futurewateroptions

FOR THE ACT REGION IN THE 21st CENTURY

2006 ANNUAL REVIEW OF PLANNING VARIABLES FOR WATER SUPPLY AND DEMAND ASSESSMENT

A review of the changes in demand assumptions for Future Water Options for the ACT

FINAL

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A review of the changes in demand assumptions for Future Water Options for the ACT

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Abbreviations

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
ACTEW	ACTEW Corporation Ltd
ActewAGL	Public/private company operating ACT water supply under contract
ACTPLA	ACT Planning and Land Authority
CGBT	Cotter to Googong Bulk Transfer
cm	centimetres
CMD	Chief Ministers Department (ACT)
CPS	Cotter pump station
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DHI	Danish Hydrological Institute
Ecowise	Ecowise Environmental Pty Ltd
ECGBT	Extended Cotter to Googong Bulk Transfer
FWO	Future Water Options
GL	Gigalitre (1,000,000,000 litres)
IPART	Independent Pricing and Regulatory Tribunal (NSW)
L	Litre
L/c/d or LCD	Litres per capita per day
m	Metre
ML	Megalitre (1,000,000 litres)
ML/d	Megalitre per day
mm	Millimetre
NSW	New South Wales
PWCM	Permanent Water Conservation Measures
SKM	Sinclair Knight Mertz Pty Ltd
WSAA	Water Services Association of Australia
WTP	Water Treatment Plant

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Executive Summary

Assessments of water supply security requires consideration of a number of variables relating to current and future performance of the water supply system. The results of the assessment can change significantly depending on the assumptions used for different variables. The Future Water Options (FWO) studies undertaken by ACTEW in 2004-2005 identified "six key planning variables that underlie predictions" of Canberra's water supply security[1], they are:

1. Climate variability and climate change,
2. Impact of bushfires on inflows to ACT reservoirs,
3. Future population growth in Canberra and Queanbeyan and the possibility of servicing additional areas,
4. Reduction targets in per capita water use set by the ACT Government in *Think Water, Act Water*,
5. Environmental Flow requirements,
6. Acceptable levels for the duration, frequency and severity of water restrictions during times of drought.

This report looks at changes to the assumptions that have occurred since the Future Water Options work in 2004 and early 2005. In addition it observes the issue of operating rules with respect to long term planning scenarios.

1 Climate variability and climate change

ACTEW's planning for the next water source includes an assumption that there has already been a shift in climate to the conservative CSIRO prediction for 2030 climate. This assumption has a very large impact on the timing of the next supply source for the ACT.

Evidence that climate change has happened and is happening continues to mount.

> *There is evidence of a shift in the last 20 years, with several locations (Michelago is an exception) near to Canberra showing a small decline in rainfall and a decrease in interannual variability after the mid to late 1980s. A similar shift has been well documented in the southwest of Western Australia.* [2]

Inflows to Googong in recent years have been considerably lower than for any other extended time period in the 1912-present historical record of gauged data. It is possible that this reduction in inflows results from either a change in climate or a change in catchment response to rainfall. Model results could vary significantly if Googong's catchment behaviour has altered.

Analysis[3] comparing the runoff into Googong reservoir with flows in similar sized catchments for the Gudgenby River (near the location of the Tennent dam option) and the Molonglo River at the ACT border, showed that similar very low runoff has been experienced in all three catchments. This would have serious negative implications for the viability of any Tennent dam option if it continues and will be carefully monitored. Whereas, while the Cotter River flows reduced, it was not to the same extent as the other three catchments.

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[1] *Future Water Options for the ACT Region – Implementation Plan: A recommended strategy to increase the ACT's water supply*, ACTEW, April 2005

[2] Bryson C. Bates, Stephen P. Charles, Mac Kirby, Ramasamy Suppiah, Neil R. Viney, and Penny H. Whetton, *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003

[3] Ecowise Environmental (2006) Report on Inflow Reduction to Googong Dam in Recent Years, by A. C. Falkland.

ACTEW is keeping watch on developments in this field in Australia, and is working with CSIRO on the current study program to improve the climate change information available for the ACT.

The difference between climate change and variability can only be assessed in hindsight. Whether or not the current weather pattern is influenced by climate change will only be known well into the future. Hence it is prudent to include climate change when planning for future water needs.

At this stage there is no new information or other reason to alter climate change predictions used in the Future Water Options work. The CSIRO predictions are expected to be updated in 2008.

2 Impact of Bushfires on inflows to ACT reservoirs

Planning for the next ACT water source includes allowance for a decrease in inflows to reservoirs from the recent and any future bushfires. The impact of bushfires on the timing of the next ACT water source looks to be relatively small compared to the impact of climate, population and demand reduction. The ultimate size of that impact will be determined by monitoring the consequences of the January 2003 bushfire.

Bushfire affects on yield in the first 2-3 years after a fire are not directly representative of the yield reduction in later years. This occurs because the amount of tree regrowth does not peak until a significant time has elapsed since the fires (estimated in FWO to reach a maximum reduction after about 17 years). Although vegetation is recovering well, there has been no measurable change in catchment yield. However, only a small number of significant rainfall events have occurred in the catchment since the fires[4].

The impact of the 2003 bushfires will be continually monitored, and any significant findings from this work will be incorporated into modelling of the water supply system. At this stage no changes to the assumptions used in the FWO project are required.

3 Future population growth in Canberra and Queanbeyan and the possibility of servicing additional areas

In calculating demand, it is necessary to predict future serviced population. This population must include the ACT, Queanbeyan and any future areas (eg. Yass, Murrumbateman, Goulburn) that are likely to be serviced by the ACT water supply system.

A number of data sources are available for projecting population growth in the ACT. The ACT Chief Minister's Department published medium growth figures in June 2003 and the Australian Bureau of Statistics (ABS) releases high, medium and low growth projections from time to time, most recently in November 2005. These two sets of projections are relatively consistent.

The Canberra Spatial Plan states that the combined Canberra-Queanbeyan population in 2032 is projected as 430 000 with moderate growth and 500 000 with high growth and recommends that "prudent planning … caters for both moderate and high population projections"[5]. The ACT Government's *Think Water, Act Water* strategy prescribes the use of high population growth projections by stating that "work being done to predict when new water supply infrastructure will be needed will therefore be using these higher growth

[4] Ian White, Alan Wade, Rosie Barnes, Norm Mueller, Martin Worthy, Ross Knee, *Impacts of the January 2003 Wildfires on ACT Water Supply Catchments*, 2006

[5] *The Canberra Spatial Plan*, ACT Planning and Land Authority, March 2004

projections for contingency planning to ensure that, if increased water supply is needed, necessary planning and design will be done well in advance of the need to begin construction"[6]. Detailed population projections for Canberra and Queanbeyan, consistent with the numbers quoted in the *Spatial Plan*, were obtained from the Chief Minister's Department (CMD) during the Future Water Options study (2004).

The extent of future supply to population outside Canberra and Queanbeyan is harder to quantify. Population projections for these areas are less common and contain even more uncertainty than projections for the ACT and Queanbeyan. Furthermore, at this stage it is unknown if or when additional areas will be connected to Canberra's water supply system. Assuming that the connection is made, it is also uncertain how much water will be supplied from Canberra and how much will be supplied from existing water sources. Nevertheless, it is important that planning consider the possible future impact of cross-border supply (i.e. additional supply to NSW beyond that currently supplied to Queanbeyan) on Canberra's water supply security. The inclusion of regional supply and specifically of Yass in future water supply planning is recommended in *Think Water, Act Water*[7].

Modelling for the Future Water Options project assumed that cross-border supply would consist of:

- An additional population of 12,000 by 2006; and
- A constant annual increase of 600 per year thereafter (i.e. reach 26,400 by 2030)

While no cross-border supply has occurred as yet, it is possible that Yass (population approximately 5000) could be supplied as early as 2008. There are currently no plans to supply water to other areas, however this could eventuate in the future.

In recent years the ACT has been experiencing a relatively slow rate of growth. ABS reported ACT's growth rate for 2005 at 0.8%[8]. This may only be a short term trend and has not caused any changes in population projection scenarios in ABS or CMD. High population projections remain as the prudent approach for water planning.

Some changes to the population predictions used in the FWO project are appropriate. In future modelling, all ACT and Queanbeyan population projections will begin from the estimated 2004 water supply population of 360 431. As no further combined projections for Canberra and Queanbeyan populations have been made since 2003, the numbers provided by the Chief Minister's Department will continue to be used. Future planning for cross border supply will use the revised assumption of:

- An additional population of 5,000 by 2008
- A constant annual increase of about 1,000 per year thereafter (i.e. reach 26,400 by 2030)

These short term changes cause little impact on the predicted timing for the next water source.

[6] *Think Water, Act Water: Volume 1: Strategy for sustainable water resource management in the ACT*, ACT Government, April 2004
[7] *Think Water, Act Water: Volume 1: Strategy for sustainable water resource management in the ACT*, ACT Government, April 2004
[8] ABS June 2006

4 Reduction targets in per capita water use set by the ACT Government in Think Water, Act Water

The ACT Government has outlined a plan to permanently reduce potable water consumption in its "*Think water, act water"* document. This document specifies a 12% reduction by 2013, and a 25% reduction in water consumption by 2023.

It is intended that a variety of means be used in order to achieve these targets, including:

- education and advertising
- permanent water conservation measures
- effluent reuse
- stormwater harvesting
- rainwater tanks
- greywater reuse
- leakage reduction
- demand management programs
- requiring new developments to achieve a 40% reduction in water use through water sensitive urban design
- ongoing pricing reform

Modelling to date has assumed that the demand reduction will be achieved linearly between 2003 and 2023. Permanent Water Conservation Measures (PWCM) were introduced in 2006. These are expected to deliver an 8% reduction in water demand. In addition, the ACT Government's water demand management program is achieving reductions in water consumption.

Hence, while the target demand reduction used in the FWO project is maintained, the rate at which it is achieved will be altered. In future modelling the demand reduction will assume PWCM impact of 8% will occur in 2006, and after that demand will be applied linearly between 8% in 2006 and the ACT Government target of 25% in 2023.

These changes will cause minimal impact on the predicted timing for the next water source.

5 Environmental Flow Requirements

The results reported for the Future Water Options project used a draft version[9] of the 2006 Environmental Flow Guidelines. Only minor changes to environmental flows, which will not have a significant influence on system security, have taken place since these results were produced. The system model has been updated to reflect these changes, and future modelling will be conducted using this updated model.

Environmental flow guidelines are due to be reviewed again five years after publication[10]. Potential changes in environmental flows will continue to be monitored to ensure that impacts on water supply security can be assessed and included in future reviews.

6 Acceptable levels for the duration, frequency and severity of water restrictions during times of drought

During the FWO project ACTEW developed system performance criteria based on the duration, frequency and severity of water restrictions. When demand growth caused the frequency, duration or severity of restrictions to exceed acceptable levels, it indicated a new supply source was required.

[9] Peter Liston, Environment ACT, *Proposed E Flows for Water Supply Catchments*, personal communication, February 2005

[10] *2006 Environmental Flow Guidelines*, Environment ACT, January 2006

The following criteria and acceptable levels were used for measuring system performance of Canberra's water supply system in the FWO project.

- System Security:
  1. The system must not run empty during the 10 000 year stochastic data run (minimum storage must be greater than 5%).
- Frequency and Duration:
  2. Not more than 5% of the time should be spent in any level of restrictions (not including PWCM).
  3. Restriction events should not occur, on average, more than once every 10 years.
- Severity:
  4. Not more than 1% of the time should be spent in stage 3 restrictions.
  5. Stage 3 restrictions should not occur more than once every 25 years.

Criteria 2 and 4 are typically the critical measures for Canberra's water supply system.

The choice of system performance criteria can have a critical influence on the timing and/or type of augmentation required to achieve acceptable system performance. Table 1 is an indication (given particular assumptions) of the year augmentation is required for acceptable times in restrictions. The table indicates that, given the assumptions used in the model, a system performance criterion of 3% time in restrictions would require augmentation 24 years earlier than an acceptable level of 5% time in restrictions. The time in restrictions can also increase quite quickly, especially in stressed systems, as shown by the increase from 5% to 20% time in restrictions in 12 years.

Table 1 – Required Date of Augmentation, Relative to Acceptable Level of Time in Restrictions

Acceptable Performance Measure for Time in Restrictions	Required Date of Augmentation
0%	1970
1%	1989
3%	2001
5%	2025
10%	2030
15%	2034
20%	2037

In order to reflect community expectations, the system performance criteria should be able to be explained to the general public and reflect the tradeoffs between meeting levels of service requirements and environmental and economic costs.

Subsequent to the FWO work by ACTEW, a paper prepared by the Water Services Association of Australia (WSAA) also highlighted these issues:

> *After a water utility has assessed its own risks, it is important that it works with the community to determine an appropriate level of service objective for a water supply system. This process inevitably involves tradeoffs between financial cost, environmental impact and the willingness of the community to accept restrictions on a periodic basis. Explaining these tradeoffs to the community has proven to be problematic in the past, not because the community does not understand them but more because the modelling used is complex and the terminology is technical in nature. Furthermore, levels of service are*

generally expressed in probabilities and probability theory is a concept that many people are not fully familiar with.

Restrictions will be required from time to time in Australia because of the variability of rainfall, unless water supply systems are 'gold plated' through the construction of generous buffer supplies. Such buffers come at a high economic and environmental cost and are hard to justify when they may only be required once every 20 years. Some sectors of the community are however becoming dependent on a high level of reliability and are prepared to pay for it. This places additional stresses on the limited water resources but needs to be taken into consideration by water managers.[11]

Canberra is prone to droughts that may last for several years. It is therefore difficult to design a water supply system for Canberra that will not contain long water restrictions events unless the system is designed to almost eliminate water restrictions (i.e. be 'gold plated').

The objective of system performance criteria is to be explainable to the public, and define the appropriate balance between the social, economic and environmental costs of supplying water under various infrastructure and restriction options. This is shown in Figure 1, reproduced from the WSAA paper on this issue.

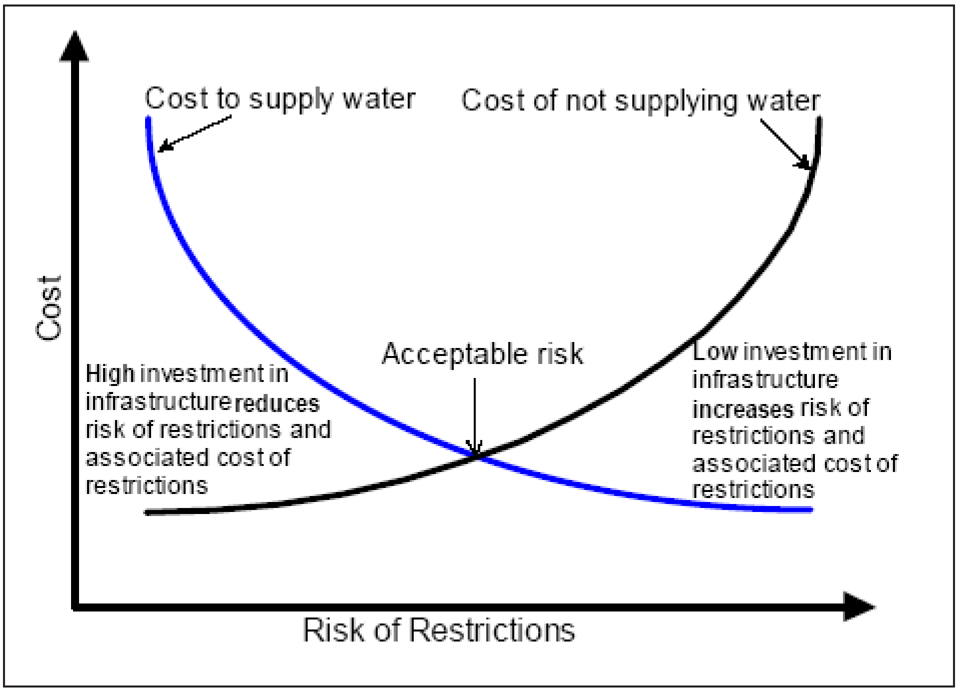


Figure 1 – Trade-off for Setting Level of Service Objectives[12]

Along with the information gathered in the FWO project, ACTEW will re-examine the balance between the social, economic and environmental costs of supplying water with the proposed restrictions, infrastructure options and varying system performance criteria.

A new water restrictions scheme is currently under review by Government. The changes proposed look at both the measures involved in a particular stage of drought restrictions, and the triggers (total storage volume) at which each stage should start and stop.

[11] Peter Erlanger and Brad Neal, *Framework for Urban Water Resource Planning*, Water Services Association of Australia, Occasional Paper No. 14 – June 2005

[12] Figure reproduced from Peter Erlanger and Brad Neal, *Framework for Urban Water Resource Planning*, Water Services Association of Australia, Occasional Paper No. 14 – June 2005

The proposal under consideration is that the number of restriction stages be reduced from five to four. This will simplify the scheme and reduce the similarity between Permanent Water Conservation Measures and Stage 1 restrictions[13].

If the proposed changes to the restrictions scheme are adopted, future modeling will use the PWCM, proposed new restrictions scheme and the expected reductions from each stage of restrictions.

7 Water supply system operating rules

There are many variables in the way the water supply system is operated. As an illustrative example, in order to truly maximise system performance Lower Cotter Dam should be used as the first source of supply. It is the furthest downstream dam and the last chance to catch water before it leaves the system, so continued operation of Lower Cotter will help minimise the water "lost" to the ACT system. However, water from Cotter dam is very expensive to pump, which also generates greenhouse gas and is expensive to treat.

ACTEW will be reviewing these operating rules to optimise system performance with respect to social, economic and environmental considerations.

8 Conclusions

For predictions of the timing of the next ACT water source, the assumptions have not changed over the last twelve months with respect to climate change and bushfire impacts.

As to what the next option might be, it is possible that if current climate trends in the Tennent Dam catchment continue, this may have implications on the long term viability of this option. This will be monitored carefully.

Changes have been identified for trends in demand reduction targets and population projections and with the new 2006 environmental flow guidelines. However, these short term changes cause little impact on the predicted timing for the next water source. Water supply modeling from July 2006 will take these changes into account.

Further work has been identified and initiated with respect to reviewing system performance criteria particularly with respect to the new Permanent Water Conservation Measures, the proposed new water restrictions scheme and the operating rules applied to the system. This will be a major focus in the 2007 review, in addition to identifying any new trends with the other assumptions.

This report is scheduled for annual review and will be released by 30 June each year.

[13] *Review of Water Restrictions Scheme*, ActewAGL, January 2006 (ActewAGL Document No. 254815)

1 Aim

Assessments of water supply security require consideration of a number of variables relating to current and future performance of the water supply system. The results of the assessment can be significantly altered according to the assumptions made when considering the variables (see Figure 14). The Future Water Options study undertaken by ACTEW in 2004-2005 identified "six key planning variables that underlie predictions" of Canberra's water supply security[14]: These are:

1. Climate variability and climate change,
2. Impact of bushfires on inflows to ACT reservoirs,
3. Future population growth in Canberra and Queanbeyan and the possibility of servicing additional areas,
4. Reduction targets in per capita water use set by the ACT Government in *Think Water, Act Water*,
5. Environmental Flow requirements,
6. Acceptable levels for the duration, frequency and severity of water restrictions during times of drought.

This report looks at changes to the assumptions that have occurred since the Future Water Options work in 2004 and early 2005. In addition it observes the issue of operating rules with respect to long term planning scenarios.

The methods used to analyse the water supply system are described in section 2. Infrastructure has been described in Section 3 and planning assumption trends described in Sections 4 to 10. Combinations of assumptions that are used for water supply planning are described in section 11 and sensitivity of different variables are described in Section 12.

This report reviewing the assumptions involved in assessing water supply security is scheduled for annual review and will be released by 30 June each year.

[14] *Future Water Options for the ACT Region – Implementation Plan: A recommended strategy to increase the ACT's water supply*, ACTEW, April 2005

2 Types of analysis

A number of modelling methods have been used to assess the performance of Canberra's water supply system. These methods are summarised below:

- Historical Analysis – The purpose of historical analysis is not to reproduce how the system performed historically but to consider how the system would perform under current or future conditions with the weather experienced historically. Historical analysis is performed by selecting a constant population, demand reduction and infrastructure and running this model through period of record inflow and demand data. The population and/or demand reduction may then be changed to assess system performance with a different demand, eg. compare current population to projected population in 2023.

  Gauged flow data are available from at least one site on the Cotter River since March 1910 and from at least one site on the Queanbeyan River since April 1912. By applying correlations to these records, inflow data for Corin, Bendora, Cotter and Googong dams may be estimated with reasonable accuracy over this period. In recent years additional gauge sites have been added to both rivers, improving the accuracy of historical record data. The period of record of the historical inflow data was recently extended to 1871 as part of the Future Water Options project. This was achieved by developing rainfall runoff models for each site and estimating rainfall from Queanbeyan or Bungendore rain gauge sites. Flow records for the Murrumbidgee and the proposed Tennent dam site have also been developed from 1871 to the present using a combination of gauged data, rainfall runoff models and correlations.

  Consumption data are available for Canberra from the 1960s to the present. After adjusting for population and consumption patterns of the time these data may be used in historical analysis of the system. Before this record begins, and during the recent water restrictions event, demand data may be estimated using a demand model based on evaporation and rainfall.

  Historical analysis is useful as it provides a reliable estimate of what would have occurred under weather conditions that were actually experienced (or the best available estimate of experienced conditions). However, it has two major drawbacks; firstly, by nature it does not consider climate change and, secondly, it is inevitable that events more severe than those experienced during the period of record will occur at some stage in the future, without considering the influence of climate change. For these reasons historical record data analysis is not ideal for assessing system performance; however, it does provide a useful comparison with stochastic data methods.

- Stochastic Analysis – The stochastic analysis looks at system performance using 10,000 years of stochastic data, generated by retaining the statistical parameters present in the historical record data. This method includes worse droughts than experienced in the period of historic record because it uses a larger data set. Like the historic data, the stochastic data set may be used with constant infrastructure, population and demand reduction for returning statistical results related to system performance. The population and demand reduction can then be amended to predict system performance under different conditions.

The stochastic data method is not intended to predict what will happen to the system during the next 10,000 years but will instead indicate how the system performs with current or future conditions under a very wide range of weather conditions. Key statistical results that may be extracted from a stochastic data event include percent of the time spent in each stage of restrictions, average recurrence of restriction events and average minimum storage experienced during the run. These results may be compared against agreed reliability criteria to assess system performance (see section 9 - System Performance Criteria). All sensitivity testing in this report uses this type of stochastic data analysis.

The stochastic analysis may be run with or without a step change to 2030 climate (i.e. two scenarios are run, one with 2030 climate and one with current climate). This step change assumption accounts for the possibility that the low inflows experienced in the past five years represent a change in climate type, rather than a dry period in an unchanged climate regime. The climate change data is created by altering rainfall and evaporation by climate change factors developed by the CSIRO specifically for Canberra. A detailed description of the climate change assumptions is provided in section 5. Climate change stochastic data analysis is the recommended method for assessing Canberra's future water supply system infrastructure needs.

3 Infrastructure additions since 2003

A number of additions have been made to Canberra's water supply system in recent years. These infrastructure changes are detailed below:

- Cotter Dam – Cotter Dam has been reinstated as part of Canberra's water supply system. Pumps 7 and 8 at the Cotter pump station (CPS) have been recommissioned and can pump approximately 50 ML/day to Mt Stromlo Water Treatment Plant (WTP). Work is continuing to increase the CPS capacity to approximately 95 ML/day.
- Cotter to Googong Bulk Transfer (CGBT) – A pipeline has been constructed to allow treated water from the Cotter system to be transferred into Googong Dam. This pipeline allows water from the Cotter River to be supplied to Googong, in order to minimise the amount of water spilling from Cotter River Dams. The transfer will not affect the amount of water that is released for environmental flows. Water may be transferred from Stromlo WTP by gravity or, if high volumes are required, by using the Hume and Deakin pump stations. The transfer is particularly useful in recent months when Googong Dam has been low relative to the Cotter storages (ie. 44% compared to 74% at the end of March 2006).
- Murrumbidgee Pump Station – A pump station has been installed to pump water from the Murrumbidgee to Cotter pump station and then on to Stromlo WTP. At present use of Murrumbidgee water will only be considered as an emergency measure in a drought. An extension of the CGBT (known as the ECGBT) is being considered and would allow the use of Murrumbidgee water as a normal supply source.
- Mt Stromlo Water Treatment Plant Upgrade – A new water treatment plant has been built at Mt Stromlo capable of treating about 250 ML/d. The treatment plant was built in response to the January 2003 bushfires, which burnt large areas of the Corin catchment and most of the Bendora catchment, leading to a deterioration in Bendora Dam water quality. This ability to treat poorer quality water also enabled Cotter Dam to be reinstated as part of the water supply system.
- Googong Water Treatment Plant Upgrade – The Googong treatment plant has been upgraded to be capable of supplying 270 ML/day. This capacity is sufficient to supply the whole town demand under most conditions.

The recommended infrastructure augmentation for Canberra is to add Murrumbidgee to the system as a normal source of supply, either by using the Murrumbidgee pump station at Cotter (the ECGBT option) or by constructing a pipeline to convey water from Angle Crossing to Googong Dam. Either of these infrastructure options will meet system security requirements until at least 2023, based on the supply and demand assumptions detailed in this report. All sensitivity analyses in this document use the Murrumbidgee at Cotter model (as a normal supply source). However, as the Murrumbidgee at Cotter and Angle Crossing models have virtually equivalent system performance results it can be accurately assumed that the sensitivity analysis is true for both infrastructure options.

4 Population Growth

In calculating demand, it is necessary to predict future serviced population. This population must include the ACT, Queanbeyan and any future areas (eg. Yass, Murrumbateman, Goulburn) that are likely to be serviced by the ACT water supply system.

In the short term, population growth is not as important a factor in determining the need to augment the water supply system as climate change or the system operating rules. However, in the medium to long term, population becomes critical to water supply planning. If predicted low or medium population growth occurs (and other assumptions hold), system augmentation will not be required until beyond 2053. However if high population growth occurs augmentation will be required during the 2020s.

4.1 Data sources

A number of data sources are available for projecting population growth in the ACT. The ACT Chief Minister's Department published medium growth figures in June 2003 and the Australian Bureau of Statistics (ABS) releases high, medium and low growth projections from time to time, most recently in November 2005. Some projected land release figures are available from the ACT Planning and Land Authority (ACTPLA) and the Land Development Agency (LDA), however these numbers are subject to change and do not provide information on growth outside the ACT.

It is important to take into account the relationship between ACT growth and Queanbeyan growth by considering the population as one unit (i.e. acknowledging that population growth in Queanbeyan may be offset by growth in Canberra, and vice versa). Population growth projections incorporate proposed new development in Canberra or Queanbeyan, including proposed major developments at Tralee and Googong.

The Canberra Spatial Plan states that the combined Canberra-Queanbeyan population in 2032 is projected as 430 000 with moderate growth and 500 000 with high growth and recommends that "prudent planning … caters for both moderate and high population projections"[15]. The ACT Government's *Think Water, Act Water* strategy prescribes the use of high population growth projections by stating that "work being done to predict when new water supply infrastructure will be needed will therefore be using these higher growth projections for contingency planning to ensure that, if increased water supply is needed, necessary planning and design will be done well in advance of the need to begin construction"[16]. Detailed population projections for Canberra and Queanbeyan, consistent with the numbers quoted in the *Spatial Plan*, were obtained from the Chief Minister's Department during the Future Water Options study (2004). The choice of population projections for this study was documented in an extensive *Future Population Estimates* Report[17]

The extent of future supply to population outside Canberra and Queanbeyan is harder to quantify. Population projections for these areas are less common and contain even more uncertainty than projections for the ACT and Queanbeyan. Furthermore, at this stage it is

[15] *The Canberra Spatial Plan*, ACT Planning and Land Authority, March 2004
[16] *Think Water, Act Water: Volume 1: Strategy for sustainable water resource management in the ACT*, ACT Government, April 2004
[17] *Future Population Estimates*, ActewAGL, June 2004

unknown if or when additional areas will be connected to Canberra's water supply system. Assuming that the connection is made, it is also uncertain how much water will be supplied from Canberra and how much will be supplied from existing water sources. Nevertheless, it is important that planning consider the possible future impact of cross-border supply on Canberra's water supply security. The inclusion of regional supply and specifically of Yass in future water supply planning is recommended in *Think Water, Act Water*[18].

4.2 Projections Currently Used for Water Supply Modelling

The Future Water Options study, modelled high, medium and low population growth in accordance with the projections for Canberra and Queanbeyan provided by the ACT Chief Minister's Department[19]. Modelling was also conducted with and without cross-border supply, making a total of six population scenarios. An allowance for cross-border supply was made by assuming that the equivalent of 12 000 residents would be supplied by 2006, increasing by 600 annually. In order to plan conservatively, the high population growth with cross-border supply was chosen for the base case or "prudent planning scenario". Figure 2 shows the six population growth scenarios developed during the Future Water Options project.

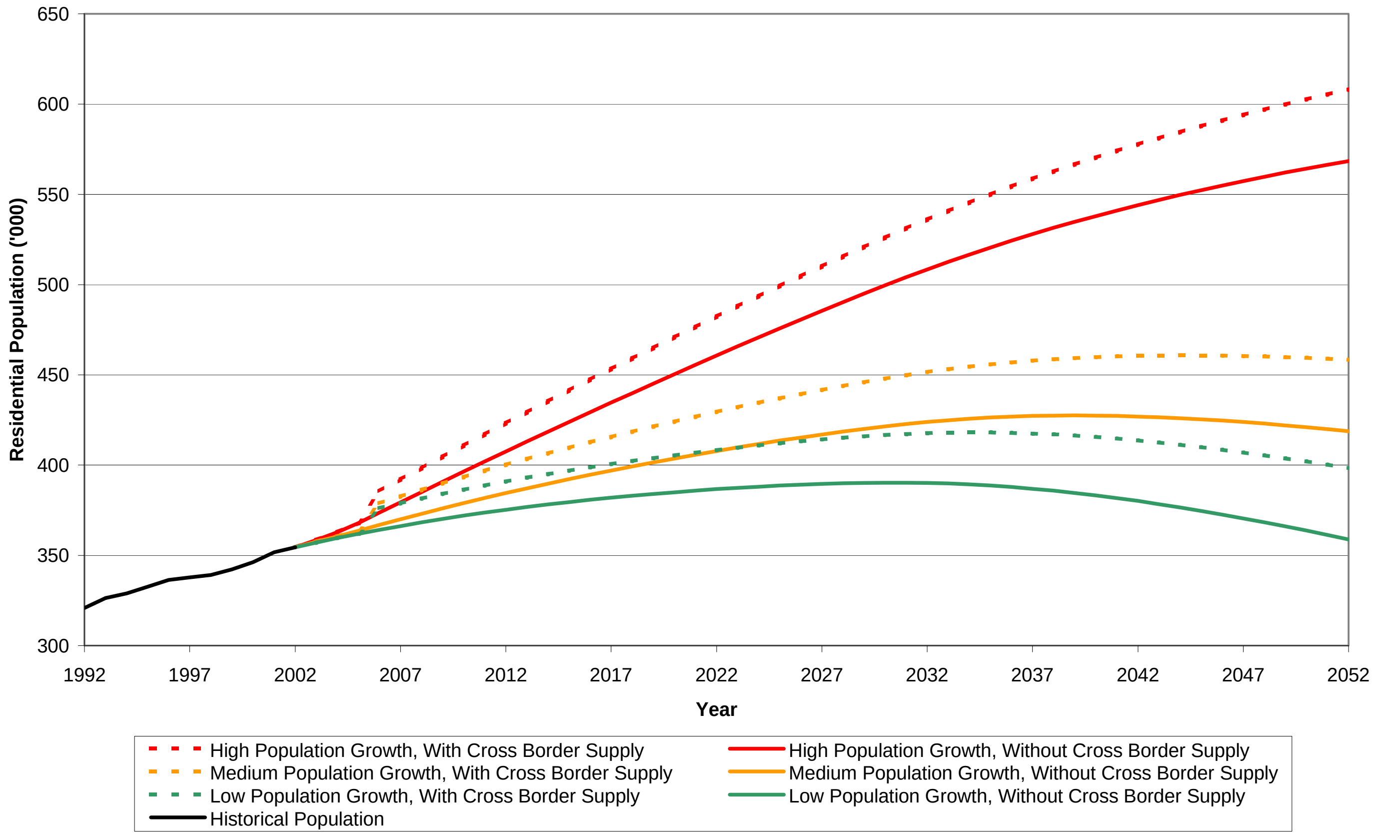


Figure 2 – Projected ACT Water Supply Serviced Population, From Future Water Options Project

[18] *Think Water, Act Water: Volume 1: Strategy for sustainable water resource management in the ACT*, ACT Government, April 2004

[19] Patrick Stakelum, ACT Demographic Unit, ACT Chief Minister's Department, personal communication, 25th May 2004

A significant issue with the medium and low projections is that they have a peak, after which population declines. Important policy decisions when planning for these growth rates is whether to design for the peak, or to accept a slightly higher risk of restrictions in those peak times, in the knowledge that projected declining population will return the risk of restrictions to acceptable levels, albeit after many years (more than 20 years). Conversely there is a risk that population will not peak and that this should be taken into consideration.

4.3 Changes since Future Water Options (2004)

4.3.1 Current Residential Population Compared With Projected Population

It is never possible to quantify the current population with absolute accuracy because of the difficulties involved in assessing population movements. For example, the November 2005 ABS population projections for the ACT begin in June 2004, and the 2004 figure is only an estimate of residential population. More information on ACT and Queanbeyan population may become available after the 2006 Census data is published. The ABS estimated population for the ACT in June 2004 is 324 100[20], while Queanbeyan population is estimated as 36 331[21], giving a total water supply population of 360 431. ABS reported ACT's growth rate for 2005 at 0.8%22. However, high population projections have not altered significantly.

Although the ABS projections are for the ACT alone, they do provide valuable estimates of current population and projected trends. Figure 3 compares the ABS low, medium and high population growth projections to the June 2003 Chief Minister's Department (CMD) medium population growth projection[23]. It is notable that the ABS population projections begin 3 200 people behind the CMD figures in 2004 and the medium population is 6 600 behind the CMD projections in 2012. However, the CMD projection peaks in 2041 while the ABS medium projection continues to grow; as a result the ABS medium projection is higher than the CMD projection from 2040 onwards. The ABS medium population growth projection has changed somewhat since the projection released in September 2003[24], which had the same population as the CMD figures in 2004 and an almost identical population to the CMD figures in 2051 (albeit with the CMD projections peaking at an earlier date than the ABS series).

[20] *Population Projections: Australia*, Australian Bureau of Statistics, November 2005
[21] John Louis Moore, Australian Bureau of Statistics, personal communication, 1st November 2005
[22] ABS June 2006
[23] *Australian Capital Territory Population Projections 2002-2032 and beyond*, Demographic Unit, Policy Group, Chief Minister's Department, June 2003
[24] Dennis Trewin, *Population Projections: Australia 2002 to 2101*, Australian Bureau of Statistics, September 2003

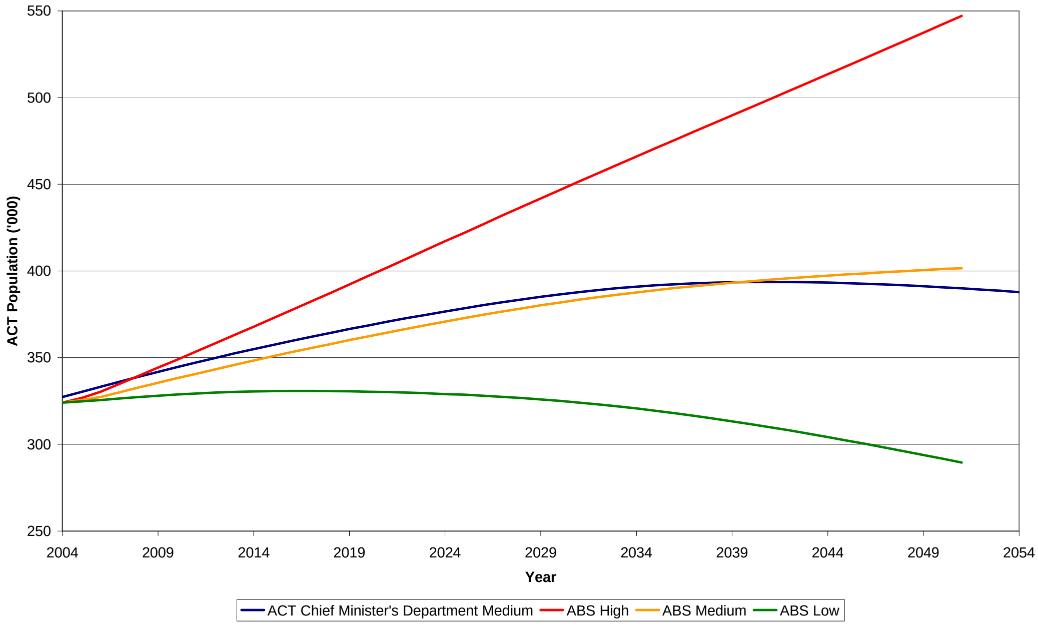


Figure 3 – Comparison Between ACT Chief Minister's Department and ABS Population Projections for the ACT

4.3.2 Cross-Border Supply

Modelling for the Future Water Options project assumed that cross-border supply would consist of:

- An additional population of 12,000 by 2006; and
- A constant annual increase of 600 per year thereafter (i.e. reach 26,400 by 2030)

While no cross-border supply has occurred as yet, it is possible that Yass (population approximately 5000) could be supplied as early as 2008. There are currently no plans to supply water to Goulburn or other areas, however this could eventuate in the future. Future planning will revise the assumption to the following:

- An additional population of 5000 by 2008
- A constant annual increase of about 1,000 per year thereafter (i.e. reach 26,400 by 2030)

It is assumed that per capita usage in new areas will be equivalent to Canberra's per capita consumption. This assumption is insignificant given the uncertainty in the volume of cross-border supply and the small size of additional cross-border supply relative to the population currently serviced. If existing township water supplies are maintained, this population allowance is sufficient to serve Yass, Goulburn and the intermediate towns and villages such as Murrumbateman, Bungendore and Collector.

4.4 Proposed Population Projections

In future modelling, all population projections will begin from the estimated 2004 water supply population of 360 431. As no further combined projections for Canberra and Queanbeyan assumptions have been made since 2003, the numbers provided by the Chief Minister's Department will continue to be used. These projections will be amended to equal the estimated 2004 population by adding or subtracting a constant value from each series, as shown in Table 2.

Table 2 –Population Projections Revised to Account for Current Population

Year	Population Projections Used for Future Water Options			Revised Population Projections		
	High	**Medium**	**Low**	**High**	**Medium**	**Low**
Amend Series By				-2406	-140	767
2004	362837	360571	359664	360431	360431	360431
2008	385105	373092	368286	382699	372952	369053
…						
2053	570424	417550	356401	568018	417410	357168

It is assumed that potential developments in the Tralee and Googong regions of NSW are included in the combined projections for Canberra and Queanbeyan. It is unlikely that the high population growth projection will be achieved without development in these areas. Cross-border supply will be included by applying an initial population of 5000 (equivalent to supplying Yass) in 2008 and increasing this figure by about 1000 people per year (see section 4.3.2, above). The two changes to projected population cause little change in predicted system security. However, the range of projected populations by 2023 is extremely broad (388 000 – low population growth without cross-border supply to 478 000 high population growth with cross border supply). Population growth assumptions, therefore, can play an important part in water supply security analyses and it is important that population growth trends continue to be monitored. In recent years the ACT has been experiencing a relatively slow rate of growth. ABS reported ACT's growth rate for 2005 at 0.8%25. This may only be a short term trend and has not caused any changes in population projection scenarios in ABS or CMD.

High population projections remain as the prudent approach for water planning. Planning should also consider the implications of multiple population growth scenarios, especially when population forecasts are required for dates well into the future. Figure 14 shows the sensitivity of system performance to population trends. In the short term, population growth is not as important a factor as climate change or the operating rules chosen to run the system. However, in the medium to long term, population becomes critical to water supply planning. If predicted low or medium population growth occurs, system augmentation will not be required until beyond 2053, however if high population growth occurs augmentation will be required during the 2020s. This demonstrates the high uncertainty in planning further than about 20 years into the future and highlights the need to review population trends and projections on a regular basis.

[25] ABS June 2006

5 Climate Change and Variability

Recent changes to local climate variability are evident in the historic records in and around the ACT. The current drought has become the worst on record for its duration.

Responsible water supply planning must consider the potentially considerable impact of climate change. Climate change is the variable with the largest impact on supply security (see Figure 14). Future climate properties are difficult to predict, and the most accurate advice can only produce quite wide ranges in possible future climate parameters.

The difference between climate change and variability can only be assessed in hindsight. Whether or not the current weather pattern is influenced by climate change will only be known well into the future. Hence it is prudent to include climate change when planning for future water needs.

5.1 Climate Change Predictions

Climate change predictions for the ACT have been obtained from the CSIRO by ACTEW Corporation[26]. The range of predicted increase or decrease in rainfall and evaporation by 2030 for each season is shown below in Figure 4. Annual rainfall is predicted to be in the range of a 9% decrease to a 2% increase while annual evaporation is predicted to increase by between 1.4% and 9.1%.

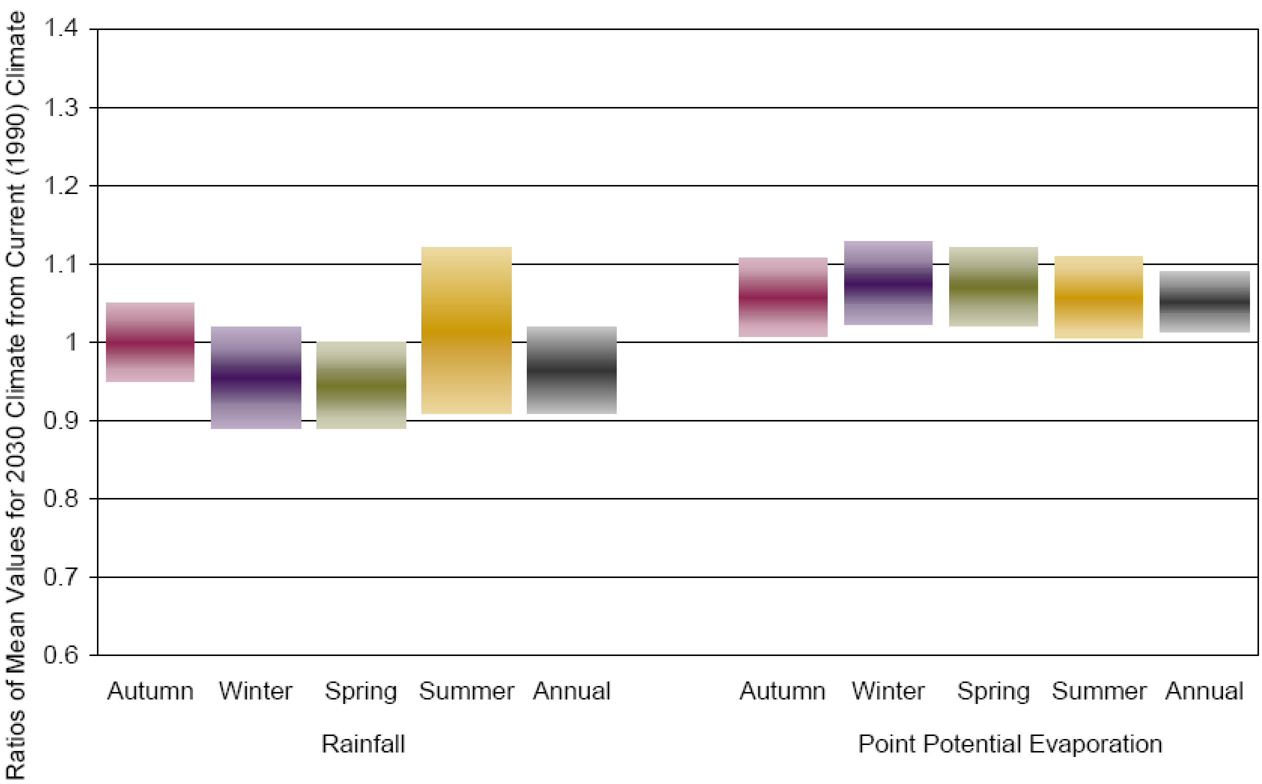


Figure 4 – CSIRO Predicted 2030 Seasonal Rainfall & Evaporation Variability

[26] Bates et al., *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003

5.2 Method of Including Climate Change

The most important model inputs for water supply planning are inflow and demand, while climate change predictions are typically expressed in temperature, rainfall and evaporation. This has been overcome by developing rainfall-runoff models (models which convert single point rainfall and evaporation to dam inflow) for each existing and proposed dam site (Corin, Bendora, Cotter, Googong & Tennent). A demand model has also been developed to estimate per capita water demand from Canberra Airport rainfall and evaporation. Stochastically generated rainfall and evaporation data at each site can be altered to represent possible future climate change.

5.3 Assumptions

5.3.1 Selection of values within the predicted range

The predicted range of changes in rainfall and evaporation is quite large for all seasons. In order to conservatively estimate the impact of climate change, the worst case prediction for annual rainfall and evaporation has been chosen. Seasonal reductions in rainfall and increases in evaporation have been selected to achieve this worst case result and are shown in Table 3. Small reductions in rainfall typically result in more significant runoff reductions. This is true for Canberra's system, where the total stochastic data inflows to Corin, Bendora and Googong Dams are reduced by 27% when climate change is applied.

Table 3 also shows the change in rainfall and evaporation observed since 2000, calculated by comparing the average Canberra Airport rainfall and evaporation since 2000 with the historical record (1967-present) Airport rainfall and evaporation. These results are only for a six year period and may just indicate a difference from the long-term mean or a permanent climate change trend. It will be many years before it can be confirmed that this is or is not climate change. For this reason, and the huge impact that it has, climate change needs to be included in water supply planning because if it is not we will have not planned prudently to best available information. It is interesting to note that evaporation is higher than the long-term average for all four seasons and the annual rainfall reduction is slightly higher than that predicted with climate change. Although summer and winter exhibit significant rainfall reductions, the bulk of the reduction occurs in autumn. The CSIRO climate models do not predict significant rainfall reductions in autumn; however recent consistently dry autumns may be a temporary anomaly.

Table 3 – Predicted, Modelled and Observed Climate Change

	Change in Rainfall				Change in Evaporation			
Season	Predicted Worst Case	Predicted Best Case	Modelled	Observed Since 2000	Predicted Worst Case	Predicted Best Case	Modelled	Observed Since 2000
Summer	-9%	12%	-8.9%	-5.7%	11.0%	0.5%	8.7%	2.0%
Autumn	-5%	5%	-4.9%	-41.8%	10.8%	0.8%	8.5%	5.4%
Winter	-11%	2%	-10.9%	-4.3%	12.8%	2.2%	10.5%	4.4%
Spring	-11%	0%	-10.9%	0.4%	12.0%	2.1%	9.7%	1.7%
Annual	-9%	2%	-9.0%	-11.8%	9.1%	1.4%	9.1%	4.1%

5.3.2 Step Change in Climate

Whilst global warming changes proportionally to the build up of greenhouse gases, it can result in rapid (“step”) climate changes in a particular region. The reduction in rainfall and runoff experienced in the Perth region in the past 30 years is often cited as an example of a step change in climate.

It is possible that the recent drought represents a shift in climate for Canberra. The past 5 to 10 years are the most severe long-term dry period in the 1871 to present extended historic record inflow sequence. Without any year being exceptionally dry, the past few years exhibit inflows that are consistently lower than average, with remarkably similar low inflows from late summer to early winter. The average system inflows during the last ten years are considerably lower than the average inflows generated with 2030 stochastic data (96 GL/year compared to 127 GL/year). Therefore, the last few years would be a drought even with predicted climate change. The inflows to Googong during this period are especially low when compared to the historic record or the stochastic data. The CSIRO climate change report comments that:

> *There is evidence of a shift in the last 20 years, with several locations (Michelago is an exception) near to Canberra showing a small decline in rainfall and a decrease in interannual variability after the mid to late 1980s. A similar shift has been well documented in the southwest of Western Australia.* [27]

Inflows to Googong in recent years have been considerably lower than for any other extended time period in the 1912-present historical record of gauged data. It is possible that this reduction in inflows results from either a change in climate or a change in catchment response to rainfall. Model results could vary significantly if Googong’s catchment behaviour has altered.

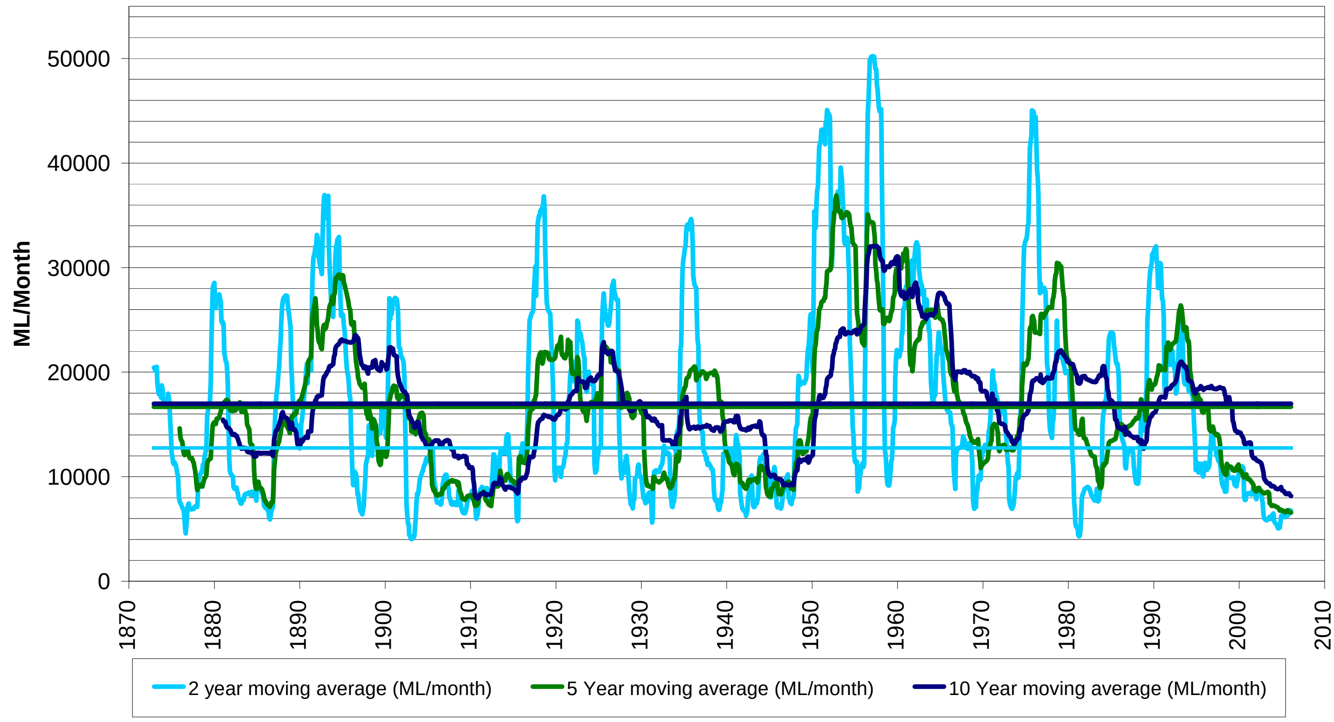
Analysis[28] comparing the runoff into Googong reservoir with flows in similar sized catchments for the Gudgenby River (near the location of the Tennent dam option) and the Molonglo River at the ACT border, showed that similar very low runoff has been experienced in all three catchments. Whereas, while the Cotter River flows reduced, it was not to the same extent as the other three catchments.

However, there is no definitive evidence that the recent drought conditions are connected to climate change. Although this drought has the lowest inflows over a long-term period there have been several short term droughts with worse inflows than any period during the last ten years (1981-83, 1944-45, 1941-42, 1918-19, 1914-15, 1901-03, 1895-6, 1885-6, 1875-6). The 1910s and 1940s also contain long-term droughts where average inflow is only a little higher than the current period.

Figure 5 shows the 2 year, 5 year and 10 year average total inflows to Canberra’s water supply system over the period of record. It is noteworthy that the period from 1950 to 1980 exhibits some consistently high inflows that are not reproduced at other times in the record. The inflows since 1980, including the current drought, appear relatively similar to the 1871-1950 portion of the period of record.

[27] Bates et al., *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003

[28] Ecowise Environmental (2006) Report on Inflow Reduction to Googong Dam in Recent Years, by A. C. Falkland.



Moving Average Total Storage Inflows

Figure 5 – Moving Average Inflows to Corin, Bendora and Googong Dams

It is uncertain whether climate change, if it occurs, will take place gradually or rapidly. It is also unknown whether the current dry period is influenced by climate change or is merely part of natural climate variability. However, model results will significantly overestimate system performance if climate change is not included in modelling and has already occurred. Therefore, it is prudent to include climate change in modelling current system performance as well as future projections. This approach was taken for the Future Water Options project and is consistent with the advice provided by the CSIRO, although their models are for 2030:

It is possible that the climate will shift in a short period to a new state, rather than show a smooth progression. Such shifts are not picked up by global climate change models. [29]

5.3.3 Distribution of Rainfall and Evaporation

The CSIRO climate change reports estimate changes in total rainfall and evaporation in each season, but offer little guidance on how the distribution of rainfall will change. It is believed that climate change may lead to more storms and more dry periods in some locations. The CSIRO reports predict “an increase in the frequency and intensity of extreme rainfall”[30], but provide no further guidance on how this should be incorporated. The distribution of rainfall and evaporation can have significant and complicated impacts on the volume of runoff. For example, if rainfall falls mainly as storms this may lead to an increase in runoff if the catchment is unable to absorb the rainfall. However, the same situation could potentially lead to decreased runoff if the catchment is typically dry and has a very high ability to absorb rainfall.

[29] Bates et al., *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003
[30] Ibid

As there are no predictions of rainfall distribution, the rainfall and evaporation have been scaled linearly using the factors displayed in Table 3. If possible, future predictions of climate change should provide an estimate of changes in rainfall distribution.

5.4 Comparison Between Historic Data and Stochastic Data[31]

Figure 6 shows flow duration curves for the historical record, no climate change stochastic and climate change stochastic inflow sequences.

The 2030 climate stochastic inflow is significantly less than 1990 climate stochastic inflow, reflecting the reduction in rainfall and increase in evaporation assumed for CSIRO conservative 2030 climate projections. The 1990 climate stochastic inflow is less than historic inflow (particularly high flows) due to scaling of stochastic climate data to 1976-2003 mean historic climate, rather than the entire 133-year historic record. The period since 1976 was chosen because "the entire 133 year period of historical record therefore may not represent the best picture of current climatic conditions" due to climate variability over time[32]. For example, the 1950s and 60s contain a wetter climate than the remainder of the historical record.

Modelling of water supply systems is highly influenced by periods of minimum storage inflow. Table 4 summarises minimum storage inflows over varying periods for extended historic climate, and for the 1990 and 2030 climate stochastic climate. The modelled 2030 climate change inflows are approximately 30% of the inflows based on extended historic record.

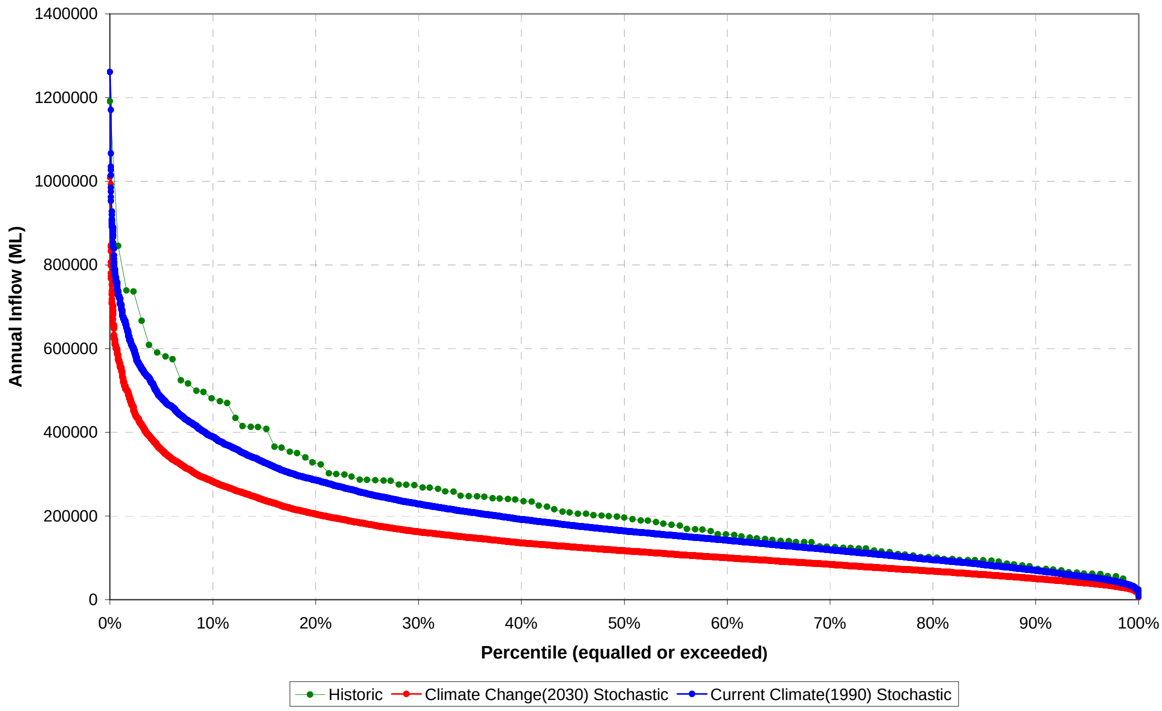


Figure 6 - Storage inflow duration curves

[31] Extract from *ACT Water Supply Augmentation Timing – Volume I*, ActewAGL, Future Water Options Project, November 2004

[32] *Update of Water Resources Strategy for Canberra and Queanbeyan*, Draft, Sinclair Knight Merz, July 2004

Table 4 - Minimum storage inflows for various durations

	Minimum Annual Moving Average Storage Inflow (GL) (combined Corin, Bendora, Lower Cotter & Googong storages)		
Sequence duration (years)	*Extended historic record (1871-2003)*	*Current Climate Sequence*	*Yr. 2030 Climate Change Sequence*
10	110.1 (to 1910)	82.2	62.0
5	99.7 (to 1910)	43.0	32.8
4	91.8 (to 1983)	44.3	34.0
3	89.6 (to 1877)	31.5	23.6
2	56.3 (to 1903)	21.1	16.1
1	18.2 (to 1902)	7.4	5.9

5.5 Conclusions

At this stage there is no new information or other reason to alter climate change predictions used in the Future Water Options work. Given the current drought and the potential impact of climate change, it is important to consider the implications of climate change in water supply modelling. However, all results should clearly state that "climate change" implies that the climate has already shifted to the most conservative CSIRO prediction of climate in the year 2030, and state that this assumption has a significant impact upon results.

The CSIRO predictions will be updated in 2008.

6 Environmental Flows

ACTEW has a licence to take water (issued under the *Water Resource Act 1998*) that includes provisions to ensure environmental flows are protected as a first priority. The required environmental flows are set out in Environment ACT's *2006 Environmental Flow Guidelines*. A summary of the 2006 guidelines are provided in Table 5.

Table 5 – 2006 Environmental Flow Guidelines

River Reach	Base Flow	Riffle Flow (see Note 1)	Pool Flow (see Note 2)	Drought - Stage 1 Restrictions	Drought - Stage 2 Restrictions and Above
Cotter Below Corin Dam	Smaller of inflow and 75% of 80th percentile	150 ML/Day for 3 days	550 ML/day for 2 days	Smallest of Inflow or 40 ML/day or 75% of the 80th percentile, plus riffle and pool flows	20 ML/Day, plus riffle and pool flows
Cotter Below Bendora Dam	Smaller of inflow and 75% of 80th percentile	150 ML/Day for 3 days	550 ML/day for 2 days	Smallest of Inflow or 40 ML/day or 75% of the 80th percentile, plus riffle and pool flows	20 ML/Day, plus riffle and pool flows
Cotter Below Cotter Dam	15 ML/Day	100 ML/day for 1 day	NA	15 ML/Day, no riffle flows	15 ML/Day, no riffle flows
Queanbeyan Below Googong Dam	Smaller of inflow or 10 ML/Day	100 ML/day for 1 day	NA	Smaller of Inflow or 10 ML/Day, no riffle flows	Smaller of Inflow or 10 ML/Day, no riffle flows

Notes:

1. Riffle Flows are required once every two months.

2. Pool Flows are required once a year between mid-July and mid- October. Pool Flows may count as part of a Riffle Flow.

The final set of results produced for the Future Water Options project used a draft version[33] of the 2006 guidelines. Only minor changes to environmental flows, which will not have a significant influence on system security, have taken place since these results were produced. The system model has been updated to reflect these changes, and future modelling will be conducted using this updated model.

6.1 Impact of Climate Change on Environmental Flows

Environmental flows from Corin and Bendora are strongly linked to the 80th percentile natural inflow to these dams, or the flow that is exceeded 80% of the time. Climate change may alter

[33] Peter Liston, Environment ACT, *Proposed E Flows for Water Supply Catchments*, personal communication, February 2005

dam inflows, which would lead to different values of the 80^{th} percentile. The 2006 guidelines raises this issue and lists two alternative approaches that may be taken regarding environmental flows:

> *One approach could be to consider climate change to be a human influence on streamflows, and that to protect aquatic ecosystems environmental flows should be based on pre-climate change flows. Alternatively, environmental flows might be amended based on the changed streamflows.* [34]

Assuming that the latter method is applied, it would be necessary to demonstrate that climate change had occurred when calculating the 80^{th} percentile flow, as several years must pass before climate change has a significant impact on the period of record. This would be problematic, given the difficulty in differentiating between climate change and climate variability. For simplicity, and to be conservative, all modelling has assumed that the environmental flows will be unchanged by climate change.

6.2 Conclusions

The results reported for the Future Water Options work in 2005 were based on a draft form of the 2006 *Environmental Flow Guidelines* and are still valid. The environmental flow guidelines are due to be reviewed again five years after publication[35]. Potential changes in environmental flows will continue to be monitored to ensure that impacts on water supply security can be assessed.

[34] *2006 Environmental Flow Guidelines*, Environment ACT, January 2006
[35] ibid

7 Ongoing bushfire impact[36]

Severe bushfire events modify catchment vegetation and have significant short and long-term impacts on catchment hydrology. Immediate impacts can include:

- enhanced stream flow due to increased rainfall runoff due to vegetation loss, and
- deterioration in water quality due to nutrient mobilisation and soil erosion.

Longer-term impacts include extended periods of reduced stream flow due to increased evapo-transpiration from rapid vegetation growth during a recovery phase lasting many decades.

7.1 Predicted Impact of 2003 Bushfires

Environmental consultants Ecowise Environmental and Danish Hydrological Institute (DHI) were commissioned to quantify the impact of severe bushfire events on catchment hydrology based on observed catchment recovery to date. Using the Mike-SHE model and early post-fire observations, the consultants predicted the stream flow yield reduction / recovery period relationship as shown in Figure 7 below.

The graph shows that the maximum inflow reduction is 15% about 17 years after the fire, and reduced inflows are predicted to occur for more than 50 years. The shape of the curve reflects the expected maximum evapo-transpiration from recovery of ground cover and shrubs at 5 to 8 years, and recovery of the eucalypt forest at 17 to 30 years.

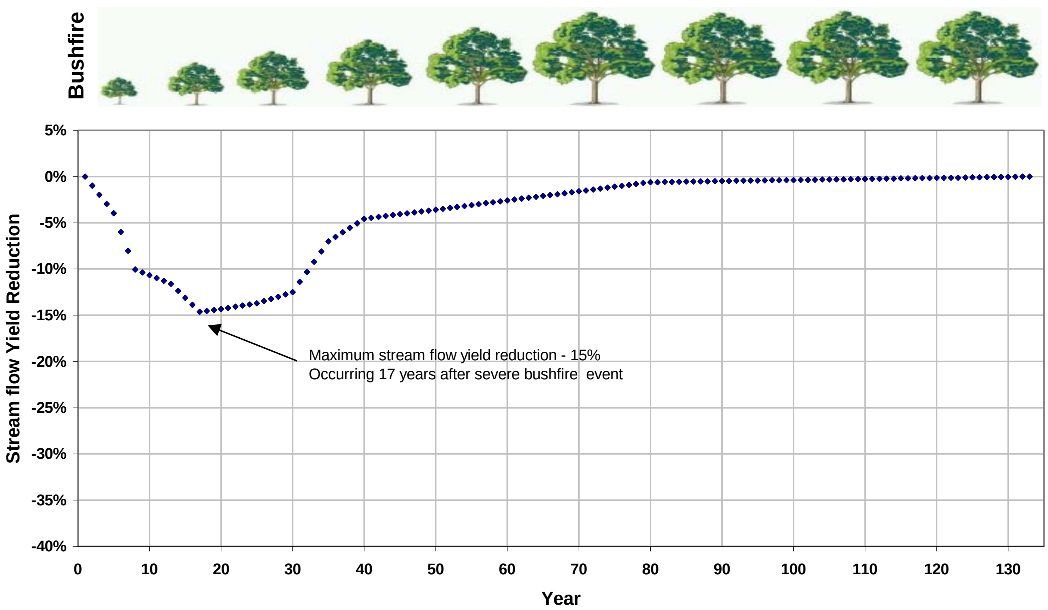


Figure 7 - Predicted ACT severe bushfire yield reduction relationship

[36] Extract from *ACT Water Supply Augmentation Timing – Volume I*, ActewAGL, Future Water Options Project, November 2004

7.2 Incorporation Into Stochastic Data

Storage inflow reductions of 15% due to bushfires have not simply been applied on a constant reduction basis, as the inflows would be underestimated during pre-bushfire periods. To allow for variability in bushfire occurrence, bushfire yield reduction has been incorporated into the stochastic climate inflow sequences by applying a bushfire trigger model for the Corin, Bendora and Cotter sub-catchments. Bushfire yield reduction was not considered for the Googong sub-catchment, as severe bushfire events are likely to have a relatively small impact on inflow given the rural residential nature and vegetation variability of the catchment.

The bushfire trigger model tests a catchment's antecedent condition for severe bushfire event potential (see Figure 8 below). The antecedent condition tests have been determined from observed catchment conditions prior to major historic bushfires, and reflect a catchment's potential fuel load, season and relative dryness. If the bushfire indicator conditions are satisfied, the model engages a probability function to potentially ignite a bushfire and apply yield reductions to stream flow. The probability function reflects the average recurrence interval of historically severe bushfire events, derived from Cotter catchment sedimentary core records.

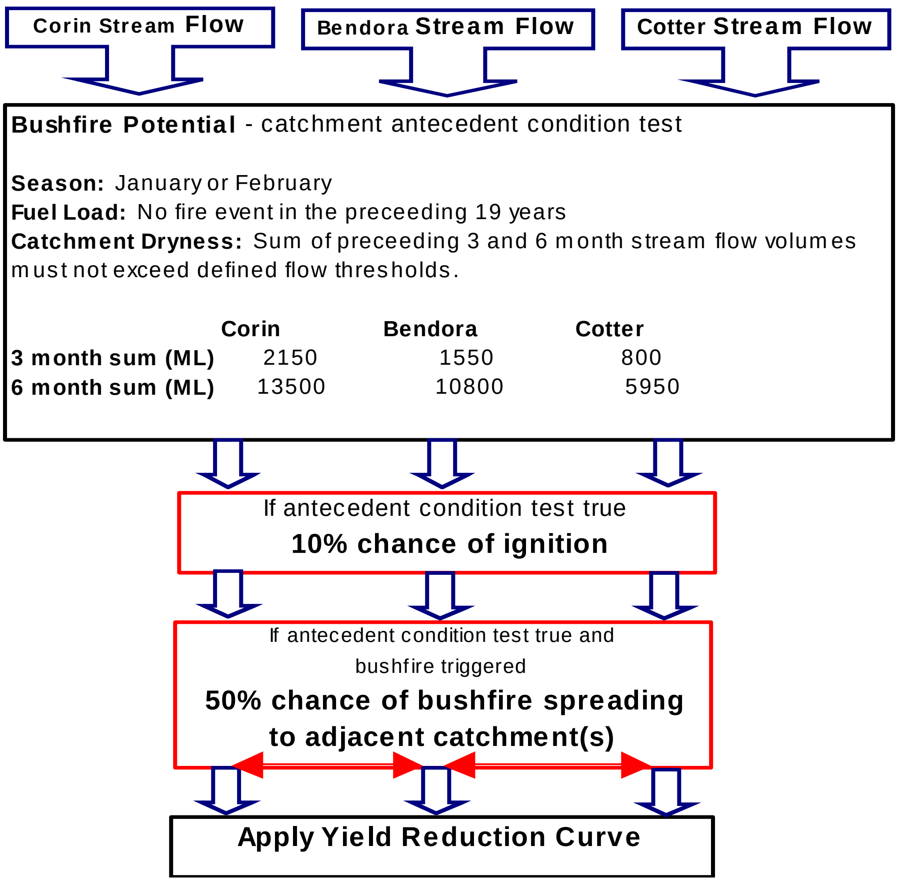


Figure 8 - Schematic diagram of severe bushfire trigger model

Table 6 below outlines the frequency with which each catchment experiences bushfire potential conditions and the recurrence interval of actual triggered bushfires for current climate and 2030 climate stochastic sequences.

Bushfire events occur more frequently within the 2030 climate stochastic sequence, reflecting the drier nature of the catchments and increased susceptibility to bushfire. "Simultaneous catchment ignition events" refer to bushfire events that ignite in all three catchments simultaneously, and represent the worst bushfire yield reduction case.

Table 6 - Predicted severe bushfire frequencies

		Corin	Bendora	Cotter	Simultaneous ignition
Current climate stochastic (Yr. 1990)	No. of bushfire potential seasons	998	1072	981	-
	% bushfire potential seasons	10%	11%	10%	-
	No. of triggered bushfires	132	137	111	6
	Average Recurrence Interval of bushfire events	76	73	90	1667
Climate change Stochastic (Yr. 2030)	No. of bushfire potential seasons	1425	1674	1399	-
	% bushfire potential seasons	14%	17%	14%	-
	No. of triggered bushfires	159	190	178	10
	Average Recurrence Interval of bushfire events	63	53	56	1000

7.3 Observations

Bushfire affects on yield in the first 2-3 years after a fire are not directly representative of the yield reduction in later years. This occurs because the amount of tree regrowth does not peak until a significant time has elapsed since the fires. Although vegetation is recovering well, there has been no measurable change in catchment yield. However, only a small number of significant rainfall events have occurred in the catchment since the fires[37].

7.4 Conclusions

The impact of the 2003 bushfires will be continually monitored, and any significant findings from this work will be incorporated into modelling of the water supply system.

[37] Ian White, Alan Wade, Rosie Barnes, Norm Mueller, Martin Worthy, Ross Knee, *Impacts of the January 2003 Wildfires on ACT Water Supply Catchments*, 2006

8 Water Demand

8.1 Demand Model

A demand model has been developed by ActewAGL to calculate monthly per capita water demand for Canberra, based on Canberra Airport rainfall and evaporation data[38] collected in that month. The demand model is calibrated for each month using the net evaporation (evaporation – rainfall) on the current and previous day and the net evaporation over the three weeks leading up to the current day. Although the demand model operates on a daily timestep, it should not be used to predict demands over intervals shorter than one month.

The demand model can be used to compare observed demand during water restriction events to predicted unrestricted demand, and to generate stochastic demand from rainfall and evaporation. As net evaporation is higher in the climate change stochastic data, the demand is also higher. Figure 9 displays the distributions of historical and stochastic annual demand.

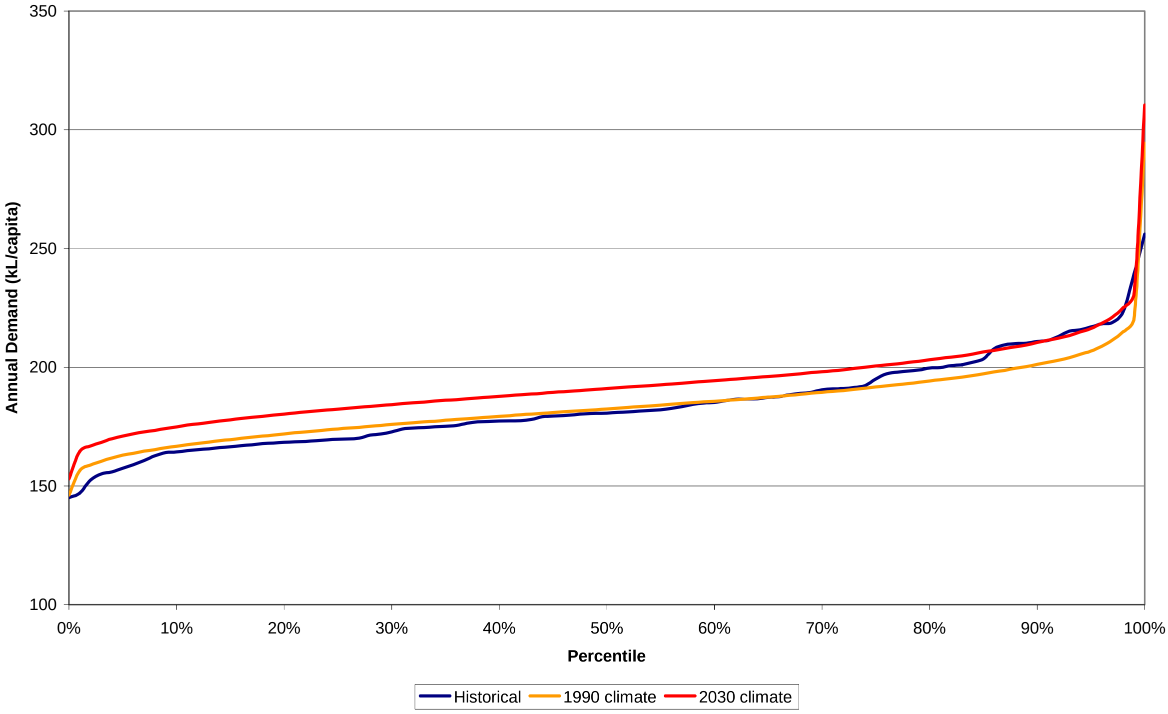


Figure 9 – Comparison Between Historical, Stochastic and Climate Change Stochastic Demand

[38] *Demand Model Detailed Description*, ActewAGL, 2004 (*ACTEW Corp Doc. No. 3727)*

8.2 ACT Government Demand Reduction Targets

The ACT Government has outlined a plan to permanently reduce potable water consumption in its "*Think water, act water"* document. This document specifies a 12% reduction by 2013, and a 25% reduction in water consumption by 2023.

It is intended that a variety of means be used in order to achieve these targets, including:

- education and advertising
- Permanent Water Conservation Measures
- effluent reuse
- stormwater harvesting
- rainwater tanks
- greywater reuse
- water efficient appliances and fittings
- leakage reduction
- Government subsidised indoor and outdoor water tune-ups
- requiring new developments to achieve a 40% reduction in water use through water sensitive urban design
- ongoing pricing reforms.

An increase in the price of water or change to pricing structure may help to limit demand[39]. Changes to the ACT water pricing structure in 2004 were expected to deliver a demand reduction of approximately 3.7%[40]. The price of water has been gradually increasing in Canberra and elsewhere. A significant demand reduction occurred in the ACT in the early 1990s. This demand reduction is discussed in section 8.3.

It is predicted that demand management alone will achieve the 12% target. However, it is expected that source substitution (eg. rainwater tanks, greywater reuse, effluent reuse, stormwater harvesting) will be required to reach the 25% target[41]. As source substitution methods are relatively expensive, it is expected that the 12% target by 2013 will be more easily achieved than the 25% target by 2023[42]. It is desirable that the costs and benefits of source substitution measures be compared with the costs and benefits of water supply augmentation. Figure 10 is a simplistic model, based on future years all being average consumption, that compares the demand reduction targets to the cumulative predicted savings in per capita demand that could be achieved from demand management, source substitution, reducing consumption in Queanbeyan and the North Canberra Effluent Reuse Scheme.

[39] Greg Barrett, *Pricing in response to ACT Government's per capita demand management targets*, University of Canberra, October 2005
[40] *Think Water, Act Water: Volume 1: Strategy for sustainable water resource management in the ACT*, ACT Government, April 2004
[41] *ACT Water Strategy: Preliminary Demand Management and Least Cost Planning Assessment*, Institute for Sustainable Futures, October 2003
[42] ibid

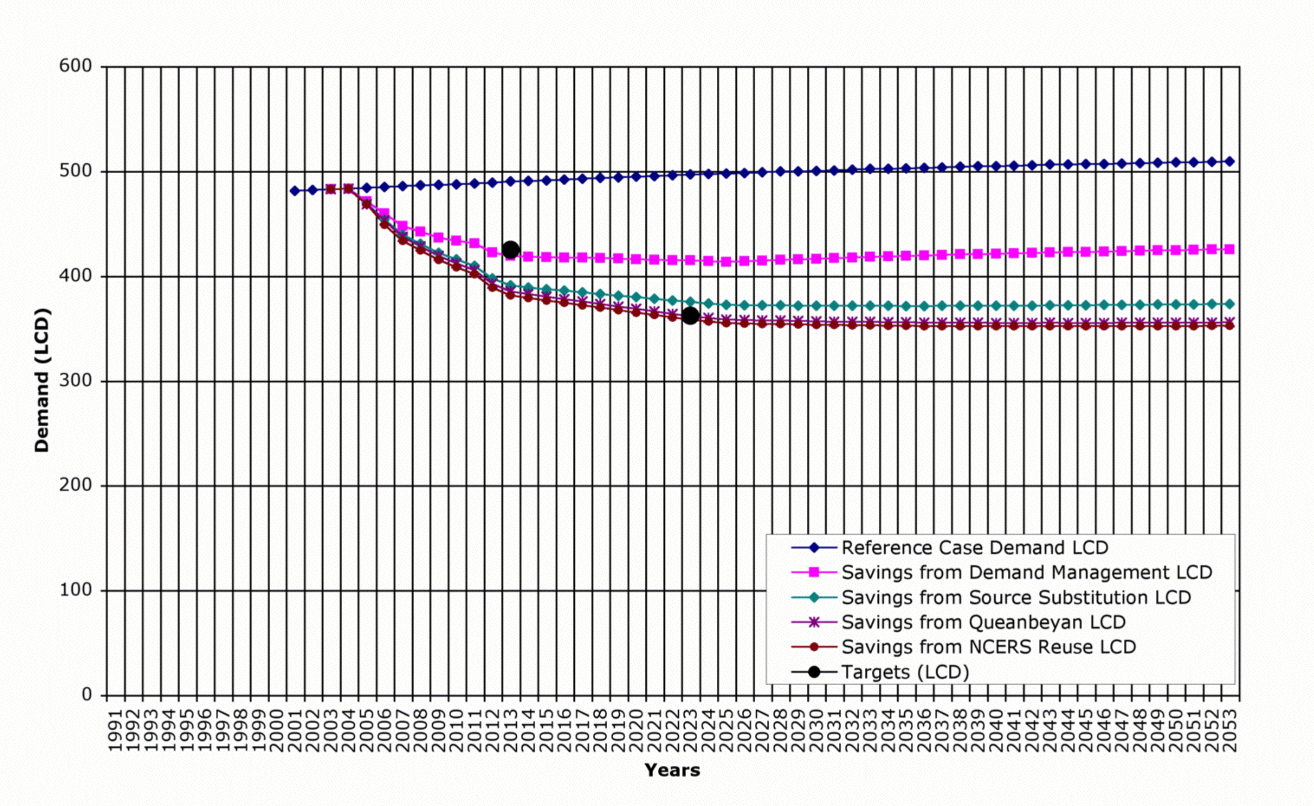


Figure 10 – Predicted Savings in Per Capita Demand[43]

Modelling to date has assumed that this demand reduction will be achieved linearly between 2003 and 2023. However, the demand reduction resulting from PWCM is expected to be higher than the calculated linear value for 2006. Future modelling will take this into account by applying an 8% demand reduction in 2006.

It is difficult to accurately measure demand reduction in a particular year because demand fluctuates greatly according to season and weather. Climate change may also lead to increased demand and should be taken into account when estimating reductions. In order to measure demand reduction, an estimate of the demand that would have occurred had reduction measures not been applied is required. The demand model described in section 8.1 is very suitable for this purpose.

ActewAGL have interpreted the demand reduction targets as meaning that the measured per capita consumption in (say) 2013 will be compared to the predicted consumption for 2013, and should be 12% lower than predicted. This detailed definition has yet to be formally agreed. However, this method will not be valid if water restrictions apply during the period of observed data, and it will be difficult to accurately determine demand reduction (separate from water restrictions) during water restrictions events.

[43] Figure taken from *ACT Water Strategy: Preliminary Demand Management and Least Cost Planning Assessment*, Institute for Sustainable Futures, October 2003

8.3 Early 1990s Demand Reduction

ACT per-capita water demand underwent a step reduction after 1992. Consumption rates since 1992 have been consistently about 24% less than those observed for pre-1992 consumption. Figure 11 shows the changes in consumption that occurred in 1992 and in 2003 when water restrictions commenced.

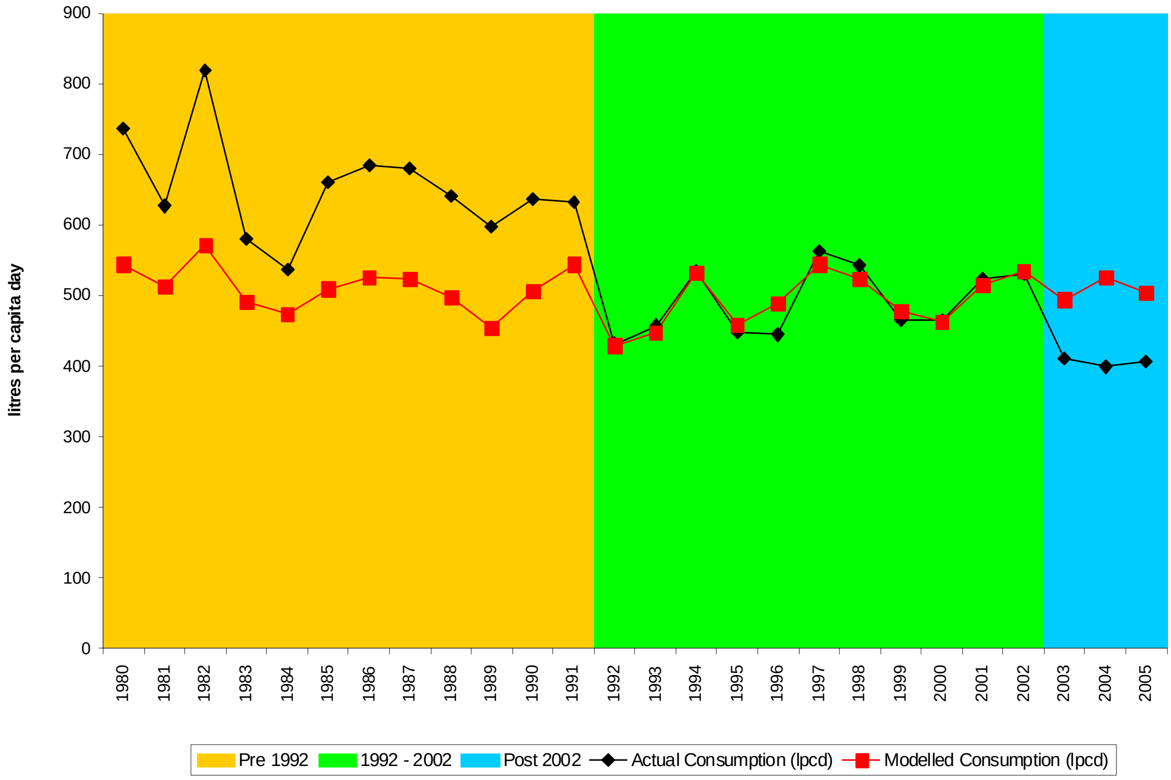


Figure 11 – Changes in Consumption Over Time

8.4 Demand Reduction After Drought

Water consumption after a drought is typically lower, at least in the short term, than before the drought. This occurs through a variety of reasons, including:

- The community learns to conserve water during a drought, partly as a result of education, advertisement and/or water restrictions. Water conservation habits are maintained after the end of the drought.
- The drought may lead to the loss of gardens with high water demand. Watering of these gardens is therefore not required after the drought.
- Water conservation measures, such as those listed in section 8.2, are often introduced during the drought, and continue to reduce water consumption in the long term.

8.5 Permanent Water Conservation Measures

Permanent Water Conservation Measures (PWCM) were recently introduced in Canberra and Queanbeyan. The aspect of PWCM that will have the most significant impact on consumption is limiting sprinkler and other irrigation systems to the hours of 6 pm to 9 am, except during winter. This measure encourages garden watering in the morning or evening when absorption rates are higher than the middle of the day. The intent behind PWCM is to discourage inefficient water use through means that should cause very little inconvenience to the community. The consumption reduction gains through PWCM are unlikely to be achieved as a result of the measures alone and require continuing community education and promotion of water conservation. For example, there is enough time overnight to irrigate gardens with far more water than they require.

It is estimated that PWCM will result in a reduction of approximately 8% in annual per capita water use[44]. Currently, the consumption reduction during PWCM is estimated at about 15%[45]. However, there are several reasons why the consumption reduction may not be maintained permanently at this level:

- PWCM have been applied after a severe drought. Awareness of water conservation is at a very high level and many gardens that require high water use were adversely affected by the drought and have not been re-established (see sections 8.3 and 8.4).
- Many users may be maintaining habits established during the water restrictions scheme such as only watering every second day.
- PWCM have applied during a hot, dry summer, when unconstrained demand is very high and the ability to reduce demand is therefore also high.

8.6 Water Restrictions

8.6.1 Water Restrictions Scheme

A new water restrictions scheme is currently under review by Government. It proposes that the number of stages be reduced from five to four, in order to simplify the scheme and reduce the similarity between Permanent Water Conservation Measures and Stage 1 restrictions[46]. Calculation of Demand Reductions During Water Restrictions

Until the recent drought there has been very little information on how much consumption is reduced by water restrictions. A sufficiently accurate model for calculating unrestricted demand, which is necessary to calculate demand reduction, has also only recently been developed as part of the Future Water Options project (see section 8.1). This model replaces a previous model which was less accurate, especially during low flow periods.

Modelling up to and including the Future Water Options project used estimates of demand reduction (also used as targets in the Water Restrictions Scheme) that proved optimistic when compared to observed values. Observed values of reduction during each restriction level have been calculated and adjusted to produce annualised values. The observed demand reductions are now included in the model of Canberra's water supply system.

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[44] *Permanent Water Conservation Measures (PWCM) – Estimated Effectiveness and Methodology for Assessment*, ActewAGL, February 2006 (ActewAGL Document No. 254091)
[45] PWCM monthly report from Richard Barratt, ActewAGL, May 2006
[46] *Review of Water Restrictions Scheme*, ActewAGL, January 2006 (ActewAGL Document No. 254815)

8.6.2 Impact of Water Restrictions Scheme on Modelled System Performance

The trigger points and target consumption reductions for each level of restrictions can have a significant impact upon modelled system performance (eg. the time spent in restrictions). In the Future Water Options project, restrictions commenced at the minimum level required to maintain adequate security (keep 10 000 year minimum storage above 5%) or 45%, whichever was higher. For the current system, it was sufficient to commence restrictions at 45%. Table 7 shows the influence of changes in water restrictions schemes on system performance. The system modelled is the existing system with Cotter pump rate 95 ML/day and the Murrumbidgee only used in Stage 3 or worse restrictions. More water must be supplied from the Murrumbidgee to achieve a time in restrictions below 5%. The proposed new restrictions scheme considers the implications of changes to triggers on system performance and suggests improvements from the existing scheme.

Table 7 – Influence of Water Restrictions Scheme on Time Spent in Restrictions

Stochastic - Climate Change	Existing Triggers (Commence at 55%)	FWO 45% Triggers
Time in Existing Stage 1 or Worse	9.94%	5.43%
Time in Proposed Stage 2 or Worse	4.01%	2.50%
Time in Proposed Stage 3 or Worse	2.33%	1.63%
Time in Proposed Stage 4 or Worse	1.03%	0.87%
Time in Proposed Stage 5	0.36%	0.36%
Minimum Storage	17.79%	13.71%
Number of Times Harsher Restrictions are Introduced	1356	914
Number of Times Harsher Restrictions are Introduced Between Dec and May	1045	692
Number of Times Harsher Restrictions are Introduced Between Dec and March	713	475

8.7 Demand Hardening

Demand hardening occurs as demand is reduced, either as a result of the PWCM or other measures designed to achieve the ACT Government 25% reduction target. The term demand hardening means that water restrictions and other water conservation measures are less effective because water use practices have already been amended to avoid wasteful water use.

Demand is not predicted to significantly increase between now and 2023, as the 25% demand reduction target is greater than population growth between 2003 and 2023, even allowing for the high prediction with cross-border supply. However, the effectiveness of restrictions decreases as the unrestricted demand is reduced. This leads to slightly increased times in restriction with the same unrestricted demand, particularly for the higher levels of restriction.

Demand hardening has been included in all modelling by maintaining the percent reductions for each restriction level at constant rates while reducing the unrestricted consumption. It has also been included in the demand reduction targets listed in the proposed new water restrictions scheme, after accounting for the 8% reduction attributed to PWCM.

8.8 Conclusions

Permanent Water Conservation Measures will be included in future modelling of the Canberra water supply system, with a predicted demand reduction of 8%. The demand reduction will then be applied linearly between 8% in 2006 and the ACT Government target of 25% in 2023.

If ratified, future modelling should reflect the proposed new water restrictions scheme. It is noted that the FWO work was based on 45% triggers.

9 System Performance Criteria

9.1 Assessing Acceptable Water Supply Security

System performance criteria must be set in order to assess whether or not water supply systems are sufficient. Another term for system performance criteria is the level of service of the water supply system. The system performance criteria may be assessed using the output from a bulk water supply model. System performance criteria used by Australian water authorities typically concern ensuring that the system will not run out of water (primary criteria) or the frequency, duration and severity of water restrictions is acceptable (secondary criteria)[47].

System performance criteria should ideally represent the expectations of the serviced community. However, for Australian water authorities "it appears likely that the criteria have been adopted on the basis of acceptance of conventional practice"[48]. In order to reflect community expectations, the system performance criteria should be able to be explained to the general public and reflect the tradeoffs between meeting level of service requirements and environmental and economic costs. Subsequent to the FWO work by ACTEW, a paper prepared by the Water Services Association of Australia (WSAA) addresses these issues:

> *After a water utility has assessed its own risks, it is important that it works with the community to determine an appropriate level of service objective for a water supply system. This process inevitably involves tradeoffs between financial cost, environmental impact and the willingness of the community to accept restrictions on a periodic basis. Explaining these tradeoffs to the community has proven to be problematic in the past, not because the community does not understand them but more because the modelling used is complex and the terminology is technical in nature. Furthermore, levels of service are generally expressed in probabilities and probability theory is a concept that many people are not fully familiar with.* [49]

The objective of system performance criteria can be summarised as a trade off between the social, economic and environmental costs of supplying water and benefits of not restricting the water supply. This is shown in Figure 12, reproduced from the WSAA paper on this issue. However, determination of the costs of restricting supply is a difficult process and is subject to some uncertainty.

[47] *Review of the Performance Criteria in Sydney Catchment Authority's Operating Licence*, Prepared for IPART by SKM, July 2003
[48] *ibid*
[49] Peter Erlanger and Brad Neal, *Framework for Urban Water Resource Planning*, Water Services Association of Australia, Occasional Paper No. 14 – June 2005

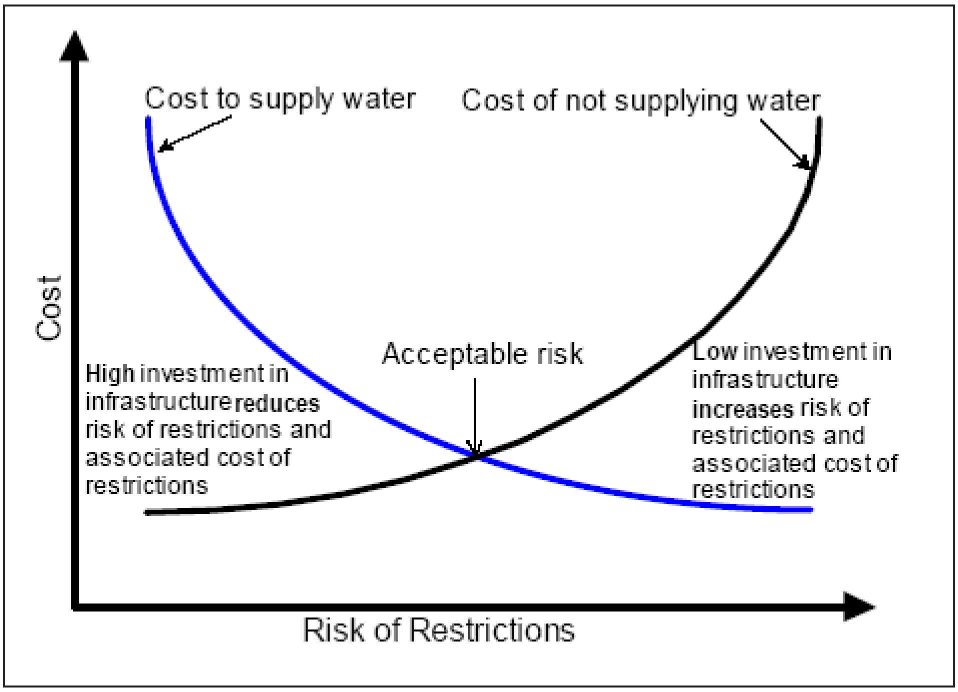

Figure 12 – Trade-off for Setting Level of Service Objectives[50]

9.2 Criteria Used for Acceptable System Performance

The following (failure) criteria have been used for measuring system performance of Canberra's water supply system in the FWO project.

- System Security:
  1. The system must not run empty during the 10 000 year stochastic data run (minimum storage must be greater than 5%).
- Frequency and Duration:
  2. Not more than 5% of the time should be spent in any level of restrictions (not including PWCM).
  3. Restriction events should not occur, on average, more than once every 10 years.
- Severity:
  4. Not more than 1% of the time should be spent in stage 3 restrictions.
  5. Stage 3 restrictions should not occur more than once every 25 years.

Criteria 2 and 4 are typically the critical measures for Canberra's water supply system.

Although criterion 2 is an amalgam of frequency and duration, there is no explicit consideration of the duration of restrictions events. While duration of events may be of concern to the community, it must be accepted that Canberra is prone to droughts that may last for several years. It is therefore difficult to design a water supply system for Canberra

[50] Figure reproduced from Peter Erlanger and Brad Neal, *Framework for Urban Water Resource Planning*, Water Services Association of Australia, Occasional Paper No. 14 – June 2005

that will not contain long water restrictions events unless the system is designed to almost eliminate water restrictions. The WSAA paper investigating levels of service notes:

> *Restrictions will be required from time to time in Australia because of the variability of rainfall, unless water supply systems are 'gold plated' through the construction of generous buffer supplies. Such buffers come at a high economic and environmental cost and are hard to justify when they may only be required once every 20 years. Some sectors of the community are however becoming dependent on a high level of reliability and are prepared to pay for it. This places additional stresses on the limited water resources but needs to be taken into consideration by water managers.*[51]

Measuring observed, rather than modelled, system performance against failure criteria is difficult, as climate variability often leads to long periods without water restrictions followed by droughts that may last for several years. For example, if 5 out of the next ten years are in water restrictions this does not mean that, in the long term, 50% of the time will be spent in restrictions because the next (say) 90 years may contain no restrictions events. Conversely, if there are no restrictions in the next ten years this does not indicate that the system meets performance criteria. Figure 13 demonstrates this by showing that there is a 45% chance of restrictions not being introduced in the next 20 years (the model was run in late 2005 with the first two months always in restrictions). However, there is only a 12.5% chance that restrictions will be reintroduced and last for a total of less than 1 year during the next 20. The model used to produce these results included climate change and the Murrumbidgee River (as a normal supply source) and commenced water restrictions at 45% of total storage.

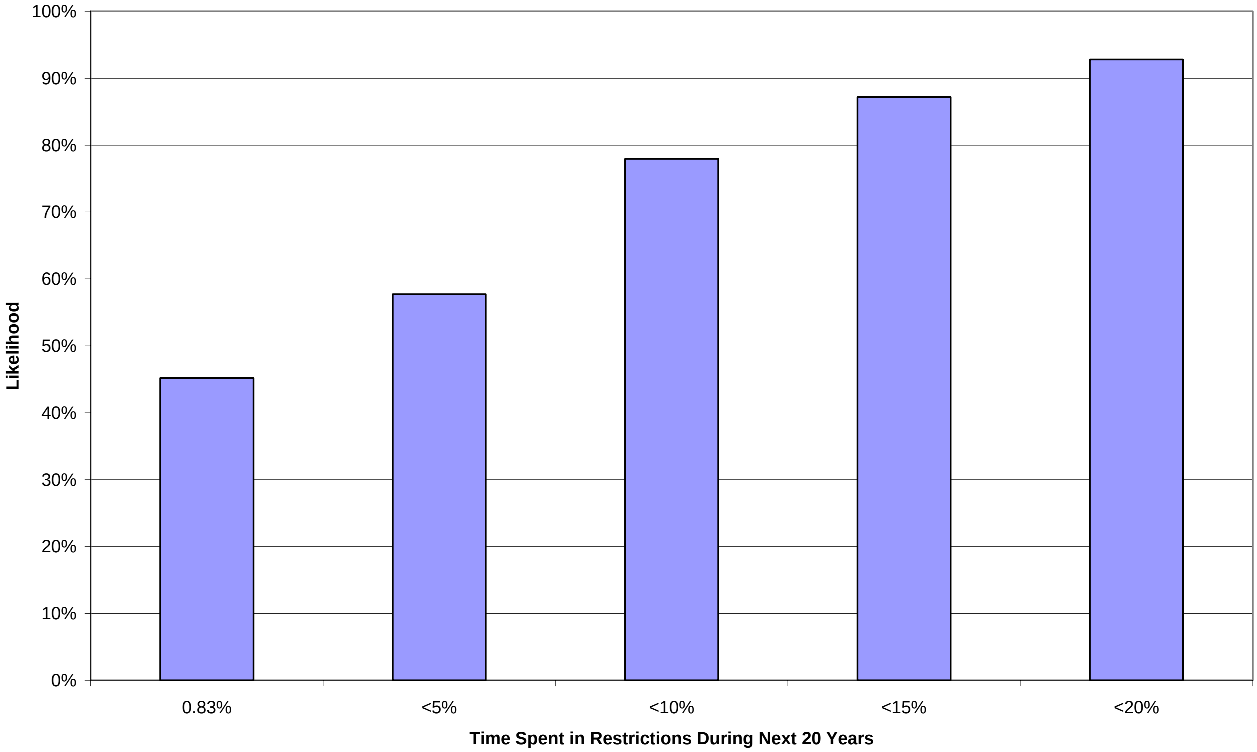

Figure 13 – Probability of Spending Time in Restrictions in Next 20 Years

[51] Peter Erlanger and Brad Neal, *Framework for Urban Water Resource Planning*, Water Services Association of Australia, Occasional Paper No. 14 – June 2005

9.3 Impact of Change in Criteria

The choice of system performance criteria can have a critical influence on the timing and/or type of augmentation required to achieve acceptable system performance. Table 8 shows the year when augmentation is required for acceptable times in restrictions ranging from 0% (never in 10000 years) to 20%. To simplify the illustration, it is only based on the trigger of total time in restrictions not considering severity of restrictions.

The model includes use from the Murrumbidgee River as a normal supply source. The table indicates that a performance criterion of 3% time in restrictions would require augmentation 24 years earlier than an acceptable level of 5% time in restrictions. This length of time is greatly increased by the 25% demand reduction that occurs during this period. The time in restrictions can also increase quite quickly, especially in stressed systems, as shown by the increase from 5% to 20% time in restrictions in 12 years.

Table 8 – Required Date of Augmentation, Relative to Acceptable Level of Time in Restrictions

Acceptable Performance Measure for Time in Restrictions	Required Date of Augmentation
0%	1970
1%	1989
3%	2001
5%	2025
10%	2030
15%	2034
20%	2037

9.4 Potential Changes to System Performance Criteria

System performance criteria should ideally represent the level of service that the community is prepared to accept and fund, i.e. a trade off between the cost of infrastructure and system performance. However, there are a several issues related to system performance criteria that should be considered:

- While Stage 1 restrictions are more onerous than Permanent Water Conservation Measures, with the introduction of PWCM the community is now always limited in how it can use water to some extent.
- Although “90% of Canberrans supported the idea of Permanent Water Conservation Measures” [52], some sections of the community are opposed to water restrictions. The community in general, finds water restrictions particularly onerous when they last for significant periods of time or are severe in nature (such as Stage 3 restrictions). The introduction of this stage impacts significantly on private, government and industry assets.
- The percentage time in restrictions criterion is used by other Australian water authorities. - Barwon Water, Melbourne Water, Hunter Water and Gosford-Wyong Water all used 5% for this performance measure in 2004, and the Sydney

[52] *New Water Saving Measures for Canberra - Our New Norm*, ACTEW Corporation press release, 22nd March 2006

Catchment Authority uses 3%. However, none of these authorities included climate change in their models[53] but are looking to do so in the near future.

- As a rule of thumb, the climate change scenario modelled for Canberra trebles time spent in restrictions. If climate change hasn't occurred, or doesn't eventuate, or is less severe than the modelled climate change scenario, system performance will be significantly improved.

To assist in determining what is the best trade-off between the investment in infrastructure to reduce restrictions, and the acceptance of restrictions, will require a further economic study. Information gathered during the FWO projects to date will contribute to such a study to be undertaken, combined with further investigations, resulting in the sort of curve shown in Figure 12.

[53] *System Performance Criteria: Final Working Document*, ActewAGL, October 2004

10 Operating Rules

Choice of system operating rules can have significant impact on system performance (see section 12). Up to date, modelling used to determine timing of system failure or performance of system augmentations has maximised ability to meet system performance criteria without considering operating cost. This method is fit for purpose, as it will provide the date where the system can no longer meet performance criteria, regardless of operating rules. However, there are some drawbacks associated with this method:

- On most occasions, operating rules that maximise system performance will have little net benefit. It may be reasonable to slightly increase time in restrictions in order to save costs and greenhouse gas generated from pumping. As an illustrative example, in order to truly maximise system performance Lower Cotter Dam should be used as the first source of supply (it is the furthest downstream dam and the last chance to catch water before it leaves the system). However, Bendora Dam is used first because water can be sourced much more cheaply and efficiently from this source and because use of Lower Cotter when Bendora is full will lead to unnecessary spills over Bendora Dam.
- In certain circumstances, operating costs associated with maximising a stressed system could be higher than the cost of constructing a new supply.

As with the system performance criteria, information gathered during the FWO projects to date will enable an economic study of the optimum operating regime to be undertaken.

11 Planning Scenarios

11.1 Planning Scenario Identified in Future Water Options Project

The Future Water Options Project identified the "prudent planning scenario" made up of the following planning variables:

- Conservative 2030 climate change, applied as a step change so that the current conditions, as well as future scenarios, are modelled with climate change.
- Predicted bushfire yield reduction.
- Predicted high population growth and an allowance for additional cross-border supply.
- 12% reduction in potable demand by 2013 and 25% reduction in potable demand by 2023, as specified in *Think Water, Act Water*.
- Current environmental flows (originally *1999 Environmental Flow Guidelines*, revised to draft 2006 Environmental Flow Guidelines when these became available).
- The performance criteria listed in section 9.2.

This scenario was intended to provide prudency in the face of many uncertainties and allow for security of supply to be guaranteed. The selection of conservative planning parameters is appropriate given the long time period required before a new water source can be constructed and available. Selection of conservative parameters also mitigates the general uncertainty of water supply modelling and climate (eg. high population growth guards against the possibility of not achieving the 25% demand reduction target).

11.2 Potential Changes to Planning Scenario

Changes since the Future Water Options project do not justify major variations to this approach. Of the variables listed above, the following changes will be adopted or considered in future reviews:

- Update population to reflect most recent estimates of current ACT and Queanbeyan populations. This will have negligible impact upon system augmentation options or timing into the future.
- Update environmental releases to *2006 Environmental Flow Guidelines*. The final stages of the Future Water Options work used a preliminary draft version of these guidelines. Changes to the guidelines since this draft will have negligible impact upon augmentation options or timing.
- Include PWCM in demand reduction by applying an 8% reduction in 2006, a 25% reduction in 2023 and scaling linearly between these dates.
- Refining appropriate system performance criteria to better reflect an optimal the balance between investment in infrastructure and cost of restrictions;

12 Sensitivity of Planning Variables

Figure 14 shows the influence that each of the above planning variables has on time spent in all stages of restrictions. The graph is produced for the proposed augmentation option for Canberra, namely, the current system with Cotter pump station at 95 ML/day plus the Murrumbidgee River as a normal supply source. These results are applicable to either of the proposed Murrumbidgee extraction sites, as the model results from both augmentation options are sufficiently similar.

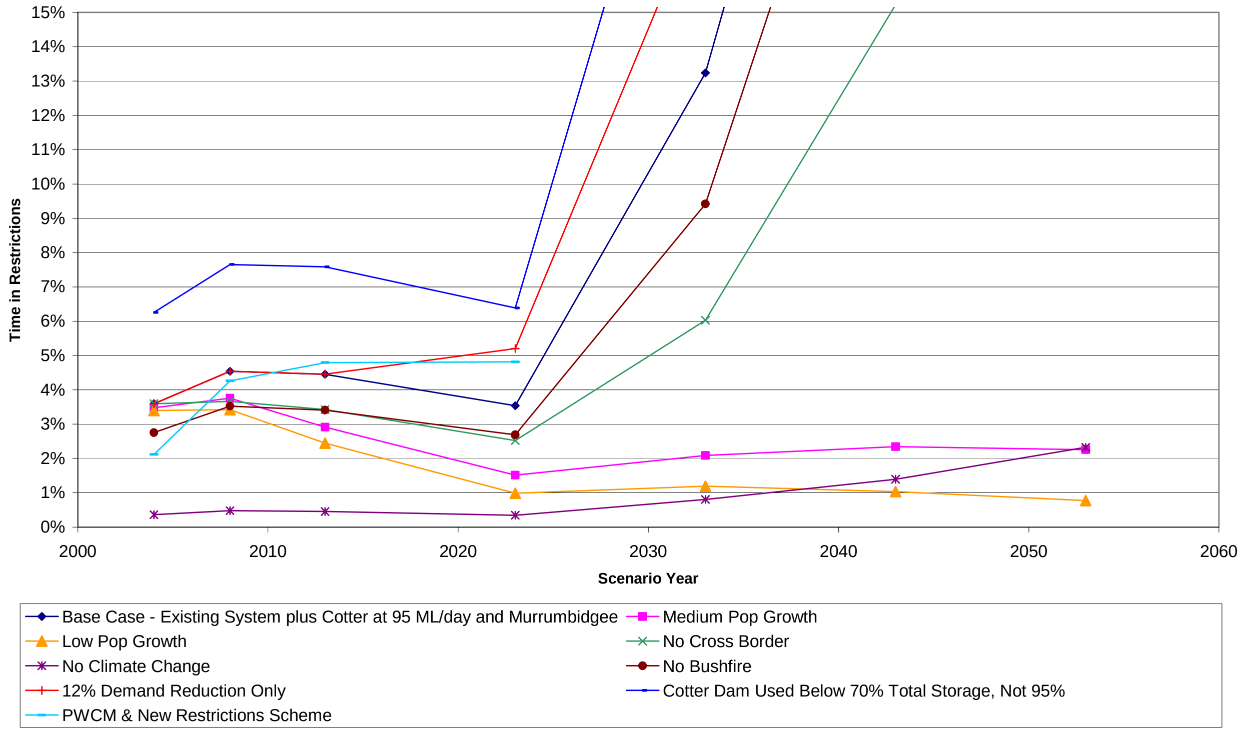

Figure 14 – Sensitivity of Planning Variables

The graph shows that, in the short term, assumptions relating to climate change and system operating rules have the largest impacts upon system performance. In the medium to long term, population growth has a very significant impact upon results. The graph also shows that if population growth is medium instead of high, the augmented system will be adequate until 2053. The system will also be adequate until 2053 if high population growth occurs without climate change. However, if high population growth and climate change occur, the system will be significantly stressed after 2023. This indicates that it is prudent to continually review developments in population and climate change and demonstrates that it is hard to plan for water supply security for planning horizons of more than about 20 years.

The sensitivity results are produced with the existing five stage restrictions scheme and without Permanent Water Conservation Measures (PWCM), with the onset of stage 1 restrictions determined by whatever storage is required to maintain adequate minimum storage over 10000 years. If PWCM and the proposed restrictions scheme are applied, without altering the onset of stage 1 restrictions, the results are not changed drastically from those produced using the alternative method.

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