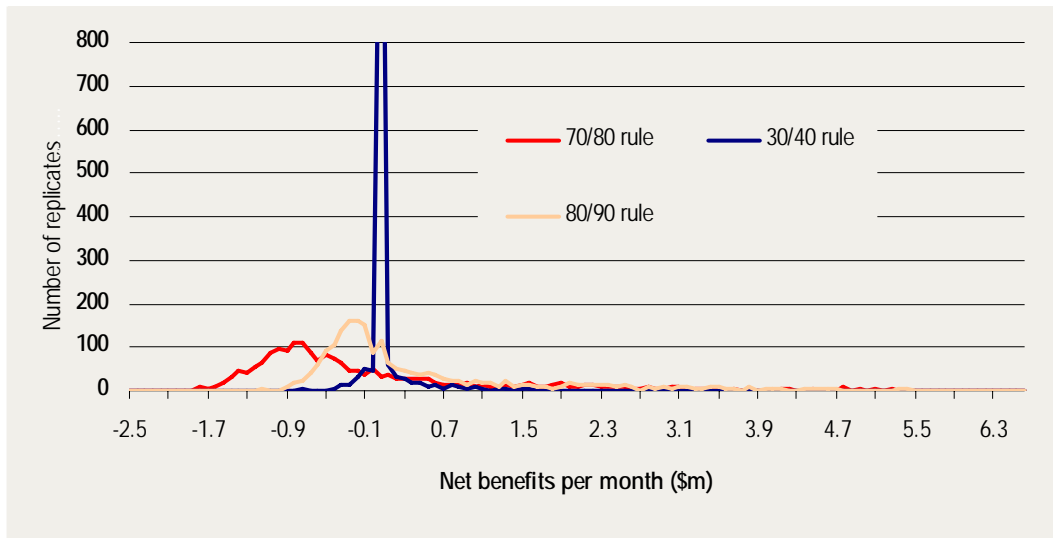
Source: TheCIE.

The skewness in outcomes can also be seen in the average net benefits from the 70/80 rule but net costs for the median replicate under this rule.

Conclusions

The distributions of net benefits for the replicates under the three rules are summarised in chart 6.6. Operating the desalination plant more often is equivalent to payer higher average premiums for higher returns under negative outcomes. The 70/80 rule provides insurance that is good value, while the additional insurance represented by the 80/90 rule is not worth buying, at least under the risk neutrality assumptions that we have used. In the next chapter we test whether high levels of risk aversion are enough to make the 80/90 insurance a good option.

6.6 Distribution of average net benefits by replicate



Data source: TheCIE.

7 *Risk analysis*

There are a number of risks that may impact on the choice of operating rule for Sydney's desalination plant. Climate change is the most important risk – lower, more volatile or persistent lack of rainfall will make the desalination plant more valuable. This chapter assesses the optimal operating rule under different climate replicates.

Other important risks for the choice of operating rule include demand risk, uncertainty about the cost of restrictions and attitudes to risk. The sensitivity of the choice of operating rule to these risks is also assessed in this chapter.

Climate change

The understanding of climate change is still very limited. The limitations are greater when looking at localized climate change, such as rainfall patterns in Sydney's catchment and inflows into Sydney's dams. DWE (2008) presents rainfall and runoff estimates from a range of climate models for the different regions of NSW. There is no consistency in predicted changes in annual rainfall and runoff between the 15 climate models that this study uses. Some models predict that annual runoff could fall in Sydney's catchment by 10 per cent to 20 per cent. Other models predict that rainfall could rise by a similar amount.

The impacts of climate change could extend beyond changes to average annual rainfall. Changes to the volatility of rainfall relative to its average or changes to the persistence of rainfall could also be important for Sydney's water supplies and the choice of operating rule for the desalination plant.

To capture these potential climate impacts, we use the hypothetical rainfall replicate data generated by the WATHNET model. To apply 'climate change' we weight replicates that capture particular climate change scenarios. We assess the desalination plant against six climate change scenarios, as well as the no climate change scenario.

1. No climate change – all 2000 replicates are used.
2. High rainfall – the 1000 replicates with the highest average inflows are used, with average annual inflows under this scenario being 15 per cent higher than the no climate change scenario.

3. Low rainfall – the 1000 replicates with the lowest average inflows are used, with average annual inflows under this scenario being 15 per cent lower than the no climate change scenario.
4. Volatile – the 1000 replicates with the highest standard deviation of monthly inflows.
5. Extreme – the 500 replicates with the highest average inflows and the 500 replicates with the lowest average inflows are used. Replicates are weighted so that the expected average inflows are the same as under the no climate change scenario.
6. Persistent – the 1000 replicates with the greatest persistence. Persistence is measured by the coefficient on lagged inflows in a regression of inflows against lagged inflows (one month lag). Replicates are weighted so that the expected average inflows are the same as under the no climate change scenario.
7. High relative volatility – the 1000 replicates with the highest standard deviation of inflows relative to average inflows. Replicates are weighted so that the expected average inflows are the same as under the no climate change scenario.

To see what these scenarios mean we can calculate summary statistics for each scenario. In table 7.1 report average monthly inflows, standard deviation of inflows and persistence of inflows.³⁸ These figures are averaged across the replicates according to the weights given in their scenarios. We also report deviation relative to the no climate change scenario.

7.1 Summary statistics for climate change scenarios

Scenario	Average inflows		Standard deviation inflows		Persistence of inflows	
	Level	Deviation	Level	Deviation	Level	Deviation
	GL/month	%	GL/month	%	Unit	%
All replicates	215	0.0	377	0.0	0.37	0.0
High rainfall	249	15.5	431	14.4	0.40	9.8
Low rainfall	182	-15.5	323	-14.4	0.33	-9.8
Volatile rainfall	245	13.9	437	16.0	0.40	10.7
Persistent rainfall	215	0.0	382	1.3	0.44	19.3
Extreme rainfall	215	0.0	378	0.4	0.37	0.3
High relative volatility	215	0.0	406	7.8	0.38	4.6

Source: TheCIE.

Inflows under the high rainfall scenario are 15.5 per cent above the no climate change scenario. The standard deviation of inflows and persistence of inflows are also higher

³⁸ Persistence is the average of the β from the regression $\text{inflows}_t = \text{constant} + \beta \cdot \text{inflows}_{t-1}$ for each replicate, weighted according to the scenario.

under this scenario. Low rainfall has the opposite characteristics to high rainfall, as it is the 1000 replicates not captured by the high rainfall scenario.

Volatility of rainfall is 16 per cent higher than 'normal' in the volatile rainfall scenario. The persistent rainfall scenario has a persistence coefficient of almost 20 per cent above the no climate change scenario.

In summary, the six climate change scenarios capture substantial deviations in future climatic conditions relative to Sydney's climate history. The scenarios could be fairly similar in the replicates that they place weight on. To test this, we report the correlation matrix of the weights on the replicates between scenarios in table 7.2. Scenarios do typically capture different sets of replicates. The exception is that the volatile and high rainfall scenarios are fairly similar in the replicates that they put weight on, with a correlation of 0.71.

7.2 Correlation of weights for each scenario

	<i>High rainfall</i>	<i>Low rainfall</i>	<i>Volatile rainfall</i>	<i>Persistent rainfall</i>	<i>Extreme rainfall</i>	<i>High relative volatility</i>
High rainfall	1.00	-1.00	0.71	-0.15	-0.06	0.03
Low rainfall		1.00	-0.71	0.15	0.06	-0.03
Volatile rainfall			1.00	-0.01	-0.04	0.27
Persistent rainfall				1.00	-0.07	0.06
Extreme rainfall					1.00	0.03
High relative volatility						1.00

Source: TheCIE.

The average monthly net benefits from each of the different operating rules and for each of the climate change scenarios are reported in table 7.3. Surprisingly, the 70-80 rule performs better than the other rules and has positive net benefits under all climate change scenarios. Even if climate change generated rainfall that was 15.5 per cent higher than average, running the desalination plant using a 70-80 rule is optimal (out of the rules evaluated). The desalination plant would run less often under a high rainfall scenario, but there would be no advantage to triggering it at a lower level. This reflects the substantial benefits that this rule has during low rainfall periods, even within an otherwise better than average rainfall environment.

The net benefits of the 70-80 rule do change substantially depending on the rainfall scenario. Under the high rainfall scenario, net benefits are \$184 000 per month, compared with over \$600 000 per month under the low rainfall scenario.

The 70-80 rule performs particularly well when inflows are persistent, but average the same as with no climate change. This is because the desalination plant faces fewer start-up and shut-down costs – the plant tends to run for a longer time period when it runs and stays closed for a longer time period when it is not running.

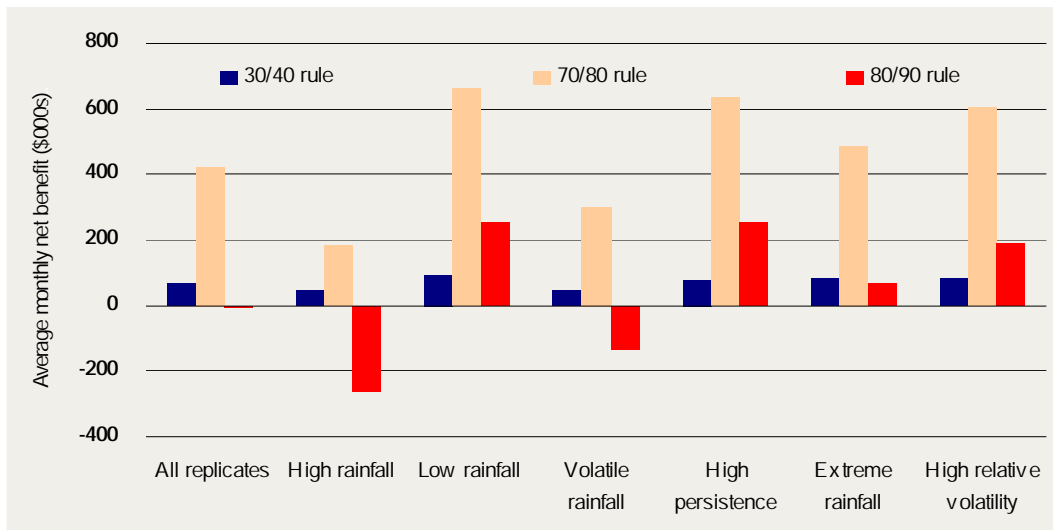
7.3 Monthly average net benefit (\$)

	30-40 rule	70-80 rule	80-90 rule
	\$ per month	\$ per month	\$ per month
All replicates	69	424	-51
High rainfall	44	184	-263
Low rainfall	95	663	253
Volatile rainfall	47	298	-134
High persistence	80	633	253
Extreme rainfall	86	488	69
High relative volatility	84	603	189

Source: TheCIE.

The net benefits of running the desalination plant at 80-90 are positive under a number of the scenarios that capture low rainfall, persistent rainfall or more extreme rainfall. But the 70/80 rule remains preferable to this rule by a substantial margin under all scenarios (chart 7.4). In fact, the 80/90 rule makes up little ground on the 70/80 rule even under low rainfall.

7.4 Net benefits under each rule and each scenario



Data source: TheCIE.

The 30/40 rule is preferred to the base case of no desalination plant under all scenarios. Its performance is closest to the 70/80 rule under the high rainfall scenario – as the amount of rainfall increases, it is more likely that high rainfall will remove the need for restrictions to be imposed. In this case, running the desalination plant at a lower trigger means fewer operating costs. But even with a low rainfall scenario, the avoided operating costs do not outweigh the additional costs of restrictions and water security.

The robustness of the findings to different climate change scenarios is surprising. Under all climate change scenarios, we find that the insurance provided by the 70/80 rule is worth buying. That is, the marginal benefits (such as the reduced time in

restrictions) outweigh the additional costs incurred of running the plant according to the 70/80 rule.

Level of risk aversion

The analysis to date has calculated the costs and benefits of different water rules under an assumption of risk neutrality. As the discussion above highlights, the different rules represent different levels of insurance. One of the key drivers of insurance is the risk aversion of the government and community. In this section we see whether the optimal rule changes under risk aversion – in particular, whether risk aversion means that the 80/90 rule, which provides more insurance is a better option than the 70/80 rule.

The concept behind risk aversion is that people prefer to face a constant level of cost than potentially very high or low costs with the same expected value. And people prefer to face constant costs over time rather than high costs sometimes and low costs at others. The technical details of the approach used to model this is in Appendix D.

Changing the attitudes to risk makes no difference to the rankings of the operating rules. This largely reflects the small size of extreme water cost events relative to household budgets. For instance, the most extreme monthly cost is about 15 per cent of household disposable income – to capture extremes we have allocated the cost of building a new desalination plant to a single month. Under the range of risk aversion parameters that we use, such a shock is not sufficiently large that people are willing to take on the additional insurance provided by running the desalination plant more often.

Under the base case, even extreme risk aversion applied to replicates (p equal to 10) only raises the costs by \$17 000 per month, less than one per cent, above the risk neutral case (table 7.5). The impact of risk aversion is smaller for the less risky alternatives, such as the 80/90 rule, but this is not enough to change the rankings of the different operating rules.

People may also value constant costs through time. If we apply the risk aversion function to costs for each replicate at each monthly period then the risk-adjusted cost is substantially above risk neutral cost. The risk-adjustment does bring the 80/90 rule closer to the 70/80 rule, but the 70-80 rule remains preferred by a substantial margin. If we had smaller gradations of operating rules (such as 71/81, 72/82 etc) then high levels of risk aversion would shift the operating rule, although probably only by a percentage point or thereabouts.

7.5 Costs under alternative risk aversion assumptions (average \$ per month)

	<i>No desalination</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
Risk neutral (\$/month)	2 663	2 594	2 239	2 668
<i>Risk aversion applied to replicates only</i>				
Risk adjusted cost (\$/month)	2 680	2 610	2 249	2 675
Deviation from risk neutral (\$/month)	17	17	9	8
Deviation from risk neutral (%)	0.6	0.6	0.4	0.3
<i>Risk aversion applied to replicates and time periods</i>				
Risk adjusted cost (\$/month)	3 192	3 114	2 447	2 848
Deviation from risk neutral (\$/month)	529	520	207	181
Deviation from risk neutral (%)	19.9	20.1	9.3	6.8

Note: Results reported use p equal to 10.

Source: TheCIE.

Demand risk

In the analysis so far reported, demand is assumed to be 519 GL (and unchanged). It is possible that demand will be lower than this, in which case there is less reason to run the desalination plant or that demand is greater than this, in which case the desalination plant may be run more often.³⁹ Changing demand requires using the WATHNET model. Sydney Catchment Authority modelled the 70/80 rule under a demand forecast of 570 GL per year. There is no baseline that captures not running the desalination plant against which to compare this and hence on which to optimize the operating rule. Nevertheless, the additional time in restrictions and costs imposed by greater demand are useful statistics.

The time in restrictions under a 70/80 rule and high demand (5.9 per cent) is similar to that with no desalination and lower demand (table 7.6). Running the desalination plant at 70/80 would approximately compensate for the additional 61 GL of demand required each year.

Under higher demand dam levels go below the 5 per cent security criterion 0.01 per cent of the time. If this were to be considered too high a risk then additional investments may be required or triggers changed to meet water security requirements.

The costs of the water system under higher demand are also obviously higher than in both the base case and 70/80 rule with low demand. More time is spent in restrictions than under low demand with the 70/80 rule and more money is spent running the desalination plant. Higher demand approximately doubles the estimated

³⁹ In the longer term, demand is expected to rise as Sydney's population grows into the future.

7.6 Impact of higher demand on water outcomes and costs

	<i>No desalination/low demand</i>	<i>70-80 rule/low demand</i>	<i>70-80 rule/high demand</i>
Time in restrictions	6.0%	3.7%	5.9%
Likelihood of triggering new investment at 30 per cent dam level	0.40%	0.11%	0.27%
Probability of dam levels below 5 per cent	0.02%	0.00%	0.01%
Costs (\$/month)			
▪ restrictions	1 631	887	1 523
▪ security	264	63	182
▪ desalination costs	0	829	1 576

Source: TheCIE.

restrictions costs and triples the estimated security costs, with an unchanged operating rule for the desalination plant. The additional operating costs to run the desalination plant more often are expected to be more than \$200 000 per month.

Environmental risks

The environmental benefits of additional spills are not well understood. The timing of spills may influence the environmental benefits. There could also be diminishing returns to water provided to the environment.

The baseline analysis uses a figure of the environmental benefit per GL lost in sustainable yield. The environmental benefit of slightly less than \$0.07 cents per kL has been applied to spills. The uncertainty around environmental impacts, both in terms of their timing and their magnitude indicates that we should test whether results are robust to changes in these benefits. The higher are estimated environmental benefits of spills the more likely we are to run the desalination plant more.

We calculate threshold environmental values at which the different rules are optimal. The 30/40 rule performs better than the 70/80 rule if environmental flows have a cost of more than \$0.55 cents per kL. It is difficult to see that additional spills could have environmental costs making it infeasible that environmental impacts would make the 30/40 rule better than the 70/80 rule.

The 80/90 rule performs better than the 70/80 rule if spills are valued at \$0.70 cents per kL. This is close to the cost of producing water from desalination. In other words, for the 80/90 rule to perform better than the 70/80 rule suggests that producing desalination water just for the environment is a good policy. Given that this is 10 times the estimated environmental value of water from BDA and Gillespie Economics (2004) and that the marginal value of environmental water is likely to be lower when additional water is spilling due to desalination, we consider that environmental uncertainty alone will not change the superiority of the 70/80 rule.

Cost of restrictions

There has been no study of willingness to pay to avoid restrictions or compensation required for restrictions in Sydney. The cost of restrictions estimates used as a baseline have, therefore been constructed using an alternative methodology that relies on estimates of the price elasticity of demand and the amount of activity affected by water restrictions. The estimates are sensitive to these parameters.

To test the sensitivity of the optimal operating rule to the estimated cost of restrictions we use three alternative estimates of cost of restrictions.

1. **Scenario 1.** Based on Grafton and Ward (2008), we assume that restrictions on average cost \$347 million, equivalent to \$226 per household. This figure accounts for the impact of restrictions on both business and residential demand. We assume a cost of \$150 million for Level 1, \$347 million for Level 2 and \$550 million for Level 3.
2. **Scenario 2.** Based on Hensher, Shore and Train (2006) analysis for the ACT, we assume that Level 3 restrictions costs \$239 per household and Level 1 and 2 restrictions impose no cost on households. There is no information reported on the costs of restrictions to businesses.
3. **Scenario 3.** A lower level of restrictions costs, based on restrictions impacting on a smaller portion of residential water uses.

The restrictions costs are scaled up to current prices uses past CPI outcomes and forecast inflation of the mid-point of the Reserve Bank's inflation target (2.5 per cent). The total restrictions costs imposed in the base case (presented in chapter 4) and under the three scenarios are summarised in table 7.7.

7.7 Assumptions of different costs of restrictions

<i>Restrictions level</i>	<i>No desalination</i>	<i>Scenario 1</i>	<i>Scenario 2</i>	<i>Scenario 3</i>
	\$m per year	\$m per year	\$m per year	\$m per year
Level 1	251	185	0	155
Level 2	394	427	0	244
Level 3	430	677	511	266

Source: TheCIE.

The estimated net benefits of all operating rules are lower under scenario 1 and higher under the other two scenarios (table 7.8).

Again, the robustness of the 70/80 rule to alternative assumptions is surprising. Even under the assumption that Level 1 and 2 restrictions cost nothing (scenario 2) the 70/80 rule has higher net benefits than the other rules and than the base case. This reflects that the 70/80 rule actually moves some replicates from Level 3 restrictions to Level 2 or 1 restrictions, which, in this case, means a large reduction in estimated

7.8 Net benefits under alternative restrictions scenarios

<i>Restrictions assumptions</i>	<i>30/40 rule</i>	<i>70/80 rule</i>	<i>80/90 rule</i>
	\$'000 per month	\$'000 per month	\$'000 per month
Base assumptions	69	424	-5
Scenario 1	92	652	233
Scenario 2	62	231	-304
Scenario 3	47	140	-353

Source: TheCIE.

costs. The pattern as well as the level of restrictions costs is important in determining the costs of the different operating rules.

Another way to assess the robustness of the cost of restrictions estimates is to calculate the threshold at which each of the rules is preferable. If the costs of restrictions were less than half of the base assumptions then the 30/40 rule is considered to be preferable. The cost of restrictions would have to be more than three times as high as estimated in the base case for the 80/90 rule to be preferable to the 70/80 rule. There is thus considerable leeway in the cost of restrictions estimates in which the 70/80 rule remains optimal (of the rules evaluated).

Other risks

There are other possible risks related to energy and the emissions trading scheme. It is unclear how the contractual arrangements change if the renewable energy certificates arrangements are removed and an emissions trading scheme is put in place. Given that the contract price for electricity is already determined, there is theoretically no risk. As such, energy price risk has not been considered in this report.

There are also risks around the size and trigger for additional investments. This will not make much difference to the results, as new investment is triggered only in a handful of the 2000 replicates (only 0.11 per cent of the time dam levels are below 30 per cent for the 70/80 rule under base case demand). There is an argument to adjust the trigger for new investment under each of the different operating rules so that all operating rules meet the water security criteria as defined in the SCA's operating license. This would have to be done in conjunction with including the additional water from new investments into the WATHNET modelling, which was outside the scope of this report.

Conclusions

The 70/80 rule is robust to some of the biggest risks to this evaluation. It performs better than the other rules considered in six possible climate change scenarios, ranging from 15.5 per cent higher rainfall to 15.5 per cent lower rainfall and more

volatile, extreme or persistent rainfall. The 70/80 rule appears to be the best insurance against poor rainfall outcomes for all these scenarios.

The 70/80 rule is also robust to the level of risk aversion. Even if people are at a maximum level of risk aversion the analysis indicates that the extra insurance provided by the 80/90 rule is not good value for money.

The 70/80 rule is reasonably robust to different estimates of the cost of restrictions. The 70/80 rule is the lowest cost of the rules considered even if Level 1 and 2 restrictions have zero cost, there is zero cost to businesses and households face costs in the order of those found in Canberra for Level 3 restrictions. Estimates of the costs of restrictions would have to be half their base level for the 30/40 rule to be preferable and almost four times their base level for the 80/90 rule to be preferable.

The risk analysis indicates that the 70/80 rule is the most preferred, amongst those rules considered, under a fairly wide range of parameter values, climatic changes and risk aversion preferences.

8 Conclusions

The analysis conducted in this report considers the variable costs of operating the plant as well as the benefits that the desalination plant provides. The main benefits include the reduction of time in restrictions as well as a reduction in the chances of dam levels falling to critical levels which triggers the need for additional infrastructure. Operating the desalination plant also have a range of indirect benefits, such as:

- reducing the volume of water that needs to be drawn from the Shoalhaven system (which also reduces the greenhouse gas emissions) because dam levels can be maintained at higher levels which reduces the need to trigger pumping from the Shoalhaven system; and
- maintaining river health through increasing the volume of water that flows into rivers through supporting the environmental flows regime and increasing the volume of water that spills from storages.

The analysis indicates that operating the desalination plant in the midst of a drought, when dam levels are low, has limited benefit either in providing greater security or in terms of reducing time in restrictions. The value of the desalination plant comes from its ability to build up dam levels prior to droughts occurring or in anticipation of droughts. By operating the desalination plant when dam levels reach 70 per cent, the expected time spent in restrictions falls and severe restrictions may be avoided. Additional infrastructure spending may also be avoided.

But operating the plant well in advance of a drought is more costly. We find that these costs are worth incurring under a 70/80 operating rule but not an 80/90 operating rule. Only if climate conditions were extreme are there likely to be additional benefits to running the desalination plant using an 80/90 rule, such as if climatic conditions were expected to be the same as occurred over the past eight years. But under most rainfall patterns, the 80/90 operating rule provides little additional insurance (compared to the 70/80 rule).

While the 70/80 rule for the desalination plant performs better than the other rules under a range of alternative assumptions, the rules should remain flexible to new information. This is consistent with the principles of adaptive management. There may be scope to pursue a better strategy by incorporating information from medium term climate forecasts, as well as adjusting the rule as our understanding of possible climate change improves. For example, if dam levels are low but significant rainfall

events are anticipated in the near future then there may be significant benefit in delaying the commencement of the desalination plant.

The rule for the desalination plant should also be subject to review as other parts of Sydney's water portfolio change. For instance, changes to the Warragamba environmental flow rules or unanticipated changes in demand may require refinements of the operating rules to extract maximum benefits from the plant.

It should also be noted that the trigger rules reflect the current capacity of the desalination plant. For example, if the second stage of the desalination plant were introduced in the future then this could change the optimal trigger levels for the plant. With the second stage the capacity of the plant will double to 500ML per day. In this circumstance, it may be that triggering the operation of the plant during a drought can significantly reduce the time in restrictions and the probability of falling into extremely low dam levels.

Appendices

A Current water restrictions policy

The current water restrictions that are applied in the Sydney region include the following.⁴⁰

- Level 1 restrictions
 - No hosing of hard surfaces.
 - No sprinklers or watering systems.
- Level 2 restrictions
 - Level 1 restrictions plus.
 - No hosing of lawns and gardens except hand-held hosing before 9am and after 5pm on Wednesdays, Fridays and Sundays.
 - No filling of new or renovated pools over 10 000L except with a permit from Sydney Water.
- Level 3 restrictions
 - Hosing of lawns and gardens only allowed on Wednesdays and Sundays before 10am and after 4pm.
 - No filling of new or renovated pools over 10 000L except with a permit from Sydney Water.
 - No hoses or taps to be left running unattended, except when filling pools or containers.
 - Fire hoses used only for fire fighting purposes – not for cleaning.

⁴⁰ Sydney Water, <http://www.sydneywater.com.au/Savingwater/WaterRestrictions/WhenWereWaterRestrictionsIntroduced.cfm>.

B Willingness to pay studies

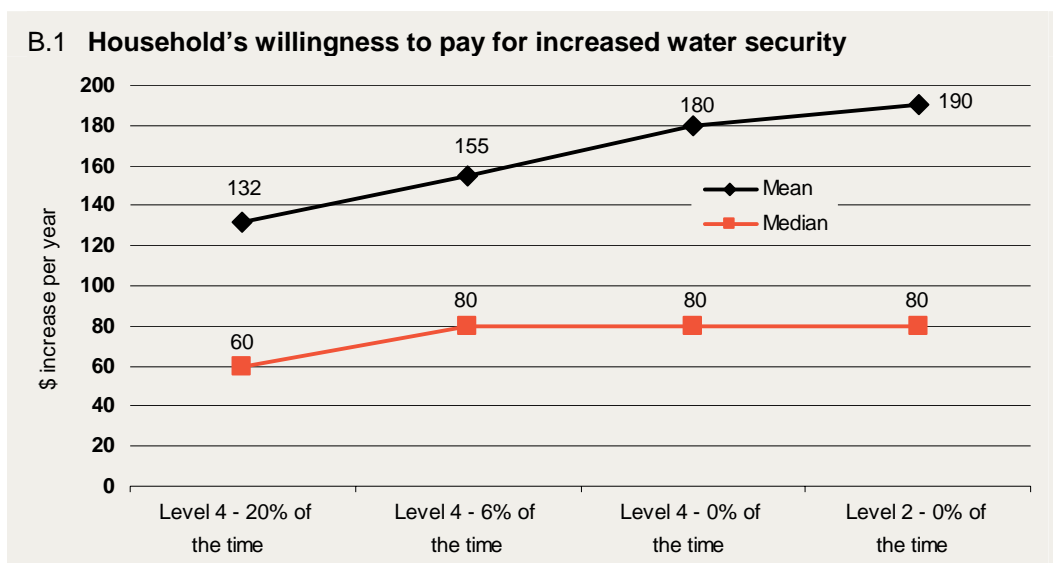
The cost of restrictions could be estimated directly through surveys of consumers. This could be done through willingness to pay studies or choice modelling.⁴¹ This appendix summarises other studies based on estimating willingness to pay for water users.

- Henscher et al. (2006) used a choice modelling approach in Canberra in 2002 and 2003 to calculate the marginal willingness to pay to avoid drought induced restrictions. They estimated the cost of restrictions at \$239 per household per year for relatively severe restrictions. Gordon et al (2001) also conducted a choice modelling survey of Canberra households in the late 1990s to compare alternative demand and supply options to water scarcity. They estimate that Level 1 and 2 restrictions in Canberra have negligible cost to households, while more severe restrictions had costs of \$239 (in 2002–03).
- Brennan et al. (2007) calculated the welfare costs in water restrictions in Perth using a household production function and experimental studies to develop a model to examine how bans on the use of sprinklers impacted on the amount of time that households had to spend watering from buckets or using hand-held hoses.

There are two separate studies recently been undertaken in SE Queensland that examine the willingness to pay for increased reliability of supply.⁴² The findings of the Allen Consulting (2007) are presented in the chart below. They found that households were willing to pay higher amounts for higher levels of reliability. For example, households were willing to pay an additional \$132 per annum to reduce the frequency of Level 4 restrictions from 50 per cent of the time to 20 per cent of the time. Household were willing to pay an additional \$190 per annum to remove the need for Level 2 (or worse) restrictions.

⁴¹ The willingness-to-pay studies referred to in this section relate to water reliability issues. WTP studies have been used in other areas of the water industry, such as in the evaluation of alternative wastewater delivery options in the Hawkesbury-Nepean (see ACIL Tasman and AC Nielsen (undated), *Hawkesbury Nepean Wastewater Strategy Economic and Financial Evaluations*, A report to Sydney Water).

⁴² We also understand that a study on the willingness to pay for reliability of supply is currently being undertaken in Victoria, although the results have not been published as yet.



Data source: Allen Consulting Group (2007, p. vi).

In undertaking its study on the willingness to pay for increased reliability of supply DBM Consultants (2007) separated the community into five separate household groups. 'Conservationists' were found to have the lowest willingness to pay (\$2 per annum) to increase water supply reliability from Level 4 water restrictions one in every four years with a duration of 24 months to restrictions one in every 30 years with 12 months duration. The highest willingness to pay for this same change was with the 'Devoted Gardeners' who were willing to pay \$270 per annum. The average across all groups was \$134 per household per annum. For the highest set of water security outcomes considered in the study (Level 4 restrictions one in 100 years, duration six months, mostly green public parks) the average willingness to pay was \$174 per annum per household.

There is difficulty in translating the findings from other jurisdictions to the Sydney context. For example, the hydrology in the Sydney region is significantly different to that in Canberra or Perth. This influences the frequency, severity and duration of water restrictions in each area. Further, the demographic profile of particular areas can also impact on the costs to households of restrictions.

However, these studies can be used as a 'sense check' or an upper bound of costs. As noted above, for the ACT, the most recent estimate is that the cost of restrictions is \$239 per household per year for relatively severe restrictions in 2002-03, equivalent to \$309 in 2011-12 dollars. The cost of restrictions in the ACT is expected to be higher for the ACT for the following reasons.

- The ACT experiences much less rainfall compared with Sydney (particularly coastal areas) and therefore a greater need for outdoor water use such as watering of gardens and lawns. Without the ability to apply water on the gardens, they can more readily deteriorate.

- The restrictions regimes, particularly Level 3 restrictions in the ACT, are more severe than Sydney. For example, under Level 3 restrictions in the ACT watering of lawns is not permitted.

It should also be noted that, like any survey analysis, the robustness of the results will depend on a range of factors such as the survey design and the sample size. Therefore, some caution should be exhibited when interpreting the results of the surveys generally. However, where surveys are well designed they can yield important results to inform the policy decisions.

C Price elasticity of demand estimates

The costs of restrictions can be measured using price elasticities. Such an approach has been taken by Grafton and Ward (2008), finding that restrictions cost \$347 million for Sydney (they do not differentiate between different types of restrictions).⁴³

The approach to calculating the welfare costs of restrictions using elasticities involves several steps:

- start with a known price/quantity pair to locate the demand curve;
- a point elasticity estimate is then used to obtain a demand function – different elasticities for different user groups can be used and demand elasticity can change across the demand curve if this information is known;
- the extent of demand impacted by water use is estimated; and
- the cost of restrictions are calculated based on the charts shown in chapter 3.

There are a range of studies available that provides useful information on the demand elasticities that can be used in calculating the welfare costs of restrictions:⁴⁴

- Hoffman, Worthington and Higgs (2006a) estimated price elasticities for two separate areas in Queensland for 2005-06. In the study for the Brisbane area, the estimated price elasticities were -0.51 in the short run and -1.167 in the long run.⁴⁵ The second study estimates the residential price elasticity across 11 local government areas. The price elasticity of demand was found to be relatively inelastic at -0.126.⁴⁶

⁴³ Grafton and Ward (2008) do not differentiate between how demand is affected for different sorts of water use. They apply a price limit on the price at which people would purchase outdoor water, reflecting other options such as rain water tanks. This reduces the impact that the price elasticity of demand has on the estimated loss to consumers.

⁴⁴ O'Dea and Cooper (2008) provide a summary of the price elasticities available for Sydney.

⁴⁵ Hoffman, Worthington and Higgs (2006a), *Urban Water Demand with fixed volumetric charging in a large municipality: the case of Brisbane, Australia*, Faculty of Commerce Working Paper Series, University of Wollongong, p. 9.

⁴⁶ Hoffman, Worthington and Higgs (2006b), *Modelling residential water demand in Queensland, A comparative analysis of price structures and estimation techniques*, Faculty of Commerce Working Paper Series, University of Wollongong, p. 7.

- Thomas (1999) estimated a price elasticity of demand of -0.4 in Hunter Water's area of operation.⁴⁷
- Grafton and Ward (2008) estimated a price elasticity of demand of -0.17 for the purposes of a study of the welfare costs of mandatory water restrictions in Sydney.
- Warner (1996) estimated a demand elasticity of -0.13. Warner used two models for the purposes of estimating the demand for water in the Sydney region, with similar results. He found that the price elasticity of demand for water in Sydney was -0.1266 under the first model, and -0.1242 under the second.

In another study (conducted for Water Services Association of Australia, WSAA) of residential customers in Sydney and Melbourne regions found that total demand for water was inelastic. The study provides marginal price elasticity of demand for water across three ranges. The study found that the price elasticity function to be non-linear with three distinct ranges. The study includes price elasticities separately for indoor and outdoor usage, as presented in table C.1.⁴⁸

C.1 Summary of the marginal price elasticity of demand for water

	<i>Change in bill</i>			
	-40–0%	0–40%	40–160%	-40–160%
Total use				
All households	-0.039	-0.309	-0.029	-0.087
Households < 400 kL pa	-0.028	-0.295	-0.033	-0.084
Households > 400 kL pa	-0.099	-0.401	-0.010	-0.106
Indoors use				
All households	-0.026	-0.216	-0.031	-0.067
Households < 400 kL pa	-0.019	-0.206	-0.034	-0.065
Households > 400 kL pa	-0.065	-0.277	-0.018	-0.079
Outdoors use				
All households	-0.072	-0.590	-0.048	-0.161
Households < 400 kL pa	-0.046	-0.576	-0.054	-0.157
Households > 400 kL pa	-0.205	-0.681	-0.015	-0.186

Source: Water Services Association of Australia (2004).

In 2003-04 IPART conducted a detailed literature review of the estimates of price elasticity of demand.⁴⁹ It concluded that the literature shows that most price elasticity estimates in Australia and international locations with broadly similar

⁴⁷ Thomas, J.F. et al. (1999), *Water and the Australian Economy*, Australian Academy of Technological Sciences and Engineering, Melbourne.

⁴⁸ KPMG (2004), *Pricing for demand management*, Report conducted for WSAA, April.

⁴⁹ IPART (2003), *Investigation into price structure to reduce the demand for water in the Sydney Basin – Issues Paper*, p. 15.

conditions to Sydney (that is, high rainfall variability, multi-year water storage and exposure to extended droughts) are in the range of -0.4 to 0. In undertaking its review of price structure in the Sydney Basin in 2003-04 IPART believed that the following elasticities were appropriate:

- Low water users: -0.01 to -0.05
- Medium water users: -0.2
- High water users: -0.3.⁵⁰

The National Water Commission and the Productivity Commission recently conducted reviews of the role of prices in reducing water consumption. These reports summarised the price elasticities of demand currently available in Australia but did not conduct separate analysis to estimate the price elasticity of demand. The studies concluded that price can play an important role in reducing consumption. These conclusions are not inconsistent with the evidence that prices are relatively inelastic.

The number of studies estimating the elasticity of demand for industrial water users is relatively small compared with households and irrigators. However, there are a range of studies from overseas that can be used.⁵¹ For example, for Canadian industries the median elasticity is approximately -0.3.⁵²

⁵⁰ IPART (2003), *Investigation into price structure to reduce the demand for water in the Sydney Basin – Final Report*, p. 12.

⁵¹ Industrial firms use water for a variety of purposes – for cooling intermediate inputs, producing high pressure steam, moving intermediate inputs, sanitation, and as a direct input. The major issue affecting accurate elasticity estimates for industry as a sector is its heterogenous composition and the uneven distribution of water use across industries. Therefore, there are limitations of using a single elasticity figure. Nevertheless, in the absence of more detailed information we have relied on a single elasticity figure but recognize its potential limitations.

⁵² CIE (2003), *Literature review of the price elasticity of urban water demand*, prepared for the Sydney Catchment Authority, p. 21.

D Approach to risk preferences

Risk aversion can be modelled through considering the equivalent change in household disposable income that might be incurred by households in the event of different cost outcomes. This implicitly assumes that all costs are transferred to households in some way, such as through water prices, higher taxes to pay for investments, higher business prices to pay for additional costs etc. We have to use a household income level as it is the size of the shock relative to the household income that will determine the level of insurance that is required.

We use a constant relative risk aversion function as set out below. This means that as people get wealthier they are willing to take on more risk in dollars, but the same level of risk relative to their income. This is modelled by the function below.

$$TB = \frac{(I - \bar{C})^{1-p}}{1-p} = \sum_i \frac{(I - C_i)^{1-p}}{1-p} \cdot P_i$$

TB is total benefits or utility from income, I is median household disposable income in Sydney, estimated at \$1259⁵³, C_i is the cost for each replicate i (and/or time period), P_i is the probability of events i and p is a parameter that determines risk aversion. \bar{C} is the cost which, if certain, gives equivalent welfare to the set of possible events. We label this the **risk-adjusted cost**.

If p is equal to zero then the household is assumed to be risk neutral. The more positive is p the more risk averse is the policymaker.

Empirical estimates of p are spread across a wide range of values.⁵⁴ We use p equal to zero in the base case (risk neutrality) and consider the ranking of the different rules under p equal to 1, 2 and 10. We only report results for p equal to 10, a highly risk averse scenario, as the risk aversion parameters make little difference to the results.

⁵³ ABS (2008), *New South Wales in Focus*, table 2.

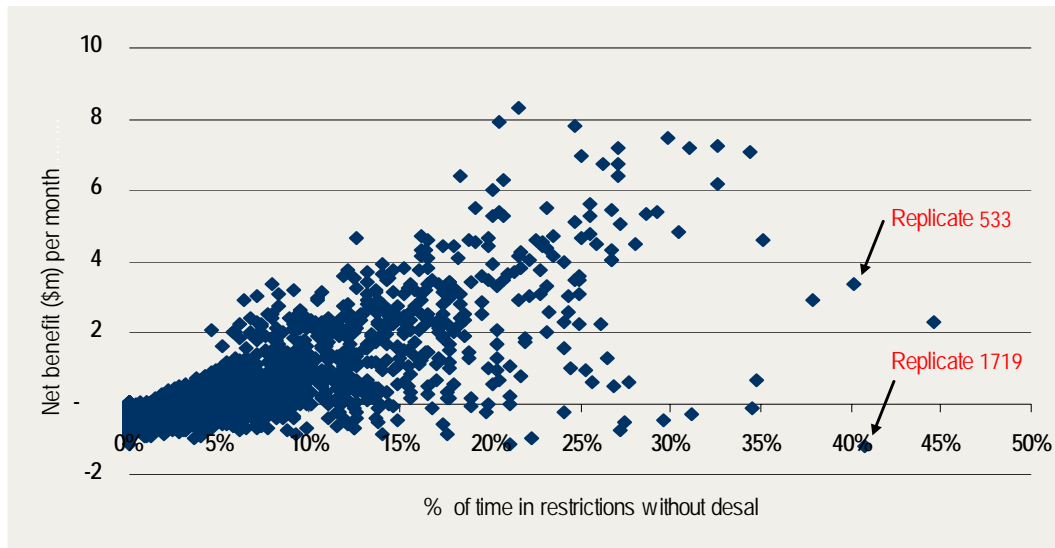
⁵⁴ For a survey of estimation results see Hartley, R., G. Lanot and I. Walker (2005), 'Who really wants to be a millionaire: estimates of risk aversion from game show data', University of Warwick Economic Research Papers, No. 719.

We present results using the risk-adjusted cost. We apply risk-adjusted costs in two ways. Firstly, we apply the risk-adjusted cost concept across replicates. This captures differences in average costs between replicates but not the volatility of costs within a replicate. Secondly, we apply risk-adjusted costs both across time and across replicates. This means that people dislike volatility in the costs of water through time as well as uncertainty around the costs related to water at a point in time.

E Explanation of 'Outliers'

This appendix seeks to explain the underlying data behind the scatter plots in more detail. We illustrate this by use of the scatter plots of net benefits for the 70/80 Operating Rule (chart E.1) and consider two separate 'outliers'. As noted previously, each point on the scatter plot represents an alternative rainfall scenario (or replicate) produced by the Sydney Catchment Authority's hydrology model, WATHNET.

E.1 Distribution of net benefits — 70/80 Operating Rule

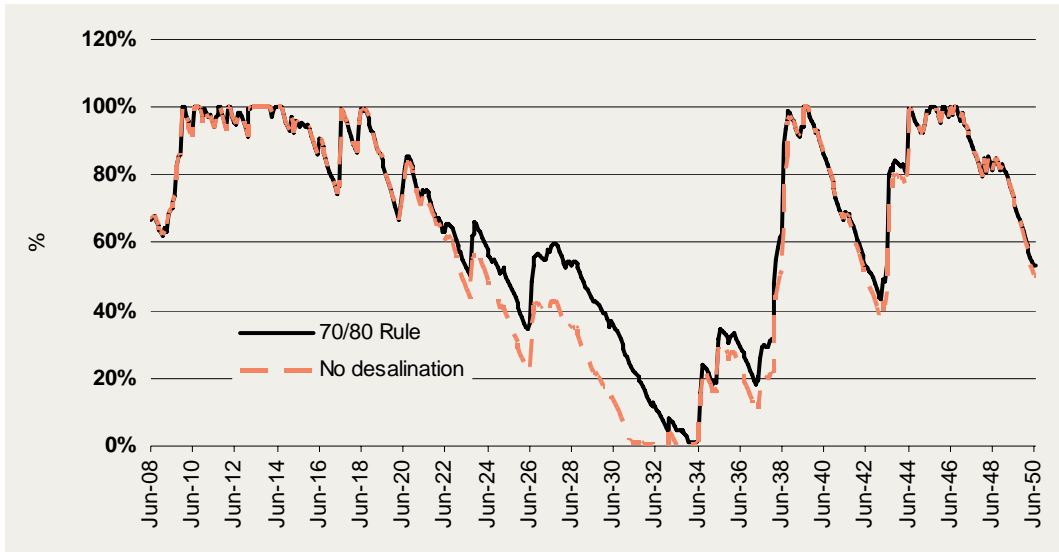


Data source: TheCIE.

The replicates we have chosen to examine are labeled Replicate 533 and Replicate 1719. In each of these replicates approximately 40 percent of time is spent in restrictions. Yet, they deliver significantly different net benefit results. In order to understand how this can occur we illustrate how dam levels change in each of these replicates. These are presented in charts E.2 and E.3 below.

In Replicate 1719 the rainfall patterns are particularly harsh, characterised by a general trending downward of dam levels from June 2020 to June 2034, followed by a particularly sharp rise in dam levels from June 2037 to June 2039 where dams are at full capacity. The lower quartile of dam levels is 35 percent, with the upper quartile at 93 percent. Under these relatively harsh climatic conditions the desalination plant can defer the imposition of restrictions or the need to invest in new supplies for only a short period of time. This is highlighted by the fact that median dam levels are at 70 percent with and without the desalination plant operating.

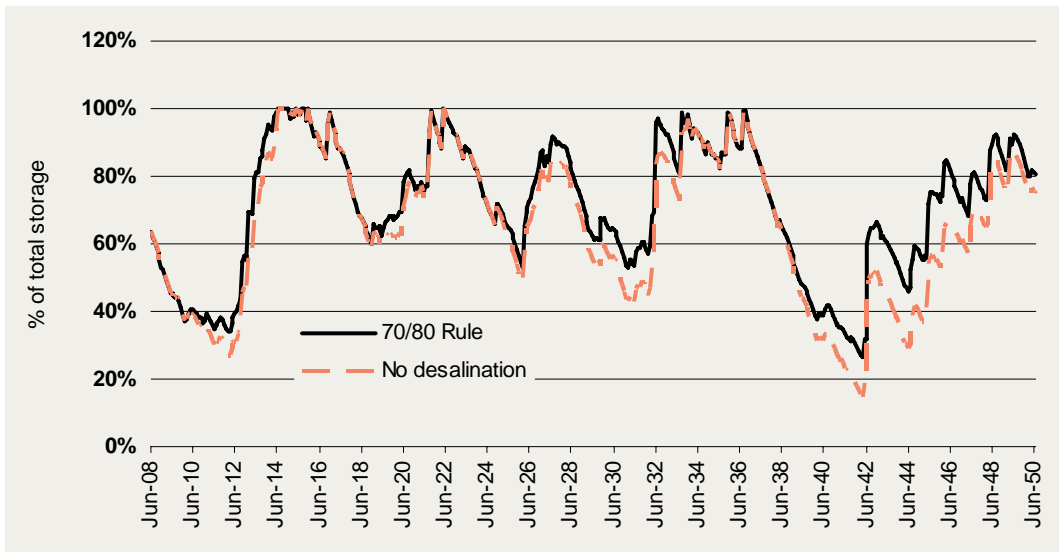
E.2 Storage levels over time, Replicate 1719



Data source: SCA, WATHNET model.

Note: In practice it is unlikely that dam levels would reach the low levels as further action to secure the water supply would have been undertaken before then, such as constructing the second stage of the desalination plant.

E.3 Storage levels over time, Replicate 533



Data source: SCA, WATHNET model.

Note: In practice it is unlikely that dam levels would reach the low levels as further action to secure the water supply would have been undertaken before then, such as constructing the second stage of the desalination plant.

Replicate 533 is typified by more moderate climatic conditions. The lower quartile of dam levels is 48 percent, with the upper quartile at 85 percent. Under these conditions, the desalination plant can make a substantial contribution to maintaining higher dam levels. Without the desalination plant, the median dam levels are 66 percent, with median dam levels at 74 percent with the desalination plant.

Table E.4 below details the amount of time spent at different levels of water restrictions under the two replicates. Under Replicate 1719, operating the

desalination plant according to the 70/80 Operating Rule does not substantially reduce the amount of time spent without restrictions – with the plant only 60 percent of the time is spent without restrictions. Further, it does not substantially reduce the amount of time spent at Level 3 restrictions – this falls from 32.4 percent to 29.6 percent of time.

E.4 Time in restrictions (% of time)

	<i>Replicate 1719</i>		<i>Replicate 533</i>	
	<i>No desal</i>	<i>70/80</i>	<i>No desal</i>	<i>70/80</i>
	%	%	%	%
No Restrictions	59.3	60.7	59.9	70.2
Lvl 1	3.4	7.7	11.3	14.0
Lvl 2	4.9	2.0	5.1	1.6
Lvl 3	32.4	29.6	23.7	14.2

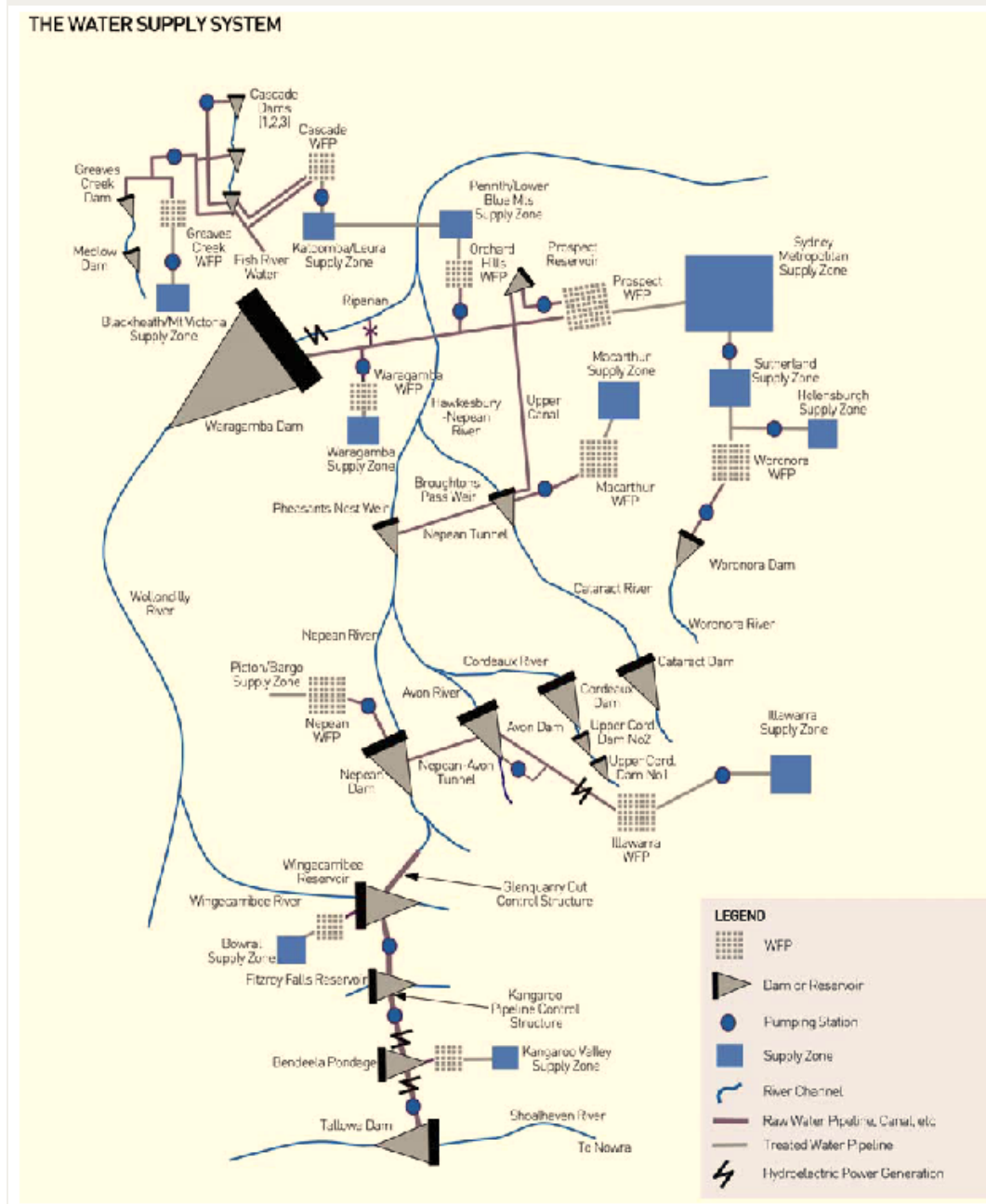
Source: SCA WATHNET model.

Under Replicate 533, however, the desalination plant makes a substantial contribution to the time spent at different levels of restrictions. For example, with the desalination plant operating restrictions do not apply in 70.2 percent of the time, compared with 59.9 percent of time without the desalination plant. Further, there is a substantial reduction in the amount of time spent at Level 2 and 3 restrictions with the desalination plant operating.

The discussion in this section illustrates how the benefits of the desalination plant depend on the underlying hydrology. The operation of the plant has substantial net benefits over a wide range of climatic conditions. However, under 'worse case' type climatic conditions, the desalination plant has the benefit of deferring the implementation of water restrictions and new investments to augment supply. However, the current capacity of the plant is not sufficient to be able to avoid these situations from occurring.

F Sydney's water supply system

F.1 Sydney's water supply system



Data source: http://www.sca.nsw.gov.au/_data/assets/pdf_file/0006/1986/watersupplydiagram.pdf.

*G Environmental flow rules*⁵⁵

Warragamba system

The SCA currently releases 33.3 million litres per day from Warragamba Dam into the Nepean River for environmental purposes. The NSW Government will consider increases to these interim releases and decide on a new regime of releases by 2015.

Shoalhaven system

The SCA releases water from Tallowa, Wingecarribee and Fitzroy Falls reservoirs to help improve the environmental health of the rivers downstream and sustain riparian rights. At Wingecarribee, at least 3 million litres of water is sent downstream every day for environmental purposes.

In 2008 the Government announced new environmental flow arrangements from Tallowa dam that are designed to better mimic natural inflows into the dam. They replace the interim flow rules, which have been in place since 1999, where up to 90 million litres of water is released daily from the dam for the health of the Shoalhaven River.

The new rules for environmental flow releases from Tallowa Dam to the lower Shoalhaven River are:

- All dam inflows less than or equal to the 80th monthly inflow percentile will be passed through the dam to protect low flows in the river downstream.
- Twenty percent of dam inflows greater than the 80th monthly inflow percentile will be passed through the dam to protect a portion of medium and high river flows downstream.
- Contingent or special purpose flow releases will be made from the dam to manage identified river health issues downstream, such as in periods of drought when the minimum operating level of the dam may be lowered to three metres – such releases will be determined in consultation with affected parties.⁵⁶

⁵⁵ <http://www.sca.nsw.gov.au/dams-and-water/environmental-flows>.

⁵⁶ <http://www.sca.nsw.gov.au/dams-and-water/metropolitan-water-plan/shoalhaven-transfers>.

At Fitzroy Falls Reservoir, environmental release levels are linked to inflow rates measured at Wildes Meadow Creek.

Upper Nepean system

The SCA releases water daily from the Upper Nepean dams and weirs for environmental purposes, including at least 4.4 million litres from Nepean Dam, 1.9 million litres from Cordeaux Dam, and 1.3 million litres from Cataract Dam. Downstream of the Upper Nepean dams, at least 10.5 million litres is released daily from Pheasants Nest Weir and 1.7 million litres at Broughtons Pass Weir. New environmental flow releases from Avon Dam in the Southern Highlands began in March 2008. New environmental releases from the other dams and weirs will start in 2010 when new outlet works are completed.

Woronora system

The SCA modified Woronora Dam's outlets in 2002 to enable environmental releases, linked to inflows. The flow regime for this dam is slightly different to the other dams and includes the following rules⁵⁷:

- When the daily volume of natural inflows into Woronora Dam is less than 5 ML per day, the volume of water that must be released shall be equivalent to the natural inflow volume.
- When the daily volume of natural inflows into Woronora Dam is greater than 5 ML per day and less than or equal to 30 ML per day, the volume of water that must be released shall be 5 ML per day plus 50 per cent of the natural inflow volume above 5 ML per day.
- When the daily volume of natural inflows into Woronora Dam is greater than 30 ML per day, the volume of water that must be released shall be 18 ML per day on average over the period.

The Licence also specifies annual high flow releases for Woronora Dam and the flow regime in severe drought periods.

Blue Mountains system

The Blue Mountains system is comprised of a six small reservoirs located high in the catchment. Apart from overflows during periods of high rainfall, there are no current environmental releases from these dams.

⁵⁷ SCA (2003), Water Management Licence, February, p. 38.

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