WATER PLANNING

2009 REVIEW OF PLANNING VARIABLES FOR WATER SUPPLY AND DEMAND ASSESSMENT

A review of the changes in water resources modelling assumptions

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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
CIE	Centre for International Economics
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
EUM	End Use Model
FWO	Future Water Options
GCM	Global Climate Model
GEB	Gross Economic Benefit
GHG	Greenhouse Gas
GL	Gigalitre (1,000,000,000 litres)
ICRC	Independent Competition and Regulatory Comission (ACT)
IPART	Independent Pricing and Regulatory Tribunal (NSW)
ISF	Institute of Sustainable Futures (University of Technology Sydney)
L	Litre
L/c/d or lpcd	Litres per capita per day
LDA	Land Development Agency
LMWQCC	Lower Molonglo Water Quality Control Centre
m	Metre
ML	Megalitre (1,000,000 litres)
ML/day	Megalitres per day
mm	Millimetre
NEB	Net Economic Benefit
NSW	New South Wales
PWCM	Permanent Water Conservation Measures
SEACI	The South East Australia Climate Initiative (CSIRO, MDBC et al)
SKM	Sinclair Knight Mertz Pty Ltd
TAMS	The ACT Department of Territory and Municipal Services
UV	Ultraviolet Treatment
WELS	Water Efficient Labelling and Standards
WSAA	Water Services Association of Australia
WSUD	Water Sensitive Urban Design
WPP	Water Purification Plant
WTP	Water Treatment Plant

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1 Executive Summary

Planning Canberra's and the region's water supply requires extensive modelling of scenarios relating to water demand, water supply and infrastructure availability. The results of such modelling depend on the assumptions made by the modellers.

This document outlines the major assumptions made in undertaking water supply assessments and explains what changes have been made to the assumptions since the last review in 2008.

This document fulfils an ACTEW Corporation request that an outline of changes to underlying assumptions be provided by ActewAGL to ACTEW Corporation each year.

Six key planning variables underpin predictions relating to Canberra's water supply security. These are:

1. Climate variability and climate change;
2. The impact of bushfires on inflows into ACT reservoirs;
3. Population growth and the area to be serviced by ACTEW;
4. Reduction in per water consumption as required by the ACT Government;
5. Environmental flow requirements; and
6. Acceptable levels for the duration, frequency and severity of water restrictions during times of drought.

The assumptions related to each of these variables are discussed in this report as well as several variables that have a smaller impact on water supply.

Assumption changes

Four assumptions were altered during 2008-09. These were:

1. Population projections;
2. Cost of water restrictions;
3. Water restriction triggers; and
4. Murrumbidgee turbidity.

The impacts of these changes are described in context of other data in sections 4 and 8.

Additional Assumption reviews that did not lead to Changes

Four additional reviews of assumptions were undertaken during 2008-09. These were:

1. Environmental flows (still in progress);
2. Demand restrictions;
3. Bushfire model; and
4. Climate sciences.

These reviews are discussed in sections, 5, 6, 7 and 8.

Infrastructure and system changes

Infrastructure changes made since 2003 have increased the complexity of modelling used by ActewAGL, but have significantly improved the overall performance of the system. Additional improvements to infrastructure planned for the next five years — enlarged Cotter Dam, Murrumbidgee to Googong Pipeline and Pumping Station, Murrumbidgee Recirculation, Cotter Pump Station Upgrades and possible purchase of water from NSW — will further improve the water supply system, both in quantity and quality of water available and diversity of source. These future projects are being considered in current modelling.

Population growth

The Australian Bureau of Statistics (ABS) released new population projections for the ACT and surrounding areas in September 2008. The main differences between the current projections and the previous 2005 projections are that there is now a higher base population and higher projected population growth.

ABS provides three sets of population projections based on different assumptions — low, medium and high population projections. While the new population projections are now included in modelling, the substantive impact on short and medium term planning is not significant as ACTEW plans on the basis of high population projections and the lead times for major infrastructure and system changes are done well in advance. In addition, the largest consideration regarding future water supply is not population but climate change.

Climate variability and climate change

Climate change is the variable with the largest impact on ACT water supply security. However, it is also the variable that is hardest to predict. The best advice from CSIRO can still only produce wide ranges in future climate predictions. It is also possible that climate change could be outside this predicted range. Therefore, it is prudent in all water supply planning to use the ‘worst-case’ scenario.

One of the biggest concerns for ACTEW is that the current drought might represent a ‘step change’ in climate. That is, while concentrations of greenhouse gases in the atmosphere increase gradually over time, climate change itself may not be gradual but rather occur in steps. That would mean that the current low inflows are not part of normal climate variability but an apparent permanent change in climate.

While it is not definite that the current South-Eastern Australian dry period is caused by climate change, model results may significantly overestimate system performance if climate change is not incorporated in modelling assumptions.

Current modelling uses the 2003 CSIRO[1] most pessimistic predictions of annual change in rainfall and evaporation (9% decrease in rainfall and 9% increase in evaporation), scaled proportionally according to estimates provided for each season.

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

Climate assumptions are currently being reviewed and new assumptions will be tested and considered during 2010.

An on-going problem is developing a successful rainfall-runoff model for the ACT's largest reservoir, Googong Dam. In 2004 a rainfall-runoff model was developed. Although the model matched the overall historical record well, it significantly overestimated flows experienced in the recent drought years. Consequently, ActewAGL revised it in 2006/07. This revision reduced average Googong inflows by approximately 20 GL/year, and tended to underestimate Googong inflows in the period preceding the 15 year calibration period.[2] However, this model continues to overestimate flows in the current drought, although to a lesser extent than the 2004 model.

ActewAGL are investigating this phenomenon. Whilst it is a difficult problem, ActewAGL hope to get better assumptions for future Googong inflows. The outcomes of this project will be incorporated in future water resources modelling. Currently the 2006/07 method is in use.

Environmental flows

Since the publication of the *Environment ACT Environmental Flow Guidelines* (2006), environmental flows are not as great a source of uncertainty as they were during earlier work. However, changes in environmental flows can significantly influence system performance. The Environmental Flow Guidelines are due to be reviewed five years after publication and if changes occur, modelling assumption changes will also be required.[3]

The environmental flows associated with new major infrastructure projects have not yet been formally specified. In the interim, current modelling assumes that the existing environmental flow regimes will continue. Changes in the required flows from these sources could significantly influence water supply security.

Ongoing Bushfire impact

Bushfires can have significant impact upon water supply catchment behaviour. As catchments recover from bushfire it is estimated that the Cotter catchment's water yields may drop by up to 15% over a sustained length of time. Therefore, a range of modelling assumptions is made regarding water yields in catchments affected by bushfires. Climate uncertainty also needs to be taken into account, as it is likely that under CSIRO climate change scenarios bushfire intensity and frequency will increase. ActewAGL undertook or commissioned two studies on the frequency and impact of the bushfires in 2008-09, and one of these is to be completed in the second half of 2009. So far, no changes to the assumptions have been made as a result of this work.

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

[2] ActewAGL, *Update of Canberra Water Resources Model Assumptions: Change 1: Impact of Googong Inflow Review and Murrumbidgee Water Quality Rule* (ActewAGL Document No. 322706), October 2007
[3] Environment ACT, *2006 Environmental Flow Guidelines*, January 2006

Water Demand

A demand model is used to calculate monthly per capita water demand for Canberra and Queanbeyan, based on monthly Canberra Airport rainfall and evaporation data.[4] 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.

In addition, demand modelling attempts to take into account, through an "End Use Model": government measures and policies, 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;
- water restrictions; and
- ongoing pricing reforms.

All water resource modelling assumes that the ACT Government 25% reduction target is met by 2023. It also assumes that the reduction occurs linearly, starting at 8% pa in 2005.

System performance criteria

System performance criteria are used to determine whether existing or planned water supply systems provide an acceptable service to the community. This will give an indication of when water supply augmentation is required. A major component in managing system performance is to test whether the potential community cost of water restrictions is greater than the community cost of building new infrastructure. If it is, then it is appropriate to construct new infrastructure.

Since the last Assumptions Review, ActewAGL has updated the costs of water restrictions to the community. These are being included in new system performance criteria.

Two smaller changes have been made that affect the assumptions underpinning the operating rules of the system. These are;

- a more rigorous model for measuring turbidity in the Murrumbidgee River that better estimates the times when pumping from the Murrumbidgee is not possible, and;

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

- a change to the triggers used for removing water restrictions. This change will reduce the frequency of changes between water restriction levels.

Conclusion

Changes made to assumptions during 2008/09 have had a minor impact on existing projections of Canberra's future water security.. The greatest uncertainty remains the future ACT climate and while the current methods used by ActewAGL to assess future water needs are considered industry best practice, they are only as good as future climate estimates. ACTEW is keeping abreast of changes in climate estimates and water modelling will be continually updated as methods, and data improve.

2 Introduction

Assessments of water supply security require analysis of a multitude of variables relating to the current and future performance of the water supply system. The results of an assessment can be significantly altered according to the underlying assumptions made by the modellers. *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[5]:

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

Alterations have been made to these variables since the initial *Future Water Options* work in 2004/05. These changes have occurred through formal assumptions reviews or on an *ad hoc* basis because of changing circumstances or improved modelling techniques. This report discusses changes made since the 2008 *Review of Planning Variables*[6].

The methods used to analyse the water supply system are described in Section 3. Infrastructure has been described in Section 4 and planning assumption trends described in Sections 5 to 10.

The aim of this report is to review the assumptions involved in assessing water supply security and document changes in these assumptions.

[5] ACTEW, *Future Water Options for the ACT Region – Implementation Plan: A recommended strategy to increase the ACT's water supply*, April 2005
[6] ACTEW, *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*, June 2006

3 Types of analyses

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 using historical weather data.

Historical analysis can provide an 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, it does not consider climate change and, secondly, it is inevitable that some future events more severe than those experienced during the period of record will occur, regardless s of the influence of climate change. For these reasons historical record data analysis is not ideal for assessing system performance, but is still used upon request.

Stochastic analysis

Stochastic data is data generated using numerical methods that are designed to produce data sequences that obey the statistical properties of an existing data set — in this case the historical data. The stochastic analysis used by ActewAGL examines system performance using 10,000 years of stochastic data. By using a large quantity of stochastic data, worse droughts than those historically experienced, but which could still be expected to occur can be modelled.

The stochastic analysis may be run with or without a step change to 2030 or 2070 climate. The climate change data are created by altering rainfall and evaporation by climate change factors developed by the CSIRO for Canberra.

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. However, the preferred method is to break the stochastic data into replicates and produce a range of forecast system behaviour for the coming period. The main advantages of this method are that:

- the initial conditions (current storage at time of model run) can be included;
- the timing of infrastructure augmentations can be included in the model; and
- the model predicts future parameters (e.g. storage, restriction level, amount of water supplied from each source), albeit as a range of possible answers.

The stochastic data method does not predict what will happen to the system during the next 10,000 years but indicates probabilistically how the system may perform with current or predicted future conditions under a wide range of weather conditions. Key statistical results that may be extracted include a time series of the probability of each stage of restrictions occurring and the likelihood of reaching various storage levels. These results can be compared against agreed reliability criteria to assess system performance.

4 Infrastructure and System Changes

Infrastructure and system additions from 2003

The following infrastructure changes have been made to the water supply system since 2003. These changes, while increasing the complexity of modelling have improved the overall performance of the system:

- **Cotter Dam** — The existing Cotter Dam has been reinstated as part of Canberra's water supply system. Four pumps have been recommissioned at Cotter pump station to enable supply of Cotter Dam and Murrumbidgee River water.
- **Cotter to Googong Bulk Transfer (CGBT)** — The system has been redesigned to allow treated water from the Cotter system to be transferred into Googong Dam via the bulk supply network. Water can now be transferred from the Cotter River or Murrumbidgee River to Googong (as well as directly to Canberra) 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.
- **Murrumbidgee Pump Station** — A new pump station has been installed to pump water from the Murrumbidgee to the Cotter pump station and then on to Mount Stromlo WTP. The Murrumbidgee was first used for supply in May 2007. This supply can be used more extensively under a wider range of water quality conditions since the installation of ultraviolet (UV) treatment facilities at Mount Stromlo WTP.
- **Mount Stromlo Water Treatment Plant Upgrade** — A new water treatment plant has been built at Mount Stromlo capable of treating approximately 250 ML/day.
- **Googong Water Treatment Plant Upgrade** — The Googong treatment plant has been upgraded to be capable of supplying 270 ML/day.
- **UV Installation at Mount Stromlo** — Ultraviolet treatment has been installed and commissioned at Mount Stromlo. This enables the treatment of a wider range of water qualities, and is particularly valuable when supplying Murrumbidgee water.

Planned additions

Projects planned for the water supply system are:

- **Enlarged Cotter Dam** — A larger dam of approximately 78 GL will be built at the site of the existing Cotter Dam. It is expected that this project will be completed by 2012.
- **Murrumbidgee to Googong** — A pump station and pipeline will be built to supply Murrumbidgee River water into Googong Dam. The planned pipeline route is from Angle Crossing, discharging into Burra Creek. The capacity of the pipeline will be approximately 100 ML/day. It is estimated to be completed by mid 2011.
- **Murrumbidgee Recirculation** — The baseflow component of the environmental flow from Cotter Dam will be supplied using Murrumbidgee River water. This reduces the need to release water from the dam.
- **Murrumbidgee at Cotter** — A second pump station will be installed on the Murrumbidgee River to increase the supply capacity to town, as well as supply the

environmental flow from Cotter Dam. A balancing tank will also be built to significantly increase the supply capacity from this source and provide improved operational flexibility.

- **Cotter Pump Station** — A new Cotter Pump Station will be built, scheduled for completion by 2012. The new pump station will increase the supply capacity from Cotter Dam and the Murrumbidgee River, provide improved pumping efficiency when the Enlarged Cotter Dam fills and improve the reliability of supply from the Cotter.
- **Other** — ACTEW is also pursuing various other water supply augmentation measures, including considering purchasing water from irrigators and storing it in Tantangara Dam.

5 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.

A range of other factors may influence demand, including demand management programs and changes in demography and housing type. These are considered later in this document.

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.

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 2009[7] and the Australian Bureau of Statistics (ABS) releases high, medium and low growth projections from time to time, most recently in September 2008[8]. The ABS also provides regular updates of ACT Estimated Resident Population[9]. This estimate was revised upwards after analysis of the 2006 Census data. The ABS also backdated earlier population figures for the ACT and Queanbeyan to match the 2006 Census data[10].

There are significant differences between the November 2005 and the September 2008 projections. These differences arise through a higher base level population and higher projections for population growth. There are two major changes to the ABS assumptions. Firstly, the method of calculating the Net Overseas Migration has been improved which has resulted in higher levels of migration. The low level of Net Overseas Migration (NOM) in the 2008 projections is the same as the high level in the 2005 projections. Secondly, the observed fertility rate has increased Australia-wide.

These changes have the effect of increasing the projected population in all three of the ABS released projections. Significantly for the ACT, the medium growth projection no longer reaches a peak before 2056. The population peak for the low growth projection also does not occur until 2044 some 30 years after the 2005 projected peak occurs. Figure 1 compares the population projections from 2008 with the projections from 2005.

[7] ACT Chief Minister's Department, *ACT Population Projections, 2007 to 2056,* June 2009 (http://www.cmd.act.gov.au/__data/assets/pdf_file/0012/3360/ACT_population_projections_2007_2056.pdf),

[8] Australian Bureau of Statistics, *3222.0 - Population Projections, Australia, 2006 to 2101*, 4th September 2008

[9] Australian Bureau of Statistics, *3101.0 - Australian Demographic Statistics* (http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0), latest version released 19th March 2008

[10] Australian Bureau of Statistics, *3218.0 Regional Population Growth, Australia* (http://www.ausstats.abs.gov.au/Ausstats/subscriber.nsf/0/A202921AA9EFDA9DCA257367008042CC/$File/32180_statistical_local_areas_96to06.xls), 2nd October 2007

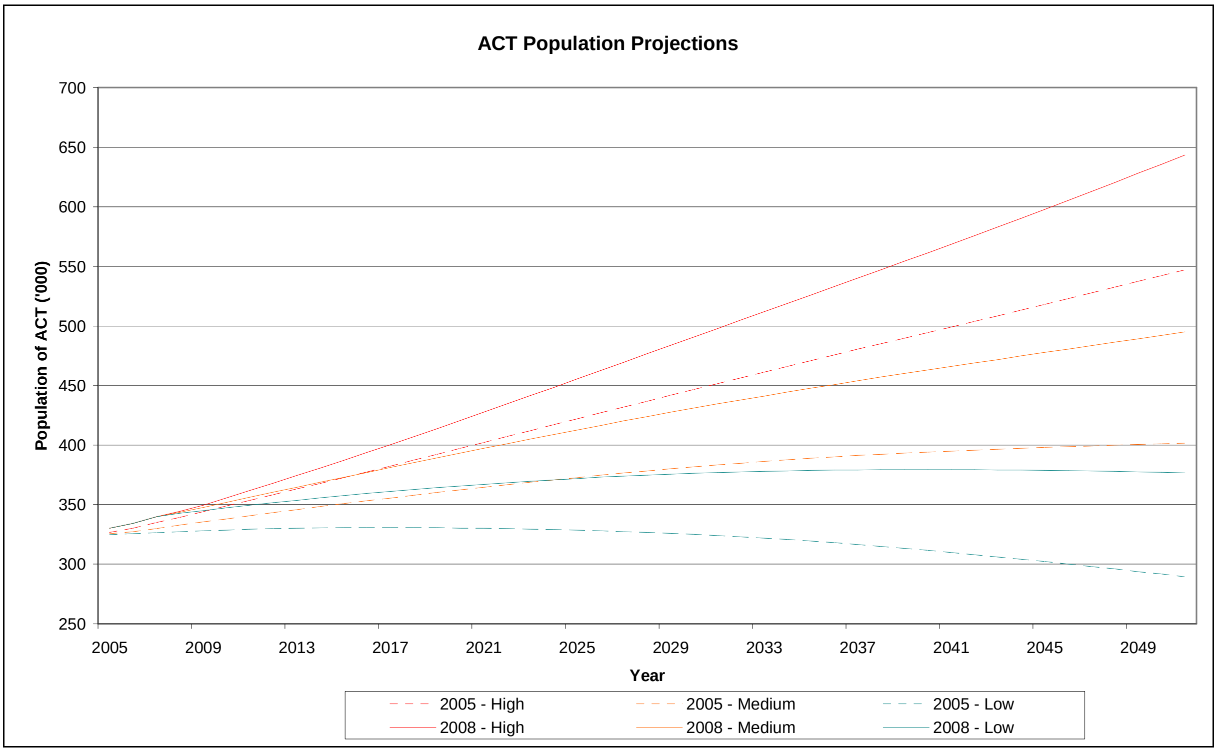

Figure 1: Comparison between 2005 and 2008 population projections

The relationship between ACT growth and Queanbeyan growth is assessed 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 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"[11]. The ACT Government's *Think water, act water* strategy prescribes the use of high population growth projections. It states 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."[12]

Additional cross-border supply

The inclusion of regional supply and specifically of Yass in future water supply planning is recommended in *Think water, act water*[13]. All modelling studies to date have included an allowance for new cross-border supply to neighbouring towns such as Yass, Goulburn, Murrumbateman, Bungendore, Collector, Sutton and Gunning.

[11] ACT Planning and Land Authority, *The Canberra Spatial Plan*, March 2004
[12] ACT Government, *Think Water, Act Water: Volume 1: Strategy for sustainable water resource management in the ACT*, April 2004
[13] ACT Government, *Think Water, Act Water: Volume 1: Strategy for sustainable water resource management in the ACT*, April 2004

In the Future Water Options Review (July 2007) the assumptions are:

- An additional population of 5,000 by January Yr. 2008; and
- A constant annual increase of 600 per year thereafter (i.e. reach 18,200 by Yr. 2030).

Since these modelling studies were run, the likelihood of supplying to neighbouring regions in the near future has decreased. In the short term, Yass Valley Council intends to increase the capacity of Yass Dam instead of obtaining water from the ACT[14]. Goulburn's supply will be augmented by a pipeline linking Wingecarribee Reservoir to the Goulburn Water Treatment Plant[15]. Other villages are currently too small to justify cross-border supply in their own right. The Australian Defence Force Joint Operations Command, which is located between Queanbeyan and Bungendore, employs approximately 1000 staff. It is self-sufficient in water supply and includes water and sewerage treatment plants.[16]

It is possible that water could be supplied from the ACT to surrounding areas of NSW in the future, with Yass via Murrumbateman the most likely pipeline route. Modelling currently assumes that Yass and Murrumbateman will be supplied from 2015, and that there will be no other new cross-border supply. This finding will be reviewed annually in this report and whenever developments in regional water supply planning occur.

For water supply modelling purposes, it is assumed that the population served in Yass and Murrumbateman is:

- zero until 2015; and
- then 1.6% of the Canberra-Queanbeyan population thereafter.

It is also assumed that the cross-border per capita consumption is equivalent to the ACT's.

The volume of water that would potentially be supplied is likely to be quite small relative to Canberra's demand, and would therefore have little impact on catchment resources. The cross-border supply assumptions are not critical because by the time it is required the additional population supplied is likely to be less than the error in the population projection for Canberra and Queanbeyan.

Proposed future population projections

Where modelling requires an estimate of future population, the most recent ABS population projections for the ACT are used (last issued in September 2008). These projections provide high, medium and low growth data (Series A, Series B and Series C). Because there is a long lead time to construct water supply infrastructure, it is prudent to plan for high population growth. However, all three of these projections are used in sensitivity analyses, and in some modelling exercises (e.g. demand forecasts) the medium growth projection is used.

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[14] Yass Valley Council, Water Supply Strategy, http://yassvalley.local-e.nsw.gov.au/roads/1932/2202.html, Retrieved 11 June 2009

[15] Goulburn Mulwaree Council, 'Goulburn Mulwaree Council unanimously secure City's Water Supply to 2040' (http://www.goulburn.nsw.gov.au/news/pages/8908/NewsDoc/Highlands_Source_Project.pdf). media release, 18th March 2009

[16] URS & Australian Government Department of Defence, *Supplementary Report to the Draft EIS: Headquarters Australian Theatre now known as Defence Headquarters Joint Operations Command (HQJOC)*, Section 13: Water Management, May 2005

Demand projections used in water supply modelling include Queanbeyan and bring the projection up to date with the most recent population data. This is achieved by applying the growth rates from the population projections series to the initial recorded Canberra and Queanbeyan population. For example:

> 2009 Canberra and Queanbeyan high population projection = 2007 Recorded Canberra and Queanbeyan population x 2009 ACT Series A value / 2007 ACT Series A Value
> = (349 865 + 38 694) x 349.6 / 339.8
> = 389 674

Potential developments in the Tralee and Googong regions of NSW are included in the combined projections for Canberra and Queanbeyan. An additional population, equivalent to 1.6% of the Canberra-Queanbeyan population, has been applied from 2015 onwards to account for possible supply to Yass, Murrumbateman and surrounding villages.

The complete population forecasts are shown in Figure 2 and Table 1.

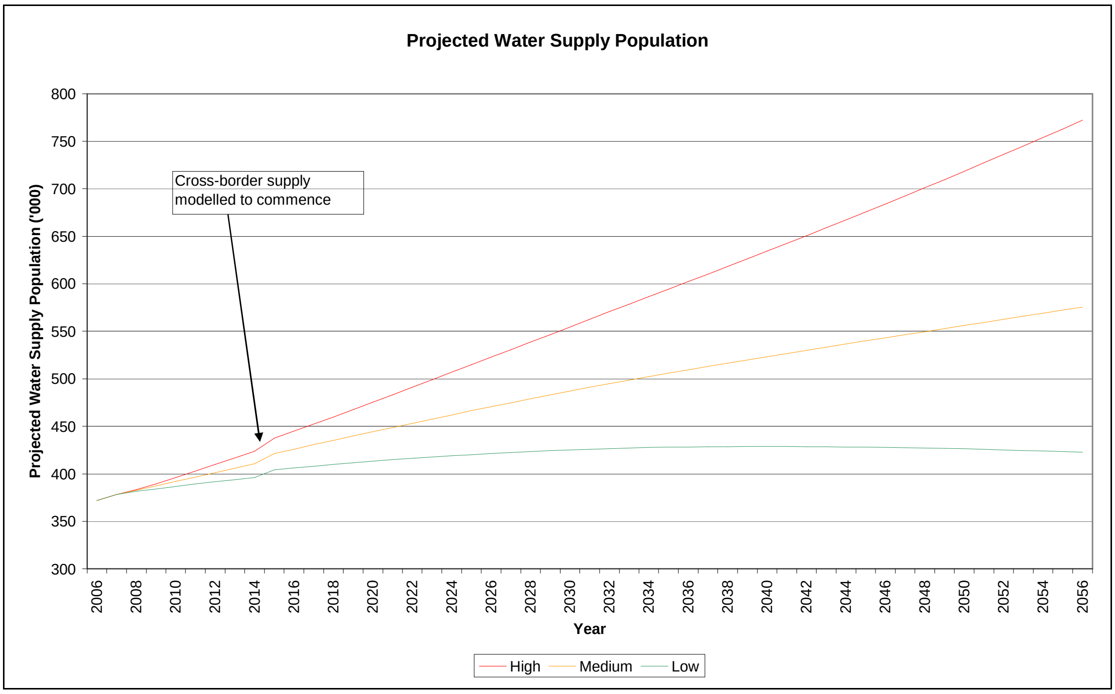

Figure 2 – ACT and Queanbeyan Projected Population

A significant issue with the low projection is that is has 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.

The range of future populations is extremely large. By 2023, the high population projection is 499,000, while the low projection is 418,000.

Table 1 – Forecast Water Supply Population

Year	Adopted Water Supply Population Series		
	High	Medium	Low
2008	383453	382785	381560
2009	389243	387239	384121
2010	396034	391915	386793
2011	402826	396591	389243
2012	409840	401267	391581
2013	416855	405944	393808
2014	423869	410508	396034
2015	437573	421412	404122
2016	444918	426046	406156
2017	452490	430679	408077
2018	459949	435313	409999
2019	467633	439833	411694
2020	475318	444353	413389
2021	483116	448874	414858
2022	491026	453281	416327
2023	498937	457689	417683
2024	506848	462096	419039
2025	514758	466390	420282
2026	522669	470685	421525
2027	530693	474866	422543
2028	538716	479047	423560
2029	546627	483116	424464
2030	554651	487071	425255
2031	562561	491026	426046
2032	570585	494869	426611
2033	578496	498598	427176
2034	586406	502327	427628
2035	594430	505944	427967
2036	602341	509447	428306
2037	610251	512950	428532
2038	618275	516453	428645
2039	626299	519844	428758
2040	634435	523234	428758
2041	642459	526624	428758
2042	650709	529902	428645
2043	658958	533179	428532
2044	667208	536569	428306
2045	675571	539846	428080
2046	684047	543124	427741
2047	692522	546401	427515
2048	701111	549678	427063
2049	709813	552843	426724
2050	718514	556120	426272

How recent growth compares to projected growth

Figure 3 compares the ACT population growth observed in recent years[17] with projected growth.[18] In each financial year since 2006-07, the observed growth has exceeded the Series A high population growth forecast. However, it is still reasonable to presume that the high population growth forecast provides a conservative estimate for water supply security purposes because:

- the discrepancy between observed growth and projected high growth is small;
- the high population growth forecast contains sustained high growth throughout the projection length, while the observed high growth has only occurred for a few years;
- this projection uses the most recent available population projection information; and
- the projections exceed the *Canberra Spatial Plan* high and medium population forecasts for 2032 Canberra-Queanbeyan population (562 000 compared to 500 000, 480 000 compared to 430 000).

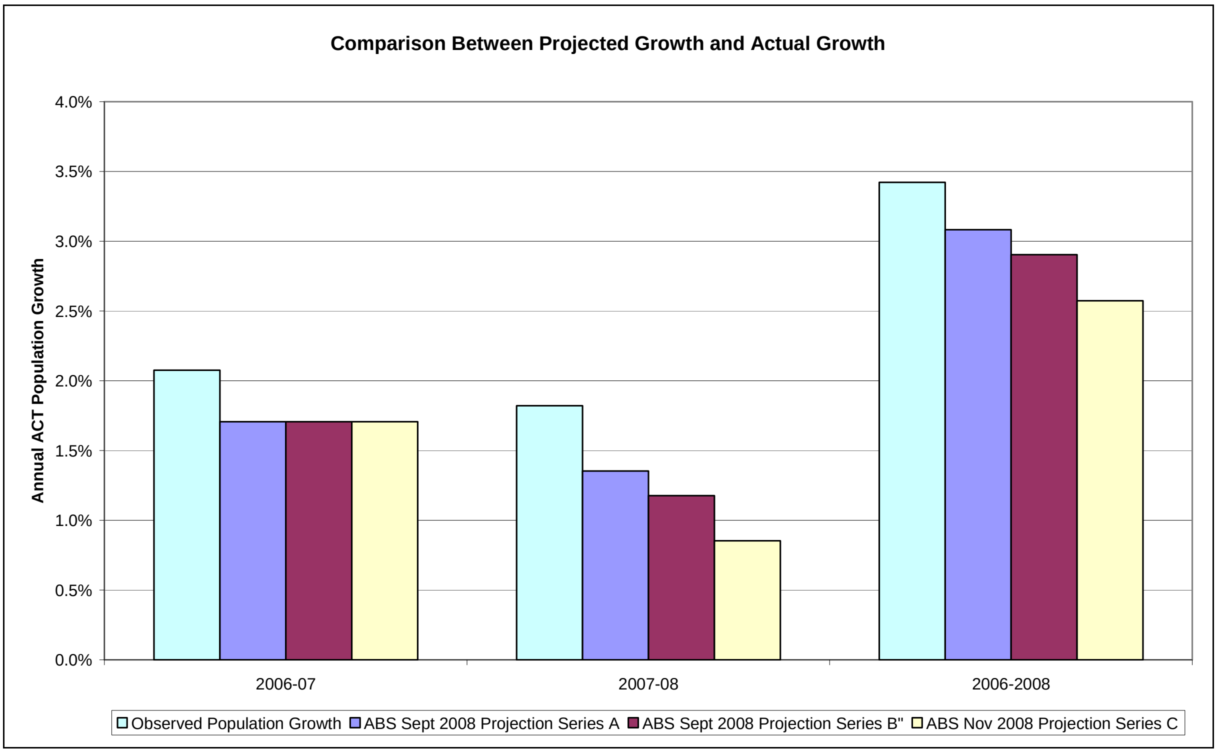

Figure 3 – Recent Population Growth Compared to Projected Growth

Population forecasts for the ACT have historically tended to overestimate consumption. For example, a 1968 report investigating the location and timing of the fourth ACT water storage (Googong Dam), gives the most likely 2002 ACT population as around 800 000[19]. This demonstrates both the potential error in all population forecasts and the need to consider possible future trends when compiling population projections.

[17] Australian Bureau of Statistics, *3101.0 - Australian Demographic Statistics* (http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0), latest version released 19th March 2008
[18] Australian Bureau of Statistics, *3222.0 - Population Projections, Australia, 2006 to 2101*, 4th September 2008
[19] *Canberra Water Supply Augmentation*, Commonwealth Department of Works for and on behalf of The National Capital Development Commission, May 1968

ACT population projections from 1992 again significantly overestimated population growth, predicting a 2002 medium growth population of 378 067 and low growth population of 366 981.[20] These projections assumed that growth would remain around 2.5% per year, whereas growth actually fell to below 1% per annum during these years.

These projections overestimated future growth because they failed to foresee significant drops in population. However, a significant rise in population growth could also significantly affect the accuracy of future population projections.

Conclusions

A high population projection remains the prudent approach for water supply planning. Planning considers the implications of multiple population growth scenarios, especially when population forecasts are required for dates well into the future. The uncertainty around population estimates increases markedly with time, so population estimates are more likely to cause errors in long term planning rather than short term. A small allowance for cross-border supply is currently included in future population estimates.

[20] *ACT Population and Employment Forecasts*, ACT Economic Development Division, Policy and Research Branch, February 1992

6 Climate Variability and Climate Change

It is widely accepted that global warming is occurring. Paleoclimatic studies confirm that the increases in global temperature observed since the mid-20th century is unusual. It is considered "very likely" that this warming has been caused by anthropogenic emissions of greenhouse gases.[21] This may mean that the ACT historic climate record no longer adequately represents current or future climate.

The CSIRO states:

> *The average surface air temperature of Australia increased by 0.7℃ over the past century – warming that has been accompanied by marked declines in regional precipitation, particularly along the east and west coasts of the continent. These seemingly small changes have already had widespread consequences for Australia. Unfortunately, even if all GHG emissions ceased today, the earth would still be committed to an additional warming of 0.2–1.0℃ by the end of the century.*
>
> *Yet the momentum of the world's fossil fuel economy precludes the elimination of GHG emissions over the near-term, and thus future global warming is likely to be well above 1℃. Analysis of future emissions trajectories indicates that, left unchecked, human GHG emissions will increase several fold over the 21st Century. As a consequence, Australia's annual average temperatures are projected to increase 0.4–2.0℃ above 1990 levels by the year 2030, and 1–6℃ by 2070. Average precipitation in s outhwest and southeast Australia is projected to decline further in future decades…*[22]

Responsible water supply planning must consider the potentially considerable impact of climate change. Climate change is the variable with the largest impact on ACT water supply security.[23] 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. Therefore, it is prudent to include climate change when planning for future water needs.

Climate variability

Climate variability is the natural variation of climate observed over time; it includes the familiar seasonal variations, and the less familiar longer-term variations that climate experts are yet to fully understand. Australia's climate is highly variable in comparison with other countries; this is largely due to large scale and long time frame natural events such as the Pacific Decadal Oscillation, Inter-decadal Pacific Oscillation, and El Nino Southern Oscillation.

ACT has only 137 years of recorded *historic climate* data. Although this period of historic record covers three major droughts, including the one at present, the ACT can reasonably expect to experience more frequent or more severe wet or dry periods in the future than have been recorded to date. To address this possibility, ActewAGL 'extended' its historic climate record by

[21] Intergovernmental Panel on Climate Change, *Fourth Assessment Report*, 2007
[22] Preston, B.L. and Jones, R.N ., *Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions*, CSIRO, February 2006
[23] ACTEW, *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*, June 2006

using a standard hydrological methodology to create a longer period of stochastic climate data ad described in Section 2.[24] The generated stochastic climate data is referred to as the *1990 stochastic climate* scenario.

Step change in climate

Whilst global warming progresses proportionally to the build up of greenhouse gases in the atmosphere, it can result in rapid 'step' climate changes in a particular region.

It is possible that the recent drought represents a shift in climate for Canberra. The past 5 to 10 years are clearly the most severe long-term dry period in the 1871 to present extended historic record inflow sequence. 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 also lower than the average inflows generated with 2030 stochastic data (88 GL/year compared to 105 GL/year). On average, a five-year period worse than the last five years would occur once every 19 years in the stochastic data. 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.* [25]

This drought has the lowest inflows over a long-term period. 2006 produced the third lowest inflows of any year on record, behind 1901 and 1982. However, the 1910s and 1940s also contain long-term droughts where average inflow is only a little higher than the current period. Figure 4 shows the 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.

[24] Sinclair Knight Merz, *Update of Water Resources Strategy for Canberra and Queanbeyan* (ACTEW Corp. Doc. No. 3959), July 2004
[25] Bates et al., *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003

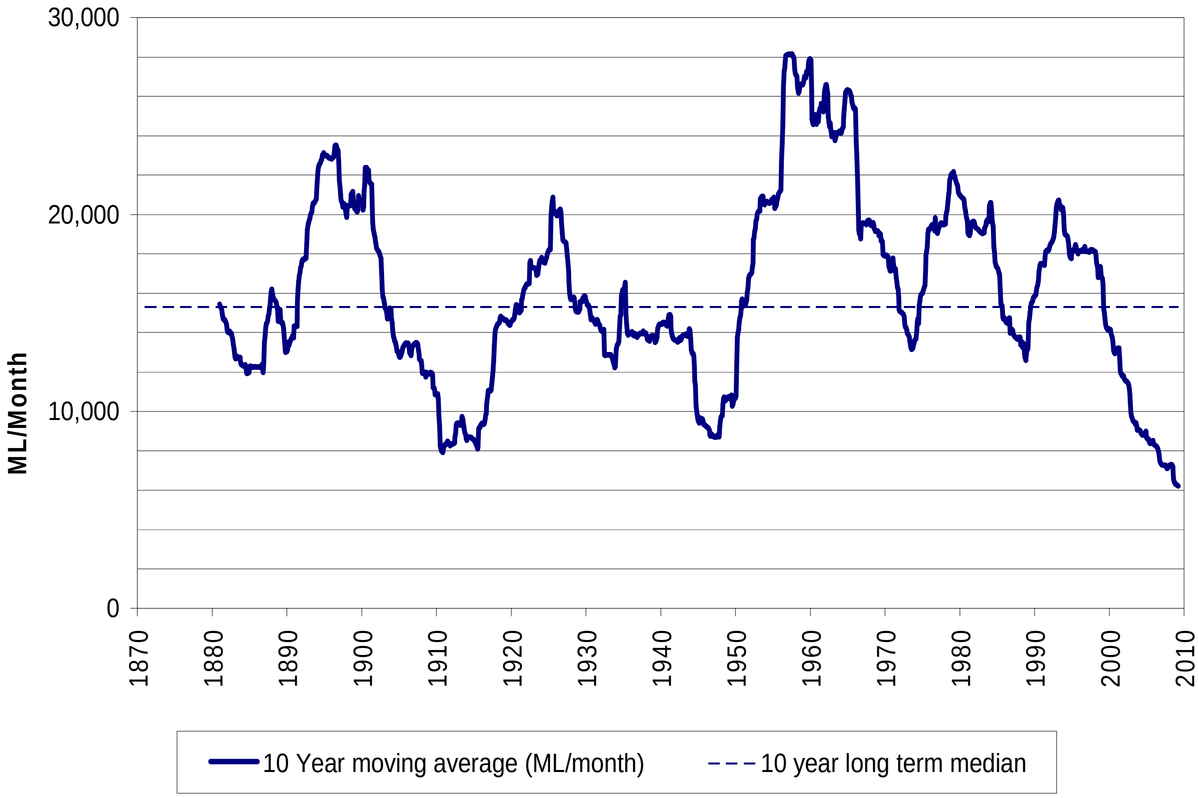

Figure 4 – Moving Average Inflows to Corin, Bendora and Googong Dams

While it is not definite that the current south-eastern Australian dry period is caused by climate change, model results will significantly overestimate system performance if climate change is not included in modelling. It is prudent to include climate change in modelling current system performance as well as future projections. This approach is consistent with the advice provided by the CSIRO:

> *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.* [26]

Climate change predictions used in current modelling

Climate change predictions for the ACT were obtained from the CSIRO by ACTEW Corporation in 2003[27]. The range of predicted increase or decrease in rainfall and evaporation by 2030 for each season is shown in Figure 5. 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%.

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 2.

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

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 45% when climate change is applied.

Current modelling uses the CSIRO 2003 most pessimistic predictions of change in rainfall and evaporation (9% decrease in rainfall and 9.1% increase in evaporation), scaled proportionally to the most pessimistic estimate for each season. These changes have been applied to the *1990 stochastic climate* scenario to produce a *2030 stochastic climate* scenario.

Table 2 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 for an eight-year period, but could indicate a permanent climate change trend. Evaporation is higher than the long-term average for all four seasons and the annual rainfall reduction is higher than that predicted with climate change. The bulk of the reduction occurs in autumn, although recent springs (2006 and 2007) have also contained below average rainfall. The CSIRO climate models do not predict significant rainfall reductions in autumn; however, recent consistently dry autumns may be a temporary anomaly.

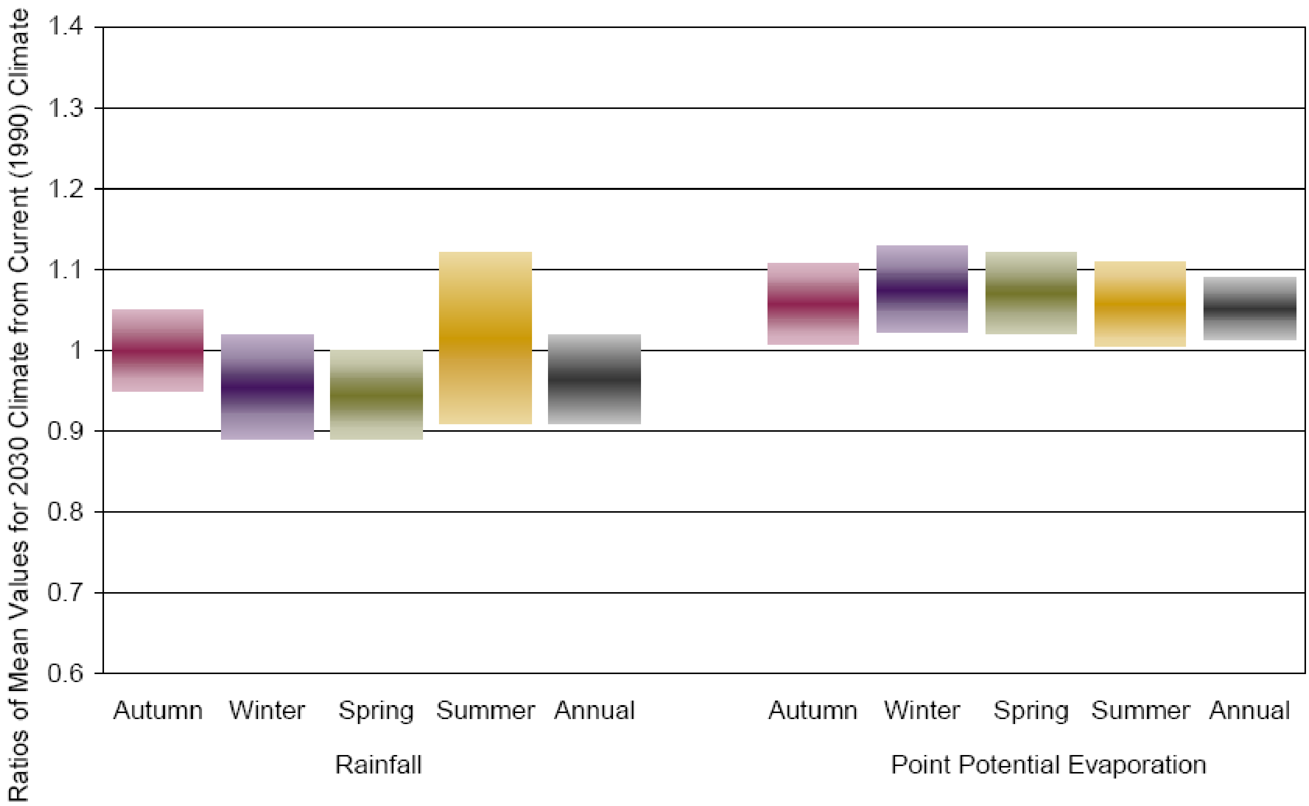

Figure 5 – CSIRO Predicted 2030 Seasonal Rainfall & Evaporation Variability

Table 2 – 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%	+1.5%	11.0%	0.5%	8.7%	0.9%
Autumn	-5%	5%	-4.9%	-51.8%	10.8%	0.8%	8.5%	5.7%
Winter	-11%	2%	-10.9%	-4.1%	12.8%	2.2%	10.5%	3.7%
Spring	-11%	0%	-10.9%	-16.5%	12.0%	2.1%	9.7%	10.9%
Annual	-9%	2%	-9.0%	-16.6%	9.1%	1.4%	9.1%	4.9%

Figure 6 shows flow duration curves for the historical record and climate change stochastic inflow sequences. The 2030 climate stochastic inflow is significantly less than the historic inflow sequence, reflecting the reduction in rainfall and increase in evaporation assumed for CSIRO conservative 2030 climate projections.

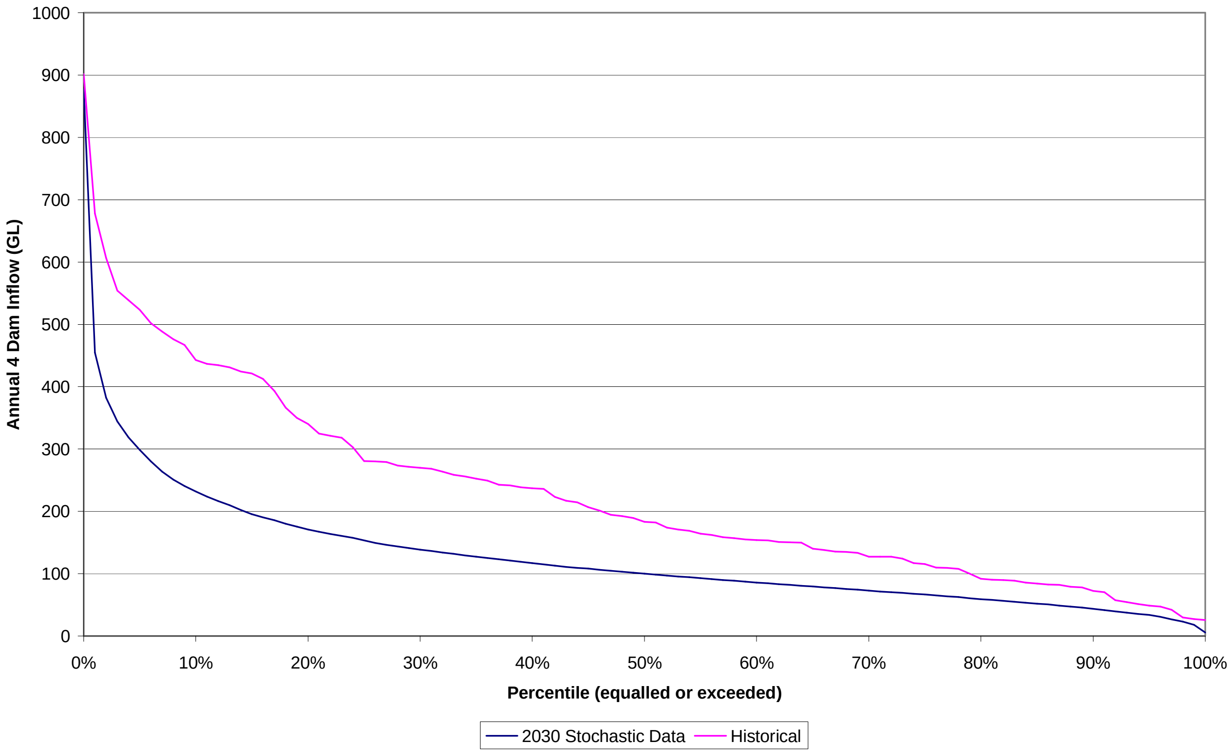

Figure 6 – Storage Inflow Duration Curves

Modelling of water supply systems is highly influenced by periods of minimum storage inflow. **Table 3** summarises minimum storage inflows over varying periods for extended historic climate, and for the 1990 and 2030 climate stochastic climate. The worst drought sequences in the stochastic data are much more severe than the worst historically observed sequences, largely because of the 10 000 year duration of the stochastic data.

Table 3 - Minimum Storage Inflows for Various Durations

	Lowest Inflow Sequence (GL/year)		
Duration	**Historic**	**2030 Climate Change Stochastic**	**% Difference**
1 Year	18.2 (to 1902)	3.6	80%
2 Years	46.4 (to 2009)	10.7	77%
3 Years	54.2 (to 2009)	17.2	68%
4 Years	73.4 (to 2009)	24.4	67%
5 Years	75.0 (to 2009)	26.3	65%
10 Years	91.9 (to 2009)	43.2	52%

Comparison of projected climate change and observed data

Table 4 compares the long term average inflows received by ACT dams with recent average inflows and the average inflows from the existing 2030 climate change stochastic data set.

Table 5 shows the percent reduction from long term average for the recent inflows and the 2030 climate change inflows.

These results indicate that the reduction in inflows experienced in recent years has been most significant for Googong Dam and least significant for Corin Dam. For the Cotter catchment, the average of the 2030 climate change data closely resembles the average inflow from recent years. However, the recent observed reduction in Googong Dam inflows has been greater than the average reduction in the stochastic data.

Table 4 – Average ACT Dam Inflows: Long Term, Recent and Climate Change Stochastic

	Average Inflow (GL)			
Dam	**1871-2009**	**Last 10 Years**	**Last 5 Years**	**2030 Climate Change Stochastic**
Corin	59	37	30	40
Bendora	38	19	15	23
Cotter	39	18	14	19
Googong	91	18	16	42
Corin, Bendora & Googong	188	74	61	105
4 Dams	228	91.9	75	123

Table 5 – Reduction in ACT Dam Inflows Relative to Long Term Average

	Reduction		
Dam	**Last 10 Years**	**Last 5 Years**	**2030 Climate Change Stochastic**
Corin	37%	49%	32%
Bendora	50%	61%	40%
Cotter	54%	64%	52%
Googong	80%	82%	54%
Corin, Bendora & Googong	61%	68%	44%
4 Dams	60%	67%	46%

Update of climate predictions

The stochastic climate series for modelling is being updated using the best available generation techniques and the most up to date estimations of future climate and will be incorporated into modelling undertaken in 2010.

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. Consequently, ActewAGL has developed rainfall-runoff models for each existing and proposed dam site (Corin, Bendora, Cotter, Googong and Tennent). A further rainfall runoff model for the Upper Murrumbidgee catchment has been developed by the CSIRO. A demand model has 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.

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 temporal 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."[28] 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.

Climate change is associated with a decline in interannual variability as well as a decline in average rainfall and runoff. This decline in variability has been well documented in south-western Australia and may also be occurring in the ACT. A decline in variability could also influence water supply modelling because it changes the frequencies of large inflow events and severe droughts.

Googong Dam inflows

Recent inflows to Googong Dam have been considerably lower than for any other extended time in the 1912-present record of 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 indeed altered.

Analysis of surrounding catchments indicates that the Googong runoff reduction is slightly higher than that experienced in the Gudgenby catchment, but not as severe as the reduction in the Molonglo catchment. Figure 7 shows the cumulative inflow in major unregulated catchments since July 1993, while Table 6 shows the inflow reduction when comparing the historical record since 1966 to the data since 2000.

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

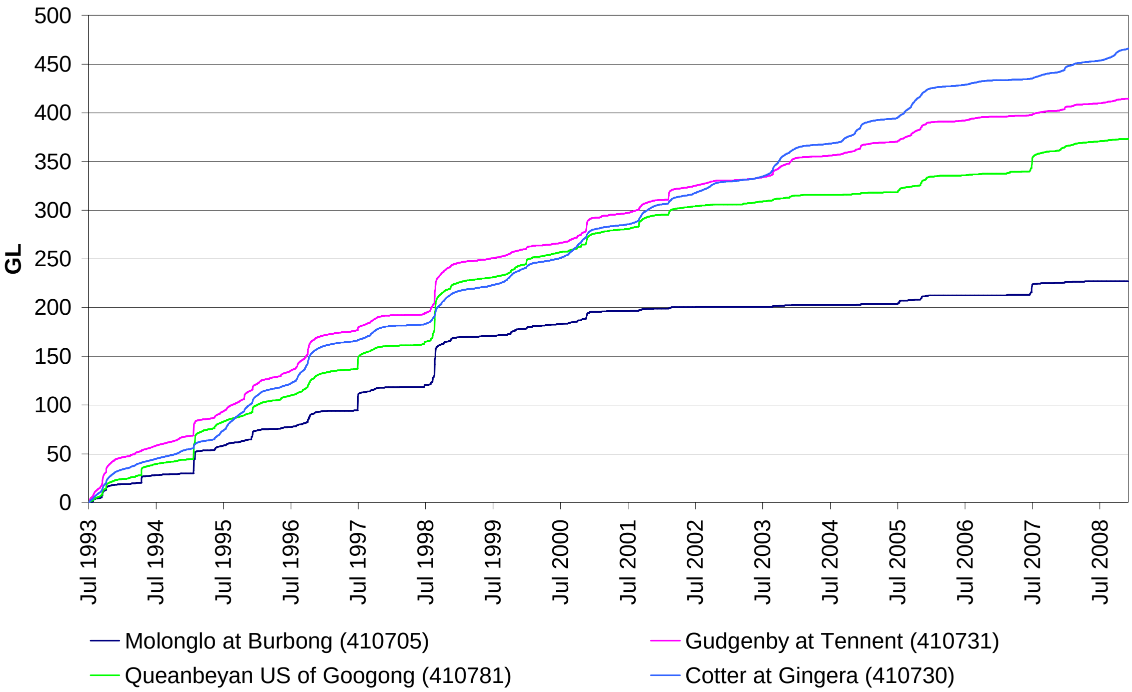

Figure 7 – Comparison of Cumulative Flows Since 1993 in Unregulated Catchments

Table 6 – Comparison of Average Inflows Before and Since 2000

	August 1966 to December 1999 (GL/year)	January 2000 to November 2008(GL/year)	Reduction
Molonglo at Burbong (410705)	43.8	5.3	88%
Gudgenby at Tennent (410731)	68.6	17.3	75%
Queanbeyan at Tinderry (410734)	76.3	12.1	84%
Cotter at Gingera (410730)	46.5	25.1	46%

While the recent reduction in rainfall explains at least some of this reduction, the full cause is a matter of debate amongst hydrologists. ActewAGL is attempting to develop a new Googong Dam Rainfall Runoff Model.

The Googong Dam Rainfall-Runoff Model

In 2004 a model using SimHyd software was developed. Although the model matches the overall historical record well, it significantly overestimates flows experienced in the recent drought years. Consequently, ActewAGL revised it in 2006/07 using inflow data from the previous 15 years only. This revision reduced average Googong inflows by approximately 20 GL/year, and tended to underestimate Googong inflows before the 15 year calibration period.[29]

Subsequent testing has shown that this model significantly overestimates flows in the last five years, although it reproduces the flow duration curve well over the 15 year period. However, as shown in Table 7, the model provides a much better estimate of inflow than the previous model.[30]

[29] ActewAGL, *Update of Canberra Water Resources Model Assumptions: Change 1: Impact of Googong Inflow Review and Murrumbidgee Water Quality Rule* (ActewAGL Document No. 322706), October 2007
[30] ActewAGL, *Performance Of Existing SimHyd Models During Recent Drought Flows* (ActewAGL Document No. 322867), October 2007

Table 7 – Comparison Between Rainfall Runoff Model and Googong Inflow in Recent Years

	Average Googong Inflow from January 2002 to November 2008 (ML/month)	Error
Observed	1159	
Current SimHyd Rainfall Runoff Model	1169	0.8%
SimHyd Rainfall Runoff Model Used in 2004/05 Future Water Options Work	3109	168%

ActewAGL has spent considerable effort in attempting to create a rainfall-runoff model that adequately reproduces this high variability in flows using three different approaches:

- Modifying the existing SimHyd model parameters;
- Using a range of rainfall-runoff models to model the Googong catchment;[31] and
- Creating an in-house rainfall runoff model.[32]

However, to date, the most accurate estimate of flows has been provided by the SimHyd model. Consequently, this model is still in use. ActewAGL has a project to improve the accuracy of the Googong rainfall runoff model. The outcomes of this project will be incorporated in future water resources modelling.

Conclusions

Given the current drought and the potential impact of climate change, it is important to include climate change in water supply modelling. However, assumptions relating to climate change have significant impacts upon results.

ActewAGL has engaged a consultant to update the predictions of rainfall and evaporation used to generate inflow and demand for water supply modelling. This update will use the latest climate change forecasts issued by the CSIRO as well as the latest stochastic data generation techniques. The new data is currently being generated. This update should be made periodically in the future as stochastic data generation or climate change estimation methods improve.

Rainfall-runoff models used to simulate Googong Dam inflows have had trouble in reproducing the extremely low average flows in the catchment in recent years. Models that reproduce baseflow conditions in recent years fail to reproduce peak flow conditions. ActewAGL will continue to work on improving the modelling of Googong Dam inflows.

[31] ActewAGL, *Performance Of Existing SimHyd Models During Recent Drought Flows* (ActewAGL Document No. 322867), October 2007

[32] ActewAGL, *Excel Rainfall Runoff Model for Googong Catchment* (ActewAGL Document No. 341454), April 2008

7 Environmental Flows

Required environmental flows from ACT water supply catchments

ACTEW has a Licence to Take Water (issued under the *Water Resource Act 2007*) that includes provisions to ensure environmental flows are protected as a first priority. The required environmental flows are set out in Environment ACTs *2006 Environmental Flow Guidelines*[33].

A summary of the 2006 Guidelines is provided in Table 8.

Table 8 – 2006 Environmental Flow Guidelines

River Reach	Base Flow	Riffle Flow (see Note 2)	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, one riffle flow required annually	Smaller of Inflow or 10 ML/day, one riffle flow required annually

* Later reduced to 27 days at 2 ML/day followed by 4 days at 20 ML/day

Notes:
1. Riffle Flows are required once every two months (except from Googong in drought conditions).
2. Pool Flows are required once a year between mid-July and mid- October. Pool Flows may count as part of a Riffle Flow.

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. Climate change may alter dam inflows, which would lead to different values of the 80th percentile. The 2006 Guidelines raise this issue and list 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]

If the latter method is applied, it would be necessary to demonstrate that climate change had occurred when calculating the 80th 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

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

difficulty in differentiating between climate change and climate variability. For simplicity, and to be conservative, all modelling uses the current 80th percentile environmental flow volume.

Murrumbidgee River environmental flows

The Murrumbidgee River has been used as part of Canberra's water supply since May 2007. This source is likely to play an increasingly important role in Canberra's water supply system in the future. The UV treatment system recently installed at Mount Stromlo Water Treatment Plant will allow more frequent use the Murrumbidgee, while the Angle Crossing to Googong pipeline will allow Murrumbidgee water to be directly piped into Googong Dam.

The *2006 Environmental Flow Guidelines* require the protection of all flows below the 80th percentile between November and May, while all flows below the 90th percentile must be left in the river between June and October (the high flow months).[35]

The current *Licence to Take Water* significantly increases the volumes of water that can be taken from the Murrumbidgee River at the Cotter pump station, as shown in Table 9.[36] However, there is no certainty that this licence condition will be maintained beyond the current drought.

Table 9 – Current Environmental Flow Requirements in the Murrumbidgee River

	Normal	Stage 1 Restrictions	Stage 2 Restrictions and Above
Required Environmental Flow at Cotter Pump Station	Unspecified. Assumed to be the 80th or 90th percentile as specified in *2006 Guidelines*	20 ML/day	20 ML/day

Modelling has shown that the Murrumbidgee environmental flow rule significantly influences water supply system performance.[37] A reduction from maintaining percentile flows to 20 ML/day, as in the current Licence, can:

- reduce the time spent in water restrictions;
- defer the need for further water supply augmentation; and
- increase the amount of water supplied from the Murrumbidgee by an average of approximately 1 GL/year.

Environmental flows associated with new infrastructure

Two major new water supply infrastructure projects are planned for the ACT:

- 78 GL Enlarged Cotter Dam (target completion date 2011); and
- Murrumbidgee River (at Angle Crossing) to Googong pipeline (target completion date 2011)

These augmentations will influence the flow regimes in the Cotter and Murrumbidgee Rivers and will be subject to environmental flow requirements. A change in this assumption could significantly affect water supply security.

[35] Environment ACT, *2006 Environmental Flow Guidelines*, January 2006
[36] ACT Environment Protection Authority, *Licence to Take Water Under the* Water Resources Act 2007, 14th January 2008
[37] ActewAGL, *Update of Canberra Water Resources Model Assumptions: Change 2: Murrumbidgee Environmental Flow Assumptions Review* (ActewAGL Document No. 326573), December 2007

ActewAGL currently assumes that the environmental flow at the Murrumbidgee to Googong pump station will prevent abstraction from reducing the flow below the 80th percentile from November to May and the 90th percentile from June to October. No concession is made during drought restrictions, unlike at the Cotter site. No allowance is made for flushing flow protection. While flushing flows may need to be protected, this rule is likely to apply to occasional high flow events and have minimal impact upon yield.

Conclusions

With the publication of 2006 *Environmental Flow Guidelines*, environmental flows are not as great a source of uncertainty as they were during earlier work. However, changes in environmental flows can significantly influence system performance. The environmental flow Guidelines are due to be reviewed five years after publication.[38]

The environmental flows associated with new major infrastructure projects have not yet been formally specified. Changes in the required flows from these sources could significantly influence water supply security.

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

8 Ongoing Bushfire Impact

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 evapotranspiration from rapid vegetation growth during the recovery phase that may last many decades.

Predicted effect of 2003 bushfires

Environmental consultants were commissioned during the 2003/04 Future Water Options project to quantify the impact of severe bushfire events on catchment hydrology based upon 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 8 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 evapotranspiration from recovery of ground cover and shrubs at 5 to 8 years, and recovery of the eucalypt forest at 17 to 30 years.

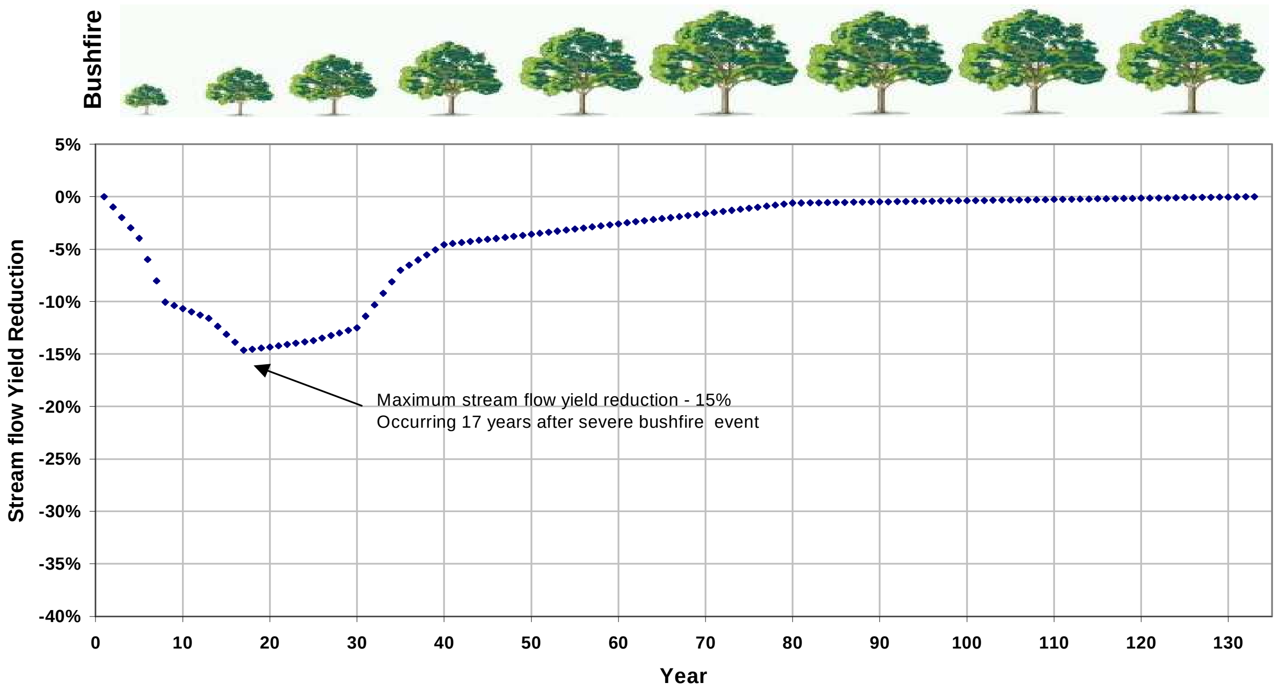

Figure 8 – Predicted ACT Severe Bushfire Yield Reduction Relationship

Ecowise Environmental has been commissioned by ACTEW to undertake a review of satellite imagery to assess the recovery of the vegetation types in the bushfire affected catchments. Following the findings of this review, DHI will update modelling to determine an updated impact on catchment inflows.

Incorporation into stochastic data

The stochastic data are separated into 200 runs, each of 50 years duration. All of these 200 runs contain the impacts of the 2003 bushfires, as quantified by the curve shown in Figure 8. The time that has passed since the bushfires is taken into account: for example, a run starting in 2009 would begin 6 years into the yield reduction curve.

The possibility of bushfires being experienced in the future has also been considered. 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. The bushfire trigger model reflects a catchment's potential fuel load, season and relative dryness and assists in calculating catchment yields in the future, under various scenarios. 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.

Table 10 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 and 2070 climate stochastic sequences than the 1990 climate 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 10 – Predicted Severe Bushfire Frequencies

		Corin	Bendora	Cotter	Simultaneous ignition
Current climate stochastic (Year 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 (Year 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

Observations

As indicated by the DHI bushfire yield reduction relationship, bushfire effects on yield in the first 5 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. This is consistent with a 2006 study that found no measurable change in catchment yield, although vegetation was recovering well. However, only a small number of significant rainfall events have occurred in the catchment since the fires, which makes yield reduction estimation difficult.[39]

The unprecedented dry period following the bushfires could change the shape of the bushfire yield reduction curve. It is possible that this dry period will have delayed or retarded regrowth in the catchment. Figure 9 is an indication of how the yield recovery could be influenced by this possible delay in regrowth. The Ecowise study will investigate how much regrowth has occurred since the 2003 fires. Similarly, the same climate conditions that cause a delay in the recovery of vegetation also reflect a delay in the development of the vegetation fuel load required to trigger a severe bushfire.

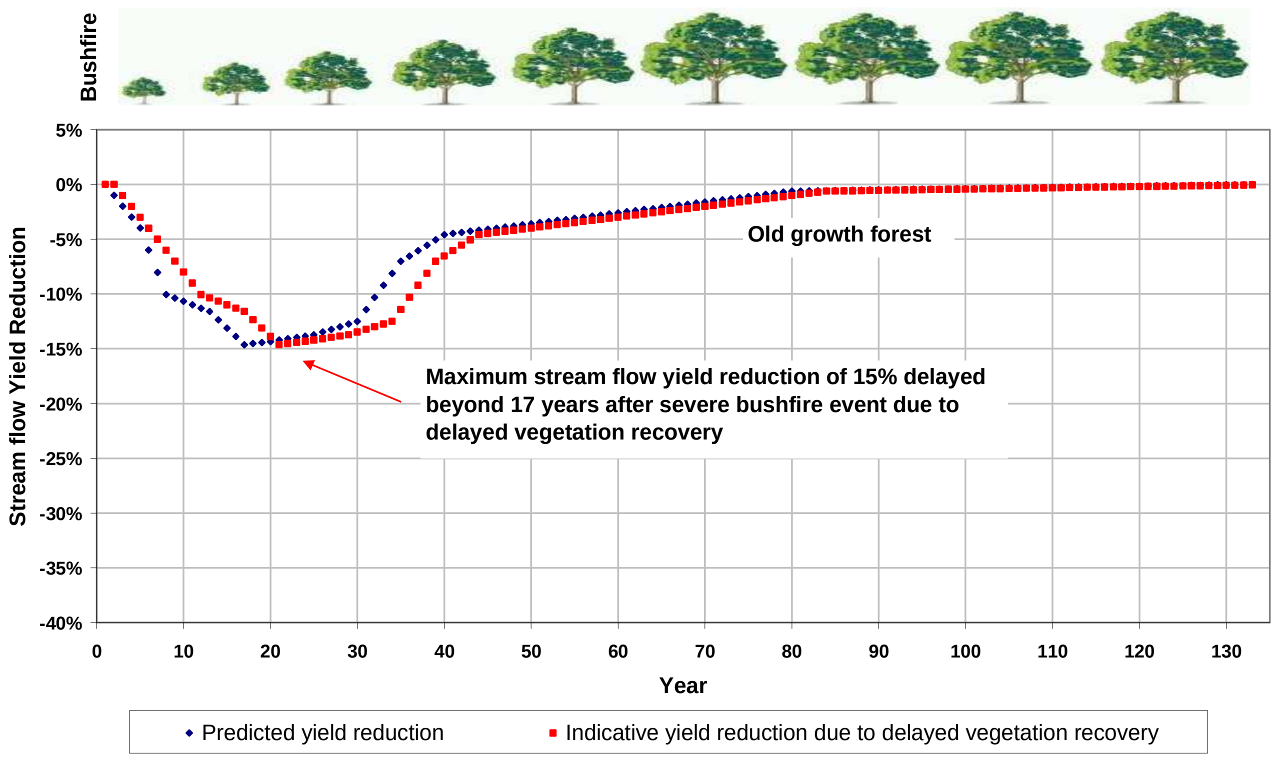

Figure 9 – Predicted ACT Severe Bushfire Yield Reduction Relationship

ActewAGL compared the bushfire trigger model with spatial based fire frequency modelling by ANU.[40] The comparison between the two models indicates that there is broad agreement between the results. Some minor modification to the ActewAGL bushfire model may be necessary to improve the projection capacity, particularly for the longer-term climate change models.

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

[40] ActewAGL Infrastructure Development Branch, *Comparison between FIRESCAPE and the Bushfire Trigger Model*, (2008) Internal Report

Conclusions

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

9 Water Demand

Demand model

A demand model has been developed by ActewAGL to calculate monthly per capita water demand for Canberra, based on monthly Canberra Airport rainfall and evaporation data.[41] 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.

The demand model can be used to compare observed demand during water restriction events with 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 10 displays the distributions of historical and stochastic annual demand.

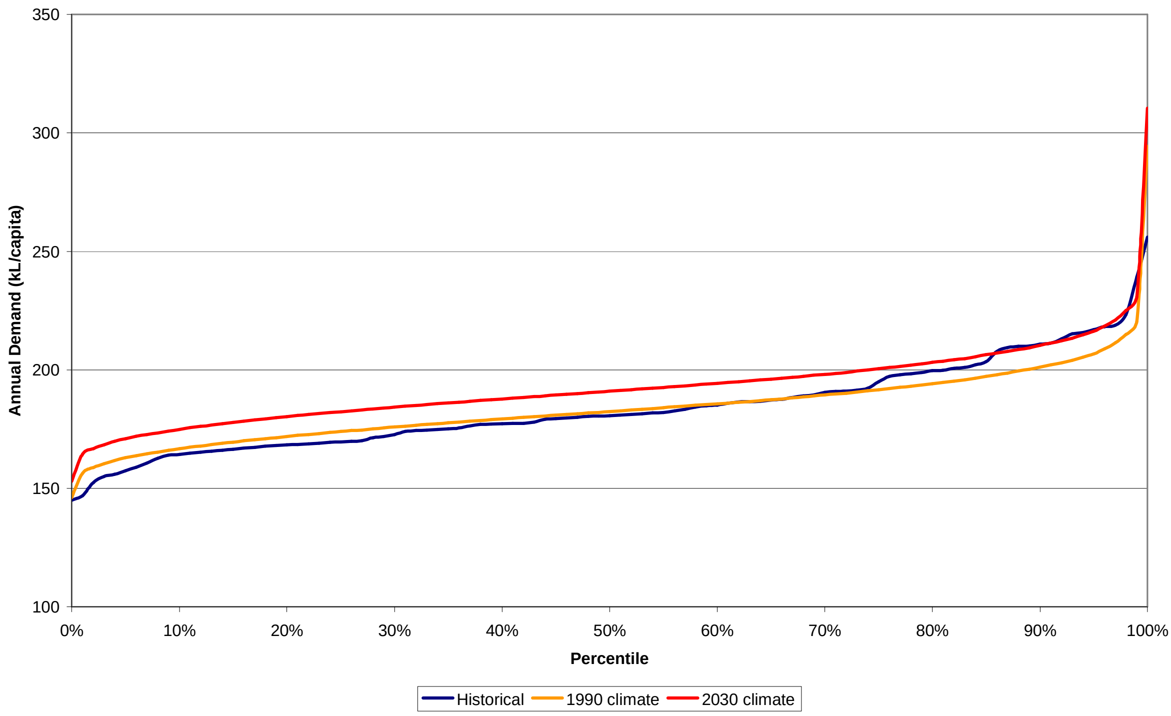

Figure 10 – Comparison Between Historical, Stochastic and Climate Change Stochastic Demand

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;

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

- 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; and
- ongoing pricing reforms.

It is expected that demand management alone will achieve the 12% target. Permanent Water Conservation Measures, the ACT Government's demand management program and a general increased awareness of the need for water conservation may well have already delivered this saving. However, it is expected that source substitution (eg. rainwater tanks, greywater reuse, effluent reuse, stormwater harvesting) will be required to reach the 25% target.[42, 43]

The latest ACT Government progress report estimates that initiatives already implemented or committed to will deliver the demand reductions specified in Table 11.

Table 11 – Expected Demand Reduction from Measures Already Implemented or Committed to by the ACT Government[44]

Year	Expected Potable Demand Saving
2005-06	12.98%
2012-13	14.82%
2023-24	16.70%

Approximately 90% of 2023-24 savings reported here are attributed to (in order of highest saving):

- PWCM;
- Information and awareness;
- Water sensitive urban design (WSUD); and
- The Water Efficient Labelling and Standards Scheme (WELS).

The progress report concludes that the "2013 target can be easily met with current initiatives but to meet the 2023 target we will need to investigate further for the best water efficient measure that can achieve further water savings in the most cost effective way."[45]

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

[42] Institute for Sustainable Futures, *ACT Water Strategy: Preliminary Demand Management and Least Cost Planning Assessment*, October 2003
[43] ACT Government, *Think water, act water: Strategy for sustainable water resource management in the ACT: 2005-06 Progress Report*, January 2007
[44] ACT Government, *Think water, act water: Strategy for sustainable water resource management in the ACT: 2005-06 Progress Report*, January 2007
[45] ACT Government, *Think water, act water: Strategy for sustainable water resource management in the ACT: 2005-06 Progress Report*, January 2007

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.

ActewAGL has 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 at least 12% lower than predicted. 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.

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. Water conservation habits may be maintained after the end of the drought.
- 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, are often introduced during the drought, and continue to reduce water consumption in the long term.

Permanent Water Conservation Measures

Permanent Water Conservation Measures (PWCM) were introduced in November 2005. The intent behind PWCM is to discourage inefficient water use through means that should cause little inconvenience to the community. They applied for a year before temporary water restrictions were reintroduced. The most significant impact of PWCM has been limiting irrigation system operation to 6 pm to 9am, except during winter. This encourages garden watering in the morning or evening when absorption rates are highest.

The target reduction for PWCM was 8%. A 23% reduction in consumption was observed during the PWCM year, relative to the pre-water restriction consumption pattern. However, this reduction is unlikely to be sustained in the long term because:

- PWCM were applied after a severe drought. Awareness of water conservation was at a very high level and many gardens that require high water use were adversely affected by the drought and had not been re-established; and
- Many users may be maintaining habits established during the water restrictions scheme such as only watering every second day. These patterns may not be maintained.

Permanent Water Conservation Measures are currently under review by ACTEW. When these changes are promulgated the assumed reduction from PWCM's and water restrictions will be reviewed.

Calculation of demand reductions during water restrictions

Until the recent drought, little information was available on how much consumption is reduced by water restrictions. However, it is now possible to estimate the consumption reduction associated with each water restriction level.

Table 12 shows the target and observed consumption reductions for the period from 1st November 2005 to 15th April 2008. Stage 2 and Stage 3 have also delivered significant water savings, but have narrowly failed to achieve the targets.

Table 12 – Target and Observed Reductions in Water Restrictions Since November 2005

Restriction Level	Target Reduction Relative to PWCM	Target Reduction Relative to Period Before Restrictions	Observed Reduction Relative to Period Before Restrictions
PWCM		8%	23%
1	10%	17%	
2	25%	31%	26%*
3	35%	40%	38%
4	55%	59%	

* Limited data, as Stage 2 only in place for 45 days.

Demand hardening

Demand hardening occurs as demand is reduced, either because of the PWCM or other measures. The term demand hardening means that water restrictions and other water conservation measures are less effective in reducing demand because water use practices have already been amended to avoid wasteful water.

Demand is not predicted to significantly increase between now and 2023, as the 25% demand reduction target is greater than the high projection of population growth. However, the effectiveness of restrictions decreases as demand is reduced — there is only a certain amount people can reduce their consumption until they become unable to achieve significant further savings.

Demand hardening has been included in all modelling by maintaining the percent reductions applied for each restriction level at constant rates. 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.

Demand restrictions review

Revised population

The original drought restriction consumption targets were calculated in January 2005. These targets were set using a population of 360,000 people, and assuming a 70th percentile consumption year.

Based on the Bureau of Statistics (BoS) 2008 projections the revised Canberra – Queanbeyan population estimate is now slightly over 385,000 people. This is a 7% increase over the 2005 population estimation. In April 2009 new consumption restriction targets for stage 1 – 4 were calculated for the period that includes Winter 2009 – Summer 2010-11 using the updated population estimates and continued high population growth as forecast by the ABS.

Average consumption for the last 12 months

During the last 12 months (April 2008 to May 2009) the average daily consumption exceeded the published target consumption for stage 3 water restrictions for 8 of the 12 months. Only during the months of May, July, September and December was the actual average consumption either equal to or less than the published target consumption for those months.

The stage 3 water restrictions that have been in place during the past 12 months have been effective in reducing the total consumption from the expected consumption by approximately 29.5 GL, or 40%.

The biggest savings were obtained during the months of December 2008 to March 2009 when the savings ranged from 3.2 GL to 4.6 GL. For all other months the savings ranged from 1.0 GL during the winter months of June and July 2008 to 2.9 GL during late spring.

End Use Model

The End Use Model (EUM) is a decision support tool that was originally developed by the Institute of Sustainable Futures (ISF) for forecasting and evaluating potable water demand and supply options.[46] The forecasting component of the EUM allows for a baseline and option impact forecast to be developed for any combination of enduse and option inputs.

ActewAGL is currently calibrating the model for the ACT. It is intended to include the impacts of seasonality, climate change and climate variability on potable water demand. Calibration is an extensive process that will be ongoing for the next few years. ActewAGL has also used the EUM for answering policy questions related to water conservation.

Conclusions

All water resource modelling will assume that the ACT Government 25% reduction target is met by 2023. It will be assumed that the reduction will occur linearly from 8% in 2005 (delivered by PWCM).

ActewAGL will continue developing the End Use Model. The End Use Model will be used to inform water resources modelling and investigate the means required to meet the ACT Government demand reduction target.

[46] Water Services Association of Australia, *EUM User Guide Version 4.1*, 2005

10 System Performance Criteria

System performance criteria are used to determine whether existing or planned water supply systems provide an acceptable service to the community. They can also give an indication of when water supply augmentation is required. System performance criteria are chosen to ensure that the system never runs out of water.

Current method

During FWO (2004/05) ACTEW set a series of service level targets relating to water restrictions. Once the targets could no longer be met, the water supply was augmented. While this system worked, it ignored the inherent trade-off between the cost of meeting a target and the cost of not providing that level of service. This weakness led to a new method of determining when the system needs to be augmented. The current method of assessing water infrastructure projects attempts to quantify the benefit to the community that will be delivered by the water supply project. This benefit is derived from an increase in water supply security, which can be quantified by the reduction in the probability of experiencing water restrictions events.

This method is in line with the latest WSAA advice on this issue.[47] 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 11.

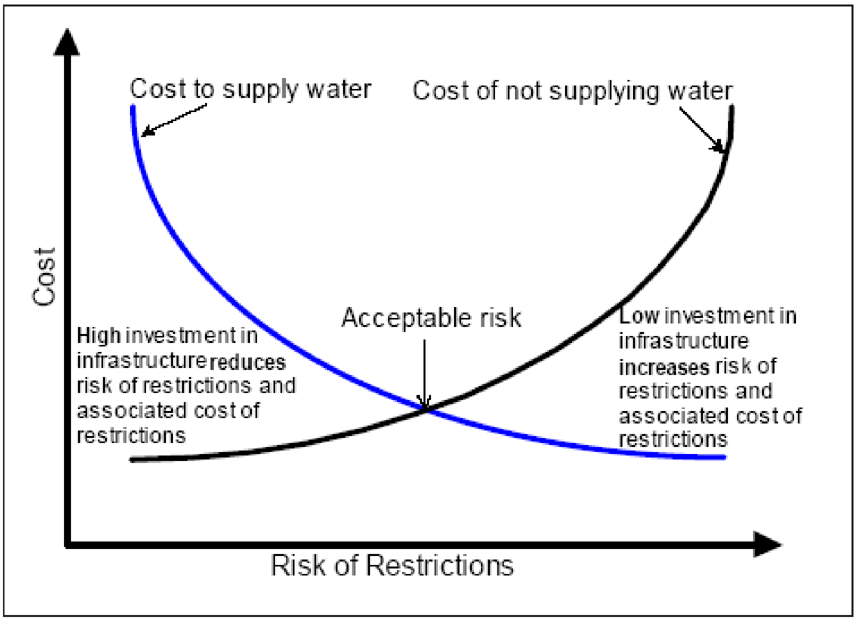

Figure 11 – Trade-off for Setting Level of Service Objectives[48]

This method has two main advantages over the earlier level of service targets. It attempts to maximise the benefit to the community, rather than meet arbitrarily chosen targets; and it applies different costs to each level of restrictions. This better allows for the different community

[47] Peter Erlanger and Brad Neal, *Framework for Urban Water Resource Planning*, Water Services Association of Australia, Occasional Paper No. 14 – June 2005
[48] 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

requirements of each stage and the different water supply security risks associated with each stage.

The principle behind this method was reinforced by the 2008 water price determination by the ACT Independent Competition and Regulatory Commission (ICRC). This determination increased the price of water to pay for new infrastructure, but noted that this infrastructure is expected to deliver a benefit to the community:

> *Having increased prices to allow for the funding of new investment, ACT consumers should expect that ACTEW will now deliver on the greater water security this new investment is designed to provide. The Commission will be monitoring performance against this overall objective to ensure that ACTEW meets its performance obligations to the ACT community.*[49]

Water resources modelling by ActewAGL will continue to report on other performance indicators, such as probability and return interval of water restrictions, volumes of water that can be supplied from each source, greenhouse gas emissions of each option etc. These indicators will be used to inform decision-making as well as consideration of the net economic benefit.

Determining Net Economic Benefits

The net economic benefit (NEB) approach follows from the underlying philosophy of the WSAA framework. NEBs are derived from the gross community benefits expected from any reduced probability of water restrictions provided by implementing an option, less the capital and operating costs of putting that option into operation. Community benefits are quantified by applying a cost to each water restriction level.

Net economic benefits are typically converted to a present value using a discount factor across all three costs.

NEB = Gross Economic Benefit less Costs of Implementation

where: (i) GEB = cost of restrictions x (probability of time in restrictions for Do Nothing - probability of time restrictions for augmentation option)

(ii) Implementation costs = Capital cost of augmentation + (system operating cost with augmentation – system operating costs for Do Nothing)

The target for NEB is simply that it should be positive — the benefits of an option should outweigh the costs of implementing the option. When comparing options, the option with the highest NEB is considered the best, although, at times, other non-economic factors may prevail. Combinations of options can also be evaluated: Option A and Option B should only be implemented if both options together produce a greater NEB than the individual benefit of either Option A or Option B.

The use of stochastic climate data enables a wide range of climate scenarios to be examined. 200 different possible versions of the next 50 years were modelled and each of these 200 replicates contains different weather patterns. Each produces a different NEB (with drier replicates likely to produce higher NEBs). The average net economic benefit from these 200 replicates can be considered, but this does not provide an indication of the range of possible benefits that may occur. An example cumulative probability distribution is shown below in Figure 12. In this distribution, 77% of the replicates produce a small economic loss (driven by the

[49] ICRC, *Water and Wastewater Price Review: Final Report and Price Determination*, Report 1 of 2008, April 2008

capital cost of the project), however a number of replicates produce a substantial economic gain, sometimes in the hundreds of millions.

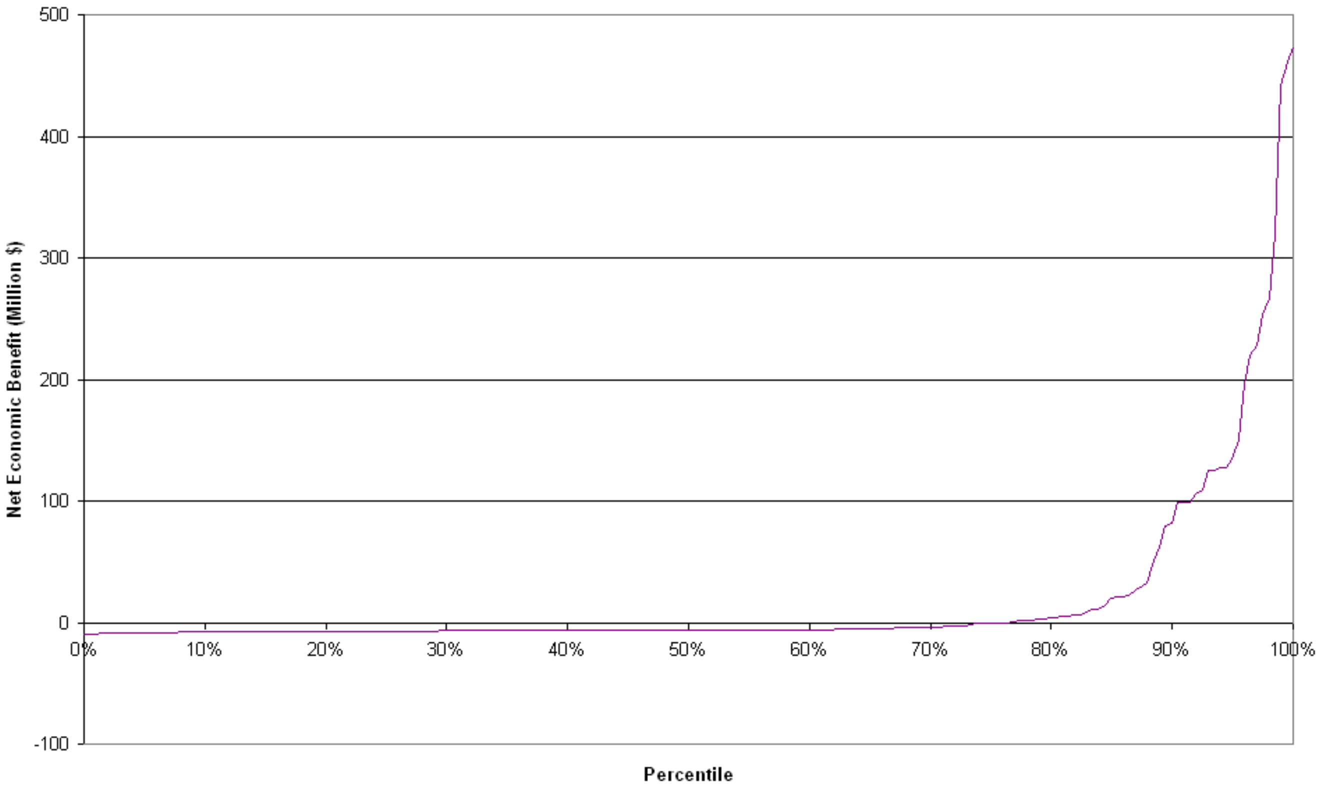

Figure 12 – Example Cumulative Probability Distribution of Net Economic Benefits

Cost of water restrictions

During FWO, the annual costs of time in each level of water restrictions were estimated from various sources; including international research of similar economic studies, an ACT choice modelling study undertaken in 1997 and an ACTEW willingness to pay survey undertaken in 2003[50] by the Centre for International Economics (CIE).

In 2008, CIE updated its estimates based on work undertaken by Colmar Brunton Social Research in June 2008.

An option's gross benefits flow to many different groups within the community: households, businesses, community groups and Government. The estimates include:

- Costs to households;
- Commercial costs;
- Recreation costs (e.g. associated with parks and sporting fields);
- Tourism costs;
- Urban environment costs (e.g. loss and replacement of street trees); and

[50] CIE, *Economic Benefit-Cost Analysis of New Water Supply Options for the ACT*, April 2005

- ACTEW and ACT Government costs, including costs of managing and enforcing water restrictions.

In Canberra, households potentially derive the highest benefit through less restricted outdoor water use and increased recreational opportunities in the broader community.

Current costs for each stage of water restrictions for 2008 are shown in Table 13. The costs are projected to gradually increase over time in real terms.

Table 13 – Estimated Cost of Water Restrictions in 2008

Water Restriction Stage	Cost of Restrictions for 2008
Stage 1	$7.0 million/year
Stage 2	$48.8 million/year
Stage 3	$121.6 million/year
Stage 4	$324.1 million/year

Operating rules

Choice of system operating rules can have a significant impact on system performance. Frequent operation of high cost sources will lead to high operations costs (and high greenhouse gas generation when the cost is related to energy usage). However, use of these high cost sources may improve system security and reduce the likelihood of experiencing severe water restrictions.

It is possible to use the net economic benefit method to optimise the operating rules of a system. The operating rules are optimised until the lowest total cost is found, where total cost is calculated from the sum of restrictions cost and operating cost.

A good example of an operating rule that requires optimisation is the trigger point for using Cotter Dam. This source is one of the most expensive for Canberra, but can also supply considerable amounts of valuable water to alleviate scarcity in a drought. Cotter is the furthest downstream dam on the Cotter River, so, unlike the other Cotter dams, there is no opportunity to capture spills over the dam if the water is not used for consumption. With the existing water supply system, cost optimisations indicate that Cotter Dam water should be used virtually all the time (unless Bendora or Googong Dams will spill imminently)[51]. The cost of using water from this source is less than the potential cost of severe water restrictions that may occur if water is allowed to spill over the dam instead of being used for town consumption. However, this could change when the system is augmented. The likelihood of experiencing severe restrictions is now reduced (and the number of ways to supply water increased), so there are now periods when it is economic to not run Cotter Dam in order to save on operating costs. Spills over Cotter Dam are now less likely to lead to severe water restrictions later.

Murrumbidgee flow and turbidity

Turbidity is used in modelling as a general surrogate for general water quality. The REALM model reduces the capacity of the Murrumbidgee at Cotter source as turbidity increases. Turbidity is estimated from Murrumbidgee flow using a probabilistic method. The amount of turbidity data from Murrumbidgee at Cotter is small because it has only been recorded since October 2006. The distribution between flow and turbidity was originally estimated using

[51] ActewAGL, *Future Water Options Review* (ActewAGL Document No. 303825), July 2007

approximately 6 months data. This distribution has been updated using approximately 19 months data.

Description of change

A detailed description is provided in *Murrumbidgee Turbidity Distribution*[52]. The key changes are:

- The distribution is now based on 19 months of data instead of 6;
- Two different flow-probability distributions are now used – one for winter and spring and another for summer and autumn – instead of an annual distribution; and
- The distribution is now based on absolute (ML/day) flows rather than percentile flows.

Resultant changes in baseline performance measures

Table 14 shows the change in supply from each source resulting from the turbidity assumption change. The new flow-turbidity probability distributions reduce the likelihood of high turbidity events because of the extended length of data used to generate the distributions. This increases the volume of water sourced from the Murrumbidgee at Cotter by 1.2 GL/year, while reducing the volume of water supplied from every other source. The overall consumption is slightly increased because the probability of water restrictions is reduced.

Table 14 – Average Volume Supplied from Each Source, 2009 to 2056

	Estimated Average Supply, 2009-2056 (GL/year)		
	Old Turbidity Distribution	New Turbidity Distribution	Increase
Bendora	36.5	36.3	-0.2
Googong	28.5	28.2	-0.3
Lower Cotter (Existing or Enlarged)	9.6	9.2	-0.4
Murrumbidgee to Stromlo	1.6	2.8	1.2
CGBT	0.9	1.0	0.1
Murrumbidgee to Googong	9.7	9.4	-0.3
Overall Consumption	**75.3**	**75.4**	**0.1**

Increased triggers for removing water restrictions

ACTEW has changed the trigger for removing water restrictions since the last review of water modelling assumptions. As water restrictions have been implemented, it has become apparent that reducing the water restriction level is undesirable if the original water restriction level needs to be reinstated shortly after. To avoid this, the storage level triggers for reducing the level of water restrictions have been increased.

Description of Change

The triggers for removing each level of water restrictions were originally set at 5% more storage than the triggers for entering each stage of water restrictions. The difference between the old and new triggers for removing water restrictions is shown in Table 15. The triggers for introducing and removing Stage 5 water restrictions are unchanged, at a constant 20% and 30% respectively.

The new triggers have already been used in some modelling (including the monthly storage forecast) but not in other modelling exercises (such as Future Water Options Review).

[52] ActewAGL Document 351720

Table 15 – Change in Triggers for Lifting Water Restrictions

	New Triggers				Old Triggers			
	Stage 1 Lift	Stage 2 Lift	Stage 3 Lift	Stage 4 Lift	Stage 1 Lift	Stage 2 Lift	Stage 3 Lift	Stage 4 Lift
January	78%	66%	48%	40%	57%	46%	40%	35%
February	75%	63%	47%	39%	54%	44%	39%	35%
March	73%	61%	46%	39%	52%	43%	38%	35%
April	69%	58%	45%	38%	51%	41%	38%	35%
May	68%	57%	45%	38%	50%	40%	38%	35%
June	67%	56%	44%	38%	49%	40%	39%	36%
July	69%	58%	44%	38%	52%	43%	39%	36%
August	72%	60%	46%	38%	55%	45%	40%	37%
September	74%	62%	47%	39%	57%	47%	41%	37%
October	77%	63%	48%	40%	60%	49%	42%	37%
November	80%	66%	48%	40%	63%	52%	43%	38%
December	79%	66%	47%	39%	60%	49%	41%	36%

Conclusions

The primary measure used to determine whether water supply infrastructure should be constructed is Net Economic Benefit (NEB) analysis. This method may also be used to determine the optimal timing of future augmentations. Other measures may also be considered when evaluating options, such as probability of water restrictions, volumes of water that can be supplied from each source, greenhouse gas emissions and operational convenience.

This type of analysis is heavily influenced by the costs applied to each level of water restrictions.

ActewAGL has also implemented a method where multiple forecasts of the next 50 years are considered. This method includes the current low storage conditions in the model and allows analysis of the range of possible outcomes driven by different weather sequences.

11 References

ABC News, 'Yass to extend dam to secure water supply' (http://abc.com.au/news/stories/2007/05/24/1931703.htm), 24th May 2007

ACT Chief Minister's Department, *ACT Population Projections, 2007 to 2056,* June 2009 (http://www.cmd.act.gov.au/__data/assets/pdf_file/0012/3360/ACT_population_projections_2007_2056.pdf),

ACT Economic Development Division, Policy and Research Branch, *ACT Population and Employment Forecasts*, February 1992

ACT Environment Protection Authority, *Licence to Take Water Under the* Water Resources Act 2007, 14th January 2008

ACT Government, *Think water, act water: Volume 1: Strategy for sustainable water resource management in the ACT*, April 2004

ACT Government, *Think water, act water: Strategy for sustainable water resource management in the ACT: 2005-06 Progress Report*, January 2007

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

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

ACTEW Corporation, *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*, June 2006

ACTEW Corporation, *Water Security for the ACT and Region: Recommendations to ACT Government*, July 2007

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

ActewAGL, *ACT Water Supply Augmentation Timing – Volume I*, Future Water Options Project, November 2004

ActewAGL, *Regional Water Supply Pre-Feasibility Study: A Preliminary Investigation into Issues, Options and Costs in Providing Water from The ACT into Surrounding NSW* (ActewAGL Document No. 291454), January 2007

ActewAGL, *Future Water Options Review* (ActewAGL Document No. 303825), July 2007

ActewAGL, *Performance Of Existing SimHyd Models During Recent Drought Flows* (ActewAGL Document No. 322867), October 2007

ActewAGL, *Update of Canberra Water Resources Model Assumptions: Change 1: Impact of Googong Inflow Review and Murrumbidgee Water Quality Rule* (ActewAGL Document No. 322706), October 2007

ActewAGL, *Investigation of CSIRO Upper Murrumbidgee Model* (ActewAGL Document No. 325227), November 2007

ActewAGL, *Update of Canberra Water Resources Model Assumptions: Change 2: Murrumbidgee Environmental Flow Assumptions Review* (ActewAGL Document No. 326573), December 2007

ActewAGL, *Impact of Demographic Change and Urban Consolidation on Domestic Water Use* (ActewAGL Document No. 334668), March 2008

ActewAGL, *Excel Rainfall Runoff Model for Googong Catchment* (ActewAGL Document No. 341454), April 2008

AGRECON, *A Preliminary Analysis of Hydrological Conditions in the Catchment of Googong Dam*, 20th June 2005

Australian Bureau of Statistics, *3222.0 - Population Projections, Australia, 2004 to 2101*, 29th November 2005

Australian Bureau of Statistics, *3218.0 Regional Population Growth, Australia* (http://www.ausstats.abs.gov.au/Ausstats/subscriber.nsf/0/A202921AA9EFDA9DCA257367008042CC/$File/32180_statistical_local_areas_96to06.xls), 2nd October 2007

Australian Bureau of Statistics, *3101.0 - Australian Demographic Statistics* (http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0), latest version released 19th March 2008

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

Birrell, B, Rapson, V, & Smith, F, *Impact of Demographic Change and Urban Consolidation on Domestic Water Use*, Water Services Association of Australia, Occasional Paper No.15, 2005

Blanchard, Megan, Australian Bureau of Statistics, personal communication (email), 30th January 2008

Chester, Heath, Territory and Municipal Services, *Future flow requirements downstream of Cotter Reservoir*, personal communication (email), 12th March 2008

CIE, *Economic Benefit-Cost Analysis of New Water Supply Options for the ACT*, April 2005

Commonwealth Department of Works for and on behalf of The National Capital Development Commission, *Canberra Water Supply Augmentation*, May 1968

CSIRO, *Climate Change in Australia: Australia's future climate >New South Wales / Australian Capital Territory Rainfall Change*, http://www.climatechangeinaustralia.gov.au/nswactrain5.php, page accessed 11th April 2008

Ecowise Environmental (Tony Falkland), *Report on Inflow Reduction to Googong Dam in Recent Years*, 2006

Environment ACT, *2006 Environmental Flow Guidelines*, January 2006

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

Gilmore, Rachel, CSIRO, personal communication (email), 8th August 2007

Goulburn Mulwaree Council, ‘Goulburn Mulwaree Council unanimously secure City’s Water Supply to 2040’ (http://www.goulburn.nsw.gov.au/news/pages/8908/NewsDoc/Highlands_Source_Project.pdf). media release, 18th March 2009ICRC, *Water and Wastewater Price Review: Final Report and Price Determination*, Report 1 of 2008, April 2008

Institute for Sustainable Futures, *ACT Water Strategy: Preliminary Demand Management and*

Least Cost Planning Assessment, October 2003

Intergovernmental Panel on Climate Change, *Fourth Assessment Report*, 2007

Pearce, David (CIE), personal communication (email), 13th March 2007

Preston, B.L. and Jones, R.N ., *Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions*, CSIRO, February 2006

Sinclair Knight Merz, *Update of Water Resources Strategy for Canberra and Queanbeyan* (ACTEW Corp. Doc. No. 3959), July 2004

Sinclair Knight Merz, *Inflow Reduction to Googong Dam*, 13th July 2006

Sinclair Knight Merz, *Future Water Source Options - Stage 2 Assessment: Assessment of Different Models for Stochastic Data Generation*, 13th April 2007

Sinclair Knight Merz, *Future Water Source Options - Stage 2 Assessment: Proposal for Stochastic Generation of Climate Data Under "Current" and "2030" Conditions*, 27th February 2008

Stanhope, John, Chief Minister, Australian Capital Territory, *Enlarged Cotter Dam, Murrumbidgee Extraction and Pilot Purification Plant Highlights Of Water Plan*, press release, 23rd October 2007

URS & Australian Government Department of Defence, *Supplementary Report to the Draft EIS: Headquarters Australian Theatre now known as Defence Headquarters Joint Operations Command (HQJOC), Section 13: Water Management*, May 2005

Water Services Association of Australia, *EUM User Guide Version 4.1*, 2005

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

Yass Valley Council, *Water Supply Strategy,* http://yassvalley.local-e.nsw.gov.au/roads/1932/2202.html, Retrieved 11 June 2009