WATER PLANNING

2011 REVIEW OF PLANNING VARIABLES FOR WATER SUPPLY AND DEMAND ASSESSMENT

A review of the changes in water resources modelling assumptions

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Statement by Branch Manager

This report was commissioned by ACTEW as a Strategic Planning and Management Services (SPMS) project under the terms of the UMA (Schedule 7 – Services). The report has been subjected to internal ActewAGL Water Division management and technical review.

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Approved for Release

Leigh Crocker
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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 Commission (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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Executive Summary

This document outlines the major model input assumptions and tracks any changes since the previous report (ActewAGL 2010, http://www.actew.com.au/News%20and%20Publications/Reports/Key%20Publications.aspx)

Planning for the Canberra Region's water supply security requires extensive modelling of scenarios relating to water demand, water supply and infrastructure availability. The results of such modelling depend on the water security target required and the assumptions input into the model.

Six key planning variables influence the level of Canberra's water supply security during the planning horizon. These are:

1. Climate variability and climate change;
2. Bushfire impacts;
3. Population growth and service area;
4. Per capita water consumption;
5. Environmental flow requirements; and
6. Level of service and Infrastructure assumptions.

The assumptions made in relation to each of these variables are discussed in this report.

Changes made to assumptions during 2010/11 have been minor and predominantly involve updating data to the present day.

Infrastructure and system changes

There are a number of additional improvements to infrastructure planned for the next five years — Enlarged Cotter Dam, Murrumbidgee to Googong Water Transfer, and the purchase of water entitlements for use in ACT, most likely by upstream releases to the Murrumbidgee River from Tantangara Reservoir. While these projects are included in the long term water supply planning, modifications to the operating rules around these will occur as they come on-line.

The following minor amendments were made to the infrastructure and the system operating rules. These amendments were made within the model to better reflect the actual practice and performance of the infrastructure.

1. The modelled capacity of Cotter Pump Station decreased from 4275ML/month to 2565ML/month; (Section 9)
2. Incorporation of a one month annual shutdown at Stromlo Water Treatment Plant in Autumn; (Section 9)
3. Reduction of the capacity of Stromlo Water Treatment Plant when sourcing water from the Murrumbidgee from 250ML/d to 100ML/d; (Section 9)
4. The introduction of Water Quality Rules for sourcing water from the Murrumbidgee to transfer to Googong Dam; (Section 10) and

5. Enlarged Cotter Dam Impoundment Dates (Section 10) changed from impounding of water whilst the dam is under construction to water is only impounded when the construction is complete

Population growth

The Australian Bureau of Statistics (ABS) released population projections for the ACT and surrounding areas in September 2008. ABS provides three sets of population projections based on different assumptions — low, medium and high population projections. ACTEW plans on the basis of high population projections because the lead times for major infrastructure require system changes to be planned well in advance. The high population projection estimates a water supply population of ~500,000 by 2023.

Climate variability and climate change.

ACTEW accepts that climate change is happening and that future climate is uncertain. Since 2003, it has largely planned on the basis of two stochastic climate scenarios based on historic observations and adjusted for climate change. The stochastic basis provides a range of different inflows, including longer and more severe droughts than have been observed in the past. The adjustment is based on CSIRO's 2003 forecasts of climate change impact on rainfall and evaporation for the ACT for the years 2030 and 2070. The stochastic data is modelled as 200 different "sub-scenarios", each of 50 years duration, to produce a range of modelling results.

Whilst currently under review, to this date ACTEW has used the dry case of projections produced by CSIRO in 2003 (9% decrease in rainfall and 9.1% increase in evaporation), scaled over the seasons. Inflows experienced in nine of the last 14 years have been below the CSIRO low estimate of the average inflow sequence by the year 2030. However, during the latter half of 2010, much of eastern Australia experienced high rainfalls due to one of the strongest La Ninãs in recorded history. This is consistent with ACTEW's planning assumptions; the inflows from the past 17 years (1994 – 2010 inclusive) are now more closely aligned with the average inflows of ACTEW's most pessimistic 2030 scenario for inflows.

Climate projections are currently being updated to incorporate more recent climate science and select appropriate water supply planning scenarios. However, the forecast range of future climate has not changed significantly since 2003 and the climate assumption used to date remains a valid dataset for ACT water supply planning.

Environmental flows

The Environment ACT *Environmental Flow Guidelines* (2006) sets out the requirements for ACTEW to release environmental flows. The Guidelines are due to be reviewed five years after publication and if changes occur; major modelling assumption changes will also be required.[1]. The draft *Environmental Flow Guidelines* (2011) has been released. At this stage, there is no change to the proposed environmental flow regime.

The environmental flows associated with new major infrastructure projects have not yet been formally specified.

The following minor amendment was made to the infrastructure and the system operating rules.

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

1. A change in environmental flow requirements at the Murrumbidgee River (Section 6) at Cotter Pump Station from a minimum of 20ML/d during restrictions to 80th or 90^{th} percentile inflows (dependent on the time of year);

Bushfire impact

Bushfires can have significant impact upon catchment yield. As ACT catchments recover from bushfire their water yields have been assessed by detailed vegetation modelling to drop by a likely 15% at peak reduction. 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.

The impact of bushfires is incorporated into the modelling in two ways:

1. By adjusting inflow estimates by a "yield reduction curve" to account for the (potential 15%) reduction in inflows generated by regrowth from the 2003 bushfires
2. Triggering bushfires within the catchment when particular conditions are met. This then resets the "yield reduction curve"

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.

Water Demand

A demand model is used to calculate monthly per capita water demand for Canberra, calibrated on monthly Canberra Airport rainfall and evaporation data on the current and previous day and the net evaporation over the three weeks leading up to the current day.[2]

In addition, an "End Use Model" is used to evaluate the potential impact of potable demand reduction policies and programs by disaggregating the demand to sectors and appliance types.

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

Level of Service 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. ACTEW measures two criteria:

(i) time in temporary water restrictions, and

(ii) net economic benefit.

Time in restrictions is a customer level of service target. The ACT government has specified a "one year in twenty" time in restrictions target.

Net economic benefit assesses whether the avoided economic cost of water restrictions is greater than the cost of building and operating any new infrastructure or administering a demand management program. If it is, then it is appropriate to undertake the proposed suite of projects or programs.

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

Conclusion

Changes made to assumptions and modelling during 2010/11 have been relatively minor. The effect of these changes on the probability of water restrictions is shown in Figure 1.

1. The modelled capacity of Cotter Pump Station decreased from 4275ML/month to 2565ML/month; (Section 9)
2. Incorporation of a one month annual shutdown at Stromlo Water Treatment Plant in autumn; (Section 9)
3. Reduction of the capacity of Stromlo Water Treatment Plant when sourcing water from the Murrumbidgee from 250ML/d to 100ML/d; (Section 9)
4. The introduction of Water Quality Rules that restrict the transfer of water from the Murrumbidgee to transfer to Googong Dam to when the water in the Murrumbidgee is within the Australian and New Zealand Guidelines for Fresh and Marine Water; (Section 10)
5. Enlarged Cotter Dam Impoundment Dates (Section 10) changed from impounding of water whilst the dam is under construction to water is only impounded when the construction is complete and
6. A change in environmental flow requirements at the Murrumbidgee River (Section 6) at Cotter Pump Station from a minimum of 20ML/d during restrictions to 80th or 90th percentile inflows (dependent on the time of year) (Section 3);

Additionally, the initial storage levels for the assumptions were also changed (60% in 2010 to 100% in 2011). This has decreased the probability of any level of water restrictions in the first few years of the model run for the 2011 assumptions compared with the 2010 assumptions.

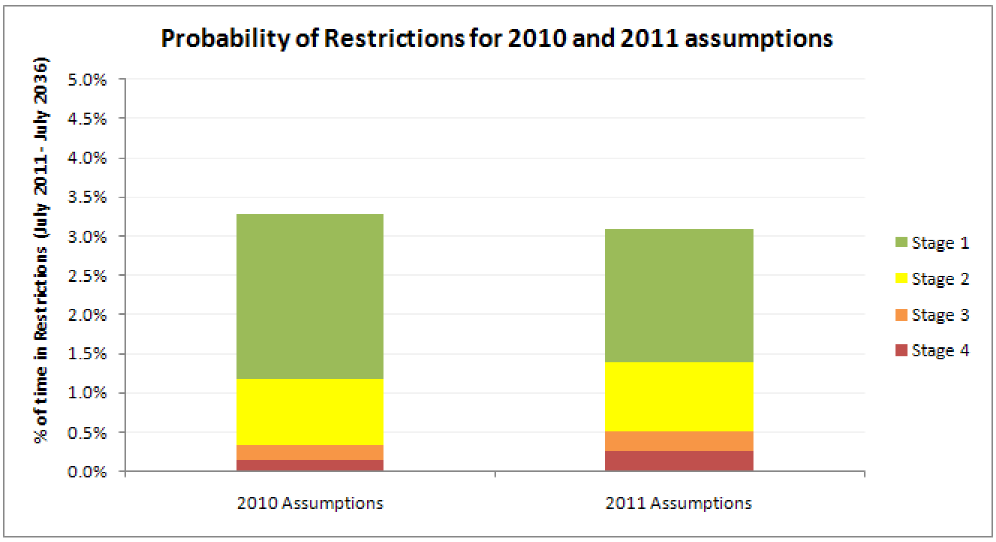

Figure 1: Probability of Restrictions for 2011 - 2036 under each set of assumptions

For other assumptions, data has been updated and brought forward to the present day. This is reflected in the values in the tables and graphs throughout this document.

The greatest uncertainty remains the future ACT climate and while the current methods used by ACTEW 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.

1 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[3]:

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 provides an overview of modelling assumptions and discusses changes made since the 2010 *Review of Planning Variables*[4].

The methods used to analyse the water supply system are described in Section 2. Infrastructure has been described in Section 3 and planning assumption trends described in Sections 4 to 9.

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

Managing with uncertainty

One of the most difficult elements in managing water supply security for a community is dealing with uncertainty. Uncertainty pervades the field of water supply planning as few variables are certain. All calculations have to be undertaken knowing that there will be some level of risk in the calculations, caused by one or more underlying assumptions being uncertain. As more assumptions are considered in any plan, the greater the level of the uncertainty as errors multiply (although it is likely that some errors will cancel each other out). Predicting the size of any model's error is partly art, as well as science.

The advent of climate change has significantly increased uncertainty in water planning. Climate change is the 'elephant in the room', and yet it cannot be predicted with any certainty where the elephant will step.

Water availability is heavily dependent on climate, and there is compelling evidence that climate is changing across the world. Inflows into ACT storages were below the long term average from 1994 to 2010. (See Chapter 5, figure 5) From 2001 to 2009 they were 63% below the long term average.

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

[4] ACTEW, *2010 Annual Review of Planning Variables for Water Supply And Demand Assessment: A review of the changes in water resources modelling assumptions*, July 2010

Current climate change interventions proposed across the globe are unlikely to have a sufficient impact in time to prevent impacts on water availability in the near future.

Climate change is expected to result in higher intensity rainfalls and floods. This can lower water quality through increasing erosion or washing of pollutants into streams and reservoirs. Additionally there is expected to be a lower overall availability of water particularly in the south-eastern areas of Australia.

Such projections, even though uncertain, mean that water planners have to make assumptions which incorporate even larger potential error possibilities than in the past.

> *The impacts of future climate change on the water sector will be very complex and at least partly unpredictable. While progress has been made in recent years on the development of probabilistic climate change projections, the available methods are simplistic and incomplete. Therefore, it is premature to make definitive statements about the levels of uncertainty (or confidence) in climate change impact assessments.*[5]

One way of handling uncertainty is not only to forecast future water supply but to supplement this approach with scenario planning.

> *Scenarios, sets of equally plausible futures, differ from forecasts, which are individual interpretations of a most probable future based on extrapolations of the best available information. Scenarios are not forecasts. Because the real world is so complex, forecasts are often wrong — especially those involving a time horizon of twenty years or more.*[6]

ActewAGL and ACTEW have commenced scenario planning and this will help supplement the current modelling being undertaken in future years.

[5] Bates BC, Walker K, Beare S & Page S, *Incorporating climate change in water allocation planning*, Waterlines report, National Water Commission, May 2010

[6] UN World Water Development Report 3: *Water in a Changing World*, World Water Assessment Program 2009.

2 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 in the past 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 such conditions). However, it has two major drawbacks. Firstly, it does not consider climate change. Secondly, it is inevitable that some future events more severe than those experienced during the period of record will occur, regardless of the influence of climate change. For these reasons historical record data analysis is not ideal for assessing system performance; and is no longer used by ActewAGL or ACTEW for this purpose.

Stochastic analysis

Stochastic data is 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 rainfall and evaporation data. The stochastic analysis used by ActewAGL and ACTEW 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 (i.e. two scenarios are run, one with 2030 or 2070 climate and one with current climate). This step change assumption accounts for the possibility that the low inflows experienced in recent years represent a change in climate type, rather than a dry period in an unchanged climate. Canberra climate change data has been created by altering rainfall and evaporation by climate change factors developed by the CSIRO.

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), although 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 reliability criteria to assess system performance.

3 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 or directly increase storage. The transfer does 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 Water Treatment Plant (WTP). The Murrumbidgee was first used for supply in May 2007. This supply can be used under a wider range of water quality conditions since the installation of ultraviolet (UV) treatment facilities at Mount Stromlo WTP in 2004.
- **Mount Stromlo WTP Upgrade** — A new water treatment plant has been built at Mount Stromlo capable of treating approximately 250 ML/day.
- **Googong WTP 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.
- **Murrumbidgee Recirculation** — The baseflow component of the environmental flow from Cotter Dam can be supplied using Murrumbidgee River water. This reduces the need to release water from the dam.
- **Cotter Precinct Work** — Addition of an extra pump and construction of a new pipeline under the Murrumbidgee
- **Purchase of water licences** – Purchase of approximately 16GL of water from irrigators in a combination of high and general security licences

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 currently under construction and it is expected that this project will be completed during 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 2012.
- **Tantangara –** pursuing mechanisms to store purchased water in Tantangara Dam with targeted release to allow for transfer to the ACT system.

4 Population Growth

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

Other factors influence demand, including demand management programs, changes in demography and housing type. These are considered later.

In the medium to long term, population is 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 and the Australian Bureau of Statistics (ABS) releases high, medium and low growth projections from time to time, most recently in September 2008[7]. The ABS also provides regular updates of ACT Estimated Resident Population[8]. 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[9]. Figure 2 shows the observed ACT population and the 2008 ABS population projections. ActewAGL and ACTEW base their population modelling on ABS data.

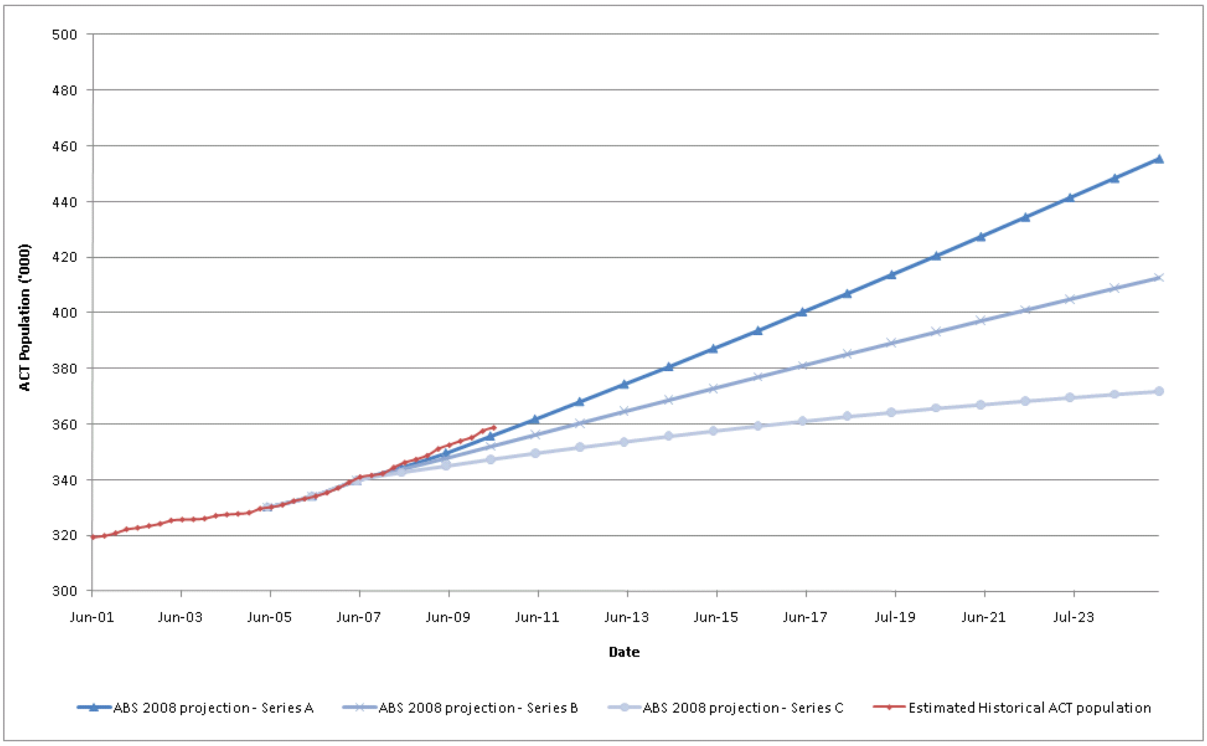

Figure 2 – ACT Preliminary Estimated Resident Population, Compared with Low, Medium and High Growth Forecasts

[7] Australian Bureau of Statistics, *3222.0 - Population Projections, Australia, 2006 to 2101*, 4th September 2008
[8] 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
[9] 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

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. Figure 3 shows the projected total population served by Canberra's water supply system, including supply to Queanbeyan and to Yass from 2015.

Growth rates in recent years have been above the high ABS projection from 2008. The projected total population has been modified to include the most recent estimates of the ACT population.

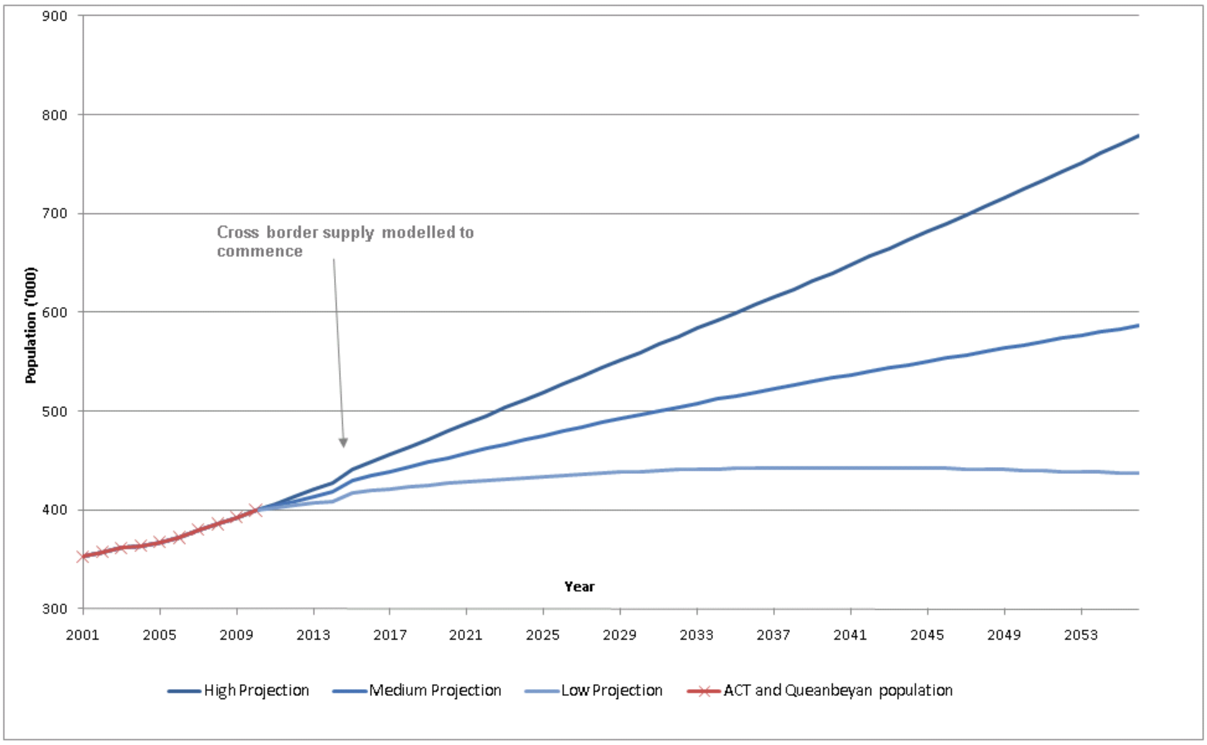

Figure 3 – Canberra Region Water Supply Projected Population

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"[10]. 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."[11]

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

Additional cross-border supply

The inclusion of regional supply (specifically Yass) in future water supply planning is recommended in *Think Water, Act Water*[12]. 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.

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

- 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[13]. Goulburn's supply will be augmented by a pipeline linking Wingecarribee Reservoir to the Goulburn Water Treatment Plant to be completed in 2011[14]. 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.[15]

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 allows Yass and Murrumbateman to be supplied from 2015, and assumes no other new cross-border supply. This finding will be reviewed regularly and whenever developments in regional water supply planning occur. For the 2010-11 planning year, these assumptions were still valid.

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 (1.6%) relative to Canberra's demand, and would therefore have little impact on ACT water security. The cross-border supply assumptions are not critical in relation to the assessment of the ACT's water security 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

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

[13] Yass Valley Council, 'Water Supply Strategy (http://www.yass.nsw.gov.au/roads/1932/2202.html http://abc.com.au/news/stories/2007/05/24/1931703.htm), 17th May 2011

[14] Highlands Source Project *Environmental Assessment (Volume 1) (2010)*

[15] 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

three of these projections may be used in sensitivity analyses, and in some modelling exercises the medium growth projection is used.

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:

> 2011 Canberra and Queanbeyan high population projection = 2009 Recorded Canberra and Queanbeyan population x 2011 ACT Series A value / 2009 ACT Series A Value= 402 826

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 3 and Table 1.

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 490,000, while the low projection is 418,000.

Table 1 – Forecast Water Supply Population

Year	Adopted Water Users Series		
	High	*Medium*	*Low*
2009	389 242	387 238	384 120
2010	396 034	391 914	386 793
2011	402 826	396 591	389 242
2012	409 840	401 267	391 580
2013	416 854	405 943	393 807
2014	423 869	410 508	396 034
2015	437 572	421 412	404 122
2016	444 918	426 045	406 156
2017	452 490	430 679	408 077
2018	459 948	435 312	409 998
2019	467 633	439 833	411 693
2020	475 318	444 353	413 388
2021	483 115	448 873	414 857
2022	491 026	453 281	416 327
2023	498 936	457 688	417 683
2024	506 847	462 095	419 039
2025	514 758	466 390	420 282
2026	522 668	470 684	421 525
2027	530 692	474 865	422 542
2028	538 716	479 047	423 559
2029	546 627	483 115	424 463
2030	554 650	487 070	425 254
2031	562 561	491 026	426 045
2032	570 585	494 868	426 610
2033	578 495	498 597	427 175
2034	586 406	502 327	427 627
2035	594 430	505 943	427 967
2036	602 340	509 446	428 306
2037	610 251	512 950	428 532
2038	618 275	516 453	428 645
2039	626 298	519 843	428 758
2040	634 435	523 234	428 758
2041	642 459	526 624	428 758
2042	650 708	529 901	428 645
2043	658 958	533 178	428 532
2044	667 208	536 569	428 306
2045	675 570	539 846	428 080
2046	684 046	543 123	427 740
2047	692 522	546 400	427 514
2048	701 111	549 678	427 062
2049	709 812	552 842	426 723
2050	718 514	556 119	426 271

How recent growth compares to projected growth

Figure 4 compares the ACT population growth observed in the past three years[16] with projected growth.[17] In all three years 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;
- the most accurate population data are only obtain every five years from censuses, so there is uncertainty in the population figures reported annually;
- 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 (570 000 compared to 500 000, 490 000 compared to 430 000).

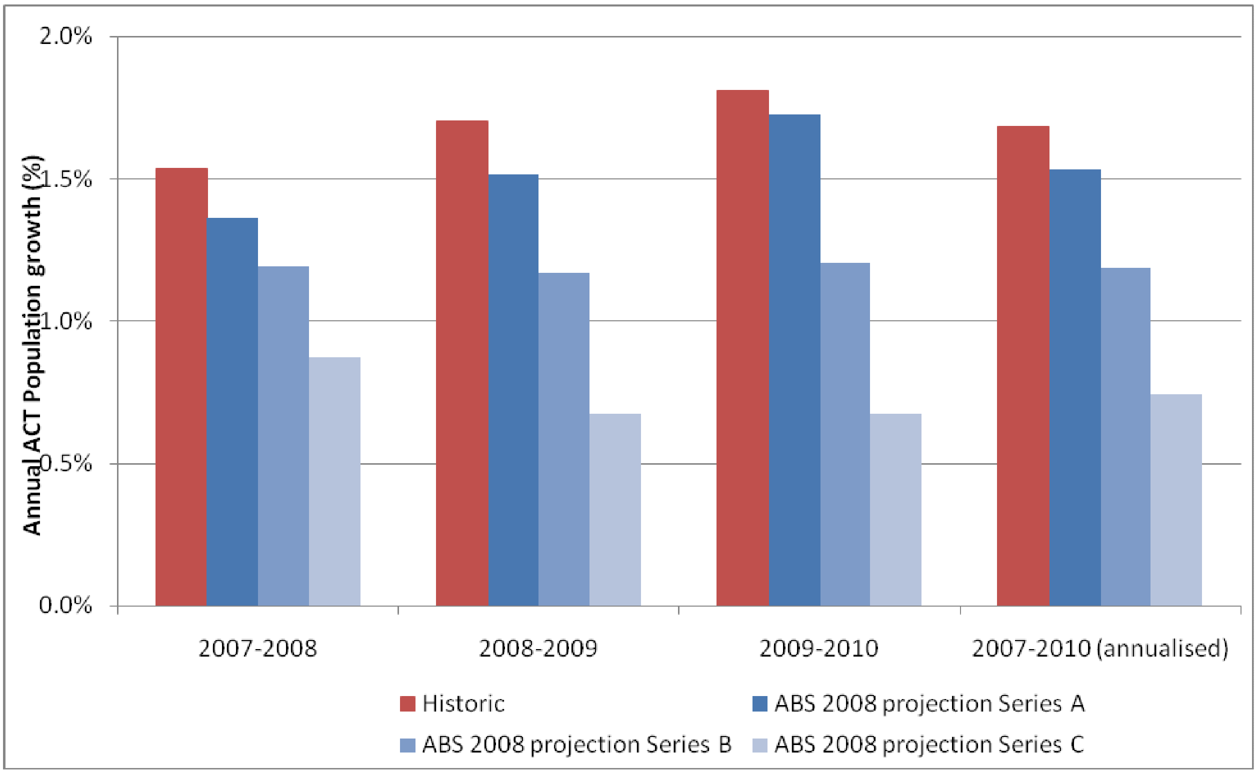

Figure 4 – Recent Population Growth Compared to Projected Growth

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[18]. This demonstrates both the potential error in all population forecasts and the need to consider possible future trends when compiling population projections.

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[16] Australian Bureau of Statistics, *3101.0 - Australian Demographic Statistics* (http://www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0), latest version released 26th March 2011

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

[18] *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.[19] 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 significantly slower growth 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.

ACTEW uses the high population growth rate, with population to reach 500,000 by around 2023, and by 2030 the population is projected to reach 554,000. A small (1.6%) cross-border supply is currently included in future population estimates, but this has negligible impact on water security for the ACT.

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

5 Climate Variability and Climate Change

It is generally accepted that global warming is occurring. Paleoclimatic studies confirm that the increase 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.[20] 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 indicate 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 20 30, and 1–6℃ by 2070. Average precipitation in southwest and southeast Australia is projected to decline further in future decades…*[21]

Further:

> *Climate model projections for the coming decades indicate an increasing risk of below average rainfall for southern and eastern mainland Australia, higher temperatures and evaporation, and below average runoff. In particular there is a significant projected increase in frequency of extremely hot years and extremely dry years.*[22]

Responsible water supply planning must include the 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 period natural events such as the Pacific Decadal Oscillation, Inter-decadal Pacific Oscillation, the Southern Annular Mode, the Sub Tropical Ridge and El Nino Southern

[20] Intergovernmental Panel on Climate Change, *Fourth Assessment Report*, 2007
[21] 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
[22] CSIRO, *Climate Variability, Climate Change and Drought in Eastern Australia,* 22 Jan 2010 (http://www.csiro.au/science/climate-and-drought-in-eastern-Australia.html#1) Accessed 21 May 2010
[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

Oscillation[24]. A recent review of rainfall and temperature sites across the Murray-Darling Basin found that all of the systems showed significant and varying trends through time.[25]

ACT has only 140 years of recorded *historic climate* data. Although this period of historic record covers three major droughts, 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, ACTEW has extended its historic climate record by using a standard hydrological methodology to create a longer period of stochastic climate data as described in Section 2[26]. The generated historic stochastic climate data is referred to as the *1990 stochastic climate* scenario as it is based on the climate conditions occurring in the 13 years either side of 1990.

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 Eastern Australia drought partly represents a shift in climate for Canberra. The 5 to 10 years to January 2010 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 ten years are also lower than the average inflows generated with 2030 stochastic data (87 GL/year compared to 105 GL/year). On average, a five-year period worse than the five years (2004 – 2009) would occur once every 19 years in the stochastic data modified to include the 2030 climate change projections. Therefore, the last few years would be a drought even with predicted climate change. The inflows to Googong during this period are especially low when compared to the historic record or the stochastic data. The CSIRO climate change report comments that:

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

The recent 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 5 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 recent drought, appear relatively similar to the 1871-1950 portion of the period of record, although the recent drought is more severe.

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[24] Kiem et al., *Water Resource Management in a changing Climate – Can we afford for climate models to give us the answer?* Practical Responses to Climate Change, October 2010

[25] Kamruzzaman, M., Beecham, S. and Metcalfe, A. V. , *Non-stationarity in rainfall and temperature in the Murray Darling Basin*. Hydrological Processes, n/a. doi: 10.1002/hyp.7928

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

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

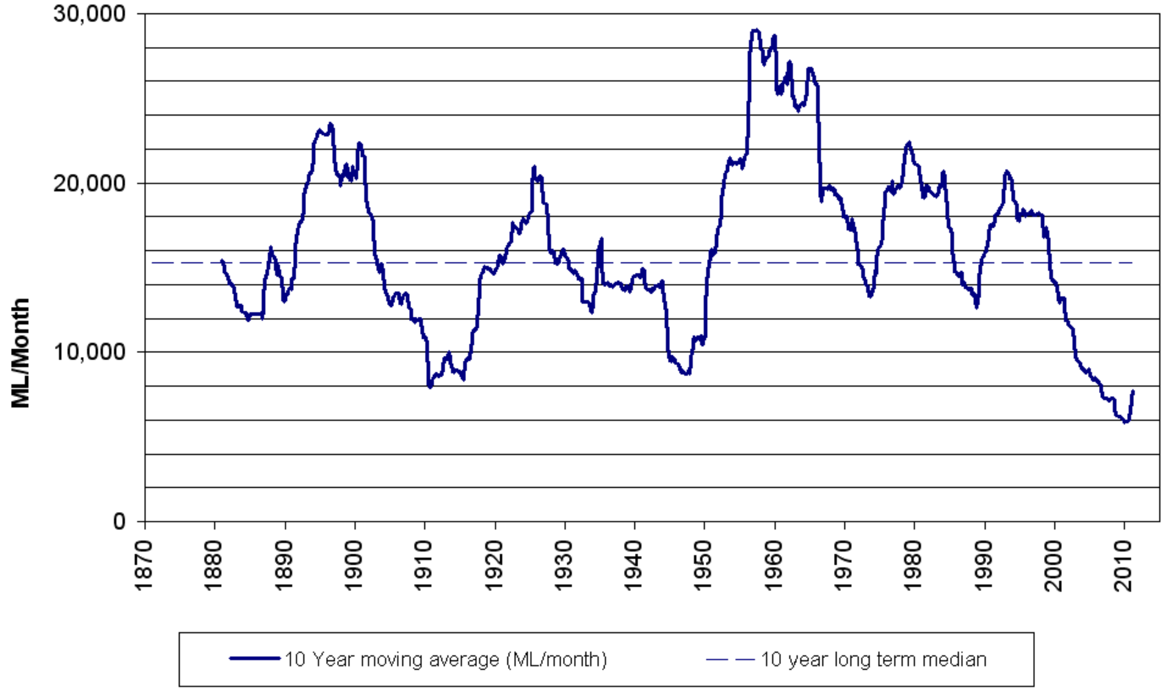

Figure 5 – Moving Average Inflows to Corin, Bendora and Googong Dams

While it is not certain 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 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. [28]

More recently, the synthesis report from phase 1 of the South Eastern Australian Climate Initiative (SEACI) concluded that the recent drought was unprecedented, and concluded that the recent rainfall decline could be attributed to climate change.

• *The current rainfall decline is at least in part attributed to climate change, raising the possibility that the current dry conditions may persist, and possibly intensify, as has been the case in south-west Western Australia.*
• *It is prudent to plan for conditions that are likely to be drier than the long-term historical average conditions because the current drought appears to be at least partly linked to climate change and climate model projections of a drier future across the south-east.*[29]

The quantity of the effect of climate change will be addressed in future phases of the SEACI program.

[28] Bates et al., *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003
[29] CSIRO (2010) Climate variability and change in south-eastern Australia: A synthesis of findings from Phase 1 of the South Eastern Australian Climate Initiative (SEACI)

Climate change predictions used in current modelling

There are a number of challenges to incorporating climate change in stochastic modelling. These include:

a) the selection of a suitable climate baseline to compare and update climate change predictions;
b) the selection of a suitable climate change scenario and
c) the selection of a suitable method for incorporating the selected climate change scenario into the selected climate baseline.

Choice of Baseline

The selection of a suitable climate to compare and update the climate change predictions is predicated on the assumption that the climate is stationary – that is, that the climate does not change over time. Recent studies30 have challenged this assumption with SEACI finding that characterising the climate baseline was of primary interest to the stakeholders.

> *Over recent years, this assumption of stationarity has been challenged by the persistently dry conditions, which raises the issue as to whether the baseline climate (as previously defined by the historical record) is changing….As a consequence, a primary interest has been in characterising an appropriate baseline climate to which climate change projections (which are expressed as percentage changes relative to the baseline) can be applied.* [31]

The Intergovernmental Panel on Climate Change Fourth Assessment Report is compared to the baseline climate of 1980 – 2000 (called the 1990-centred) climate.32 For consistency, ACTEW has adopted a 1990-centred climate as the baseline.

Selection of Climate Change Scenario

Predictions of the effects of climate change are generated from General Circulation Models (GCMs, also known as Global Climate Models), which theoretically simulate all ocean-atmospheric circulation patterns and their interactions. These will allow for the production of estimates that vary with both emissions scenarios (in line with the IPCC projections), and the time at which such projection is usable.

However, using GCM's for regional impact assessment introduces limitations and uncertainties as they do not accurately reproduce many of drivers (synoptic and otherwise) which are known to influence Australian rainfall. Additionally, as climate models output is delivered in coarse grids on an annual, they are limited in their ability to simulate regional scale processes at subannual time-steps. Kiem and Verdon-Kidd (2010) have summarized these in a recent paper.

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[30] M. Kamruzzaman, et al (2011) *Non-stationarity in rainfall and temperature in the Murray Darling Basin* Hydrological Processes 25:10:1659–1675

[31] CSIRO (2010) *Climate variability and change in south-eastern Australia: A synthesis of findings from Phase 1 of the South Eastern Australian Climate Initiative* (SEACI)

[32] Intergovernmental Panel on Climate Change, *Fourth Assessment Report*, 2007

In short climate models are designed for testing theories about our understanding of global or continental scale climate processes and they are a useful tool for doing this. However, current climate models are not designed for application at the regional scale and, even with sophisticated downscaling techniques, serious questions remain as to the applicability of climate model outputs to quantifying the risk of hydrological extremes (e.g. drought, flood, bushfire) given that most of the critical factors that drive these extremes are not well simulated by the models[33].

One of the effects of this is that there is a large variation projected outcomes for hydrological parameters. Some of the climate model runs will project increases in precipitation in the 21st Century, while others project substantial decreases in precipitation. The CSIRO Technical Report on climate change in Australia explicitly makes this point.

Different models may therefore simulate somewhat different rainfall changes. As in the CSIRO (2001) projections, it will not be possible to make definitive statements on the direction of precipitation change in many cases[34]"

Projected hydrological impacts of various climate change scenarios have changed little with time Climate change predictions for the ACT were obtained from the CSIRO by ACTEW in 2003.[35] These project an annual change in precipitation from a 9% decrease to a 2% increase for 2030. The current projections from a range of climate models for the ACT predict an annual change in precipitation from a 10% decrease to a 2% increase for 2030.[36] The overall projections are therefore substantially, unchanged, although improvements in regional downscaling and seasonal resolution may produce slightly differing results.

Current Climate Scenarios

Climate change predictions for the ACT were obtained from the CSIRO by ACTEW in 2003[37]. The range of predicted increase or decrease in rainfall and evaporation by 2030 for each season is shown in Figure 6**Error! Reference source not found.**. 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%. As noted above, this is a similar range to that produced by the climate models today.

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. 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.

[33] Kiem Anthony Stuart, Verdon-Kidd Danielle Cherie, 'What resource management in a changing climate - Can we afford to wait for the climate models to give us the answer?', *Practical Responses to Climate Change Conference 2010*, Melbourne, VIC (2010)
[34] *Chapter 5 Climate Change in Australia: Technical Report*, CSIRO (2007) accessed from http://climatechangeinaustralia.com.au/technical_report.php on May 2011
[35] Bates et al., *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003
[36] http://climatechangeinaustralia.com.au/nswactrain1.php, accessed 19 May 2011
[37] Bates et al., *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003

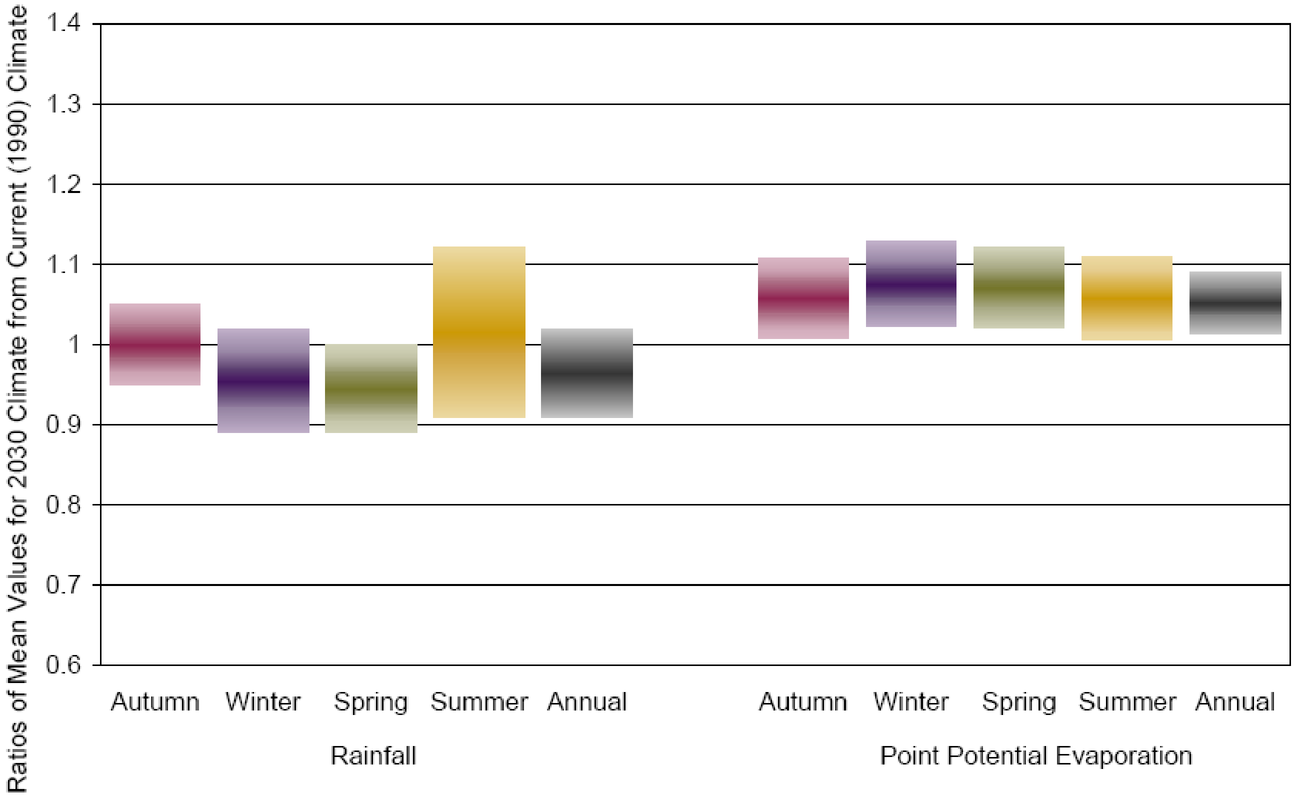

Figure 6 – CSIRO Predicted 2030 Seasonal Rainfall & Evaporation Variability

Table 2 – Projected, Modelled (ACTEW "most likely" case) and Observed Climate Change[38]

	Change in Rainfall				**Change in Evaporation**			
Season	CSIRO Projected Worst Case	CSIRO Projected Best Case	ACTEW "most likely" case	Observed Since 2001	CSIRO Projected Worst Case	CSIRO Projected Best Case	ACTEW "most likely" case	Observed Since 2001
Summer	-9%	12%	-8.9%	15.3%	11.0%	0.5%	8.7%	-1.7%
Autumn	-5%	5%	-4.9%	-43.7%	10.8%	0.8%	8.5%	3.3%
Winter	-11%	2%	-10.9%	-2.4%	12.8%	2.2%	10.5%	2.7%
Spring	-11%	0%	-10.9%	-10%	12.0%	2.1%	9.7%	7.0%
Annual	**-9%**	**2%**	**-9.0%**	**-10.1%**	**9.1%**	**1.4%**	**9.1%**	**3.0%**

Table 2 also shows the change in rainfall and evaporation observed since 2001, calculated by comparing the average Canberra Airport rainfall and evaporation since 2001 with the historical record (1967-present) Airport rainfall and evaporation. These results are for a ten-year period, but could indicate a permanent climate change trend. Evaporation is higher than the long-term average for three of the 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.

In its current modelling ACTEW adopts the most likely current climate to be the CSIRO 2003 most pessimistic predictions of the change in rainfall and evaporation by 2030 (9% decrease in rainfall and 9.1% increase in evaporation), scaled proportionally to the most pessimistic estimate for each season.

[38] To end of February 2011

This produces a climate sequence that is significantly drier than the period of record but, on average, wetter than the recent drought period. These changes have been applied to the *1990 stochastic climate* scenario to produce a *2030 stochastic climate* scenario. This is the approach recommended by the Australian National University.

Given the present scientific evidence for and understanding of the recent rainfall decline and temperature increases in the ACT region, and the impact that climate change could have on rainfall and water availability in the region, it would be prudent for ACTEW to include the currently available worst-case scenarios for reduced rainfall in planning for the future water needs of the region.[39]

Figure 7 shows flow duration curves for the historical record and climate change stochastic inflow sequences. The 2030 climate stochastic inflow (ACTEW "most likely" case) is significantly lower than the historic inflow sequence, reflecting the reduction in rainfall and increase in evaporation assumed.

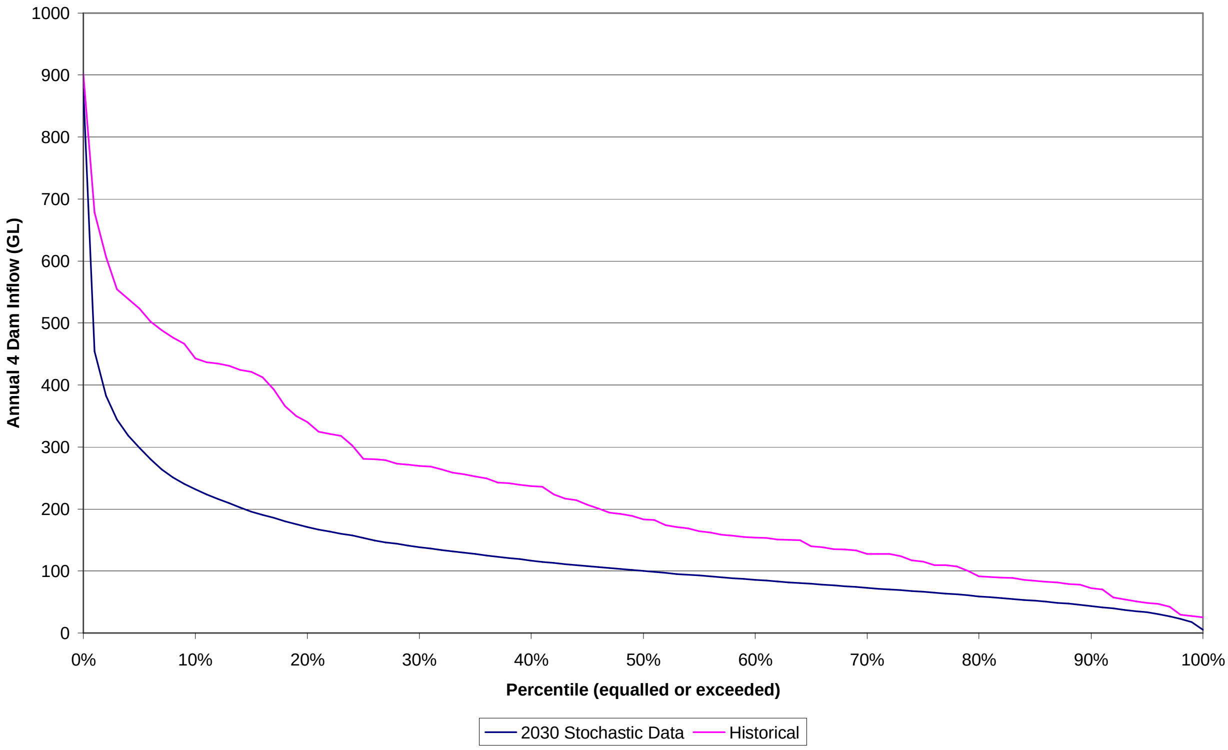

Figure 7 – Storage Inflow Duration Curves

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 ACTEW "most likely" case. 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.

[39] Davis, C. & Lindesay, J (2010). *A review of weather and climate drivers of rainfall in the Canberra Region*, Report commissioned by ACTEW

Table 3 – Minimum Storage Inflows (GL/yr) for Various Durations

Duration	Historic	Stochastic - ACTEW "most likely" case	% Difference
1 Year	18.2 (to 1902)	3.6	80%
2 Years	46.8 (to November 2007)	10.7	77%
3 Years	50.4 (to June 2009)	17.2	66%
4 Years	52.7 (to February 2010)	24.4	54%
5 Years	69.4 (to February 2010)	26.3	62%
10 Years	86.8 (to February 2010)	43.2	50%

Proposed Climate Scenarios

ActewAGL on behalf of ACTEW are currently revising the climate projections for use in future modelling work. This involves obtained a range of more recent climate projections, utilizing these to produce stochastic climate data and generating inflow and demand projections. These projections are currently being evaluated for their suitability for water supply planning. It is expected that new climate scenarios will be adopted in the 2011/12 financial year.

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 ACTEW "most likely" case.

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 dramatic for Googong Dam, with a 71% reduction in inflow and even the lowest reduction (for Corin Dam) is a 32% fall in inflows. 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 (GL/year): Long Term, Recent and Climate Change Stochastic

Dam	1871-2009	1994-2010	Last 10 Years	ACTEW "most likely" case
Corin	59	45.5	40	40
Bendora	38	21.7	20	23
Cotter	39	24.1	21	19
Googong	93	34.5	27	42
Corin, Bendora & Googong	187	101.6	87	105
4 Dams	229	125.7	109	123

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

Dam	1994-2010	Last 10 Years	ACTEW "most likely" case
Corin	30%	32%	32%
Bendora	43%	47%	39%
Cotter	38%	46%	52%
Googong	63%	71%	54%
Corin, Bendora & Googong	47%	54%	44%
4 Dams	45%	53%	46%

It is clear that the recent average flows are not only much lower than the historical record average, but are also lower than the ACTEW "most likely" case. It is unclear how much of the inflow decline in this period can be attributed to climate change and how much can be attributed to a temporary drought. The ACT is historically prone to extended droughts, so it is not reasonable to assume that the climate experienced since 2001 is typical of the ACT's future climate. However, it is possible, even probable, that the recent drought conditions are symptomatic of a permanent shift to a drier climate, although the magnitude of the shift is difficult to determine. Climate scientist Bertrand Timbal of the Bureau of Meteorology notes in a discussion of South-Eastern Australian rainfall that:

> *This change in the relative contributions by the autumn and spring seasons now more closely resembles the picture provided by climate model simulations of future changes due to enhanced greenhouse gases. However, the growing magnitude of the rainfall decline is far more severe than any of the IPCC-AR4 model projections except for the lowest deciles from the model uncertainty range, forced with the highest emission scenarios occurring later in the 21st century (2050 to 2070).*[40]

In summary, recent climate (last 17 years, 1994 - 2010) has an average inflow close to the ACTEW "most likely" case of CSIRO 2030 climate. Whilst this is not proof of a permanent shift in climate, or that there is not such a shift, ACTEW considers that 17 years of recorded low inflows makes it prudent to plan as if a permanent shift in climate took place in the ACT in around 1994. The four year's inflows from 2006 to 2009 averaged below the very severe 2070 climate average inflow. If inflows return to this level then ACTEW may need to revise its projection of "most likely" future climate downwards.

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 dam site (Corin, Bendora, Cotter, Googong). 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."[41] 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.

[40] Timbal, Bertrand (Bureau of Meteorology), *The continuing decline in South-East Australian rainfall: update to May 2009*, from P. A. Sandery, T. Leeuwenburg, G. Wang, A. J. Hollis (editors), CAWCR Research Letters, The Centre for Australian Weather and Climate Research: Issue 2, July 2009

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

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 higher than that experienced in the Gudgenby catchment, but not as severe as the reduction in the Molonglo catchment. Figure 8 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.

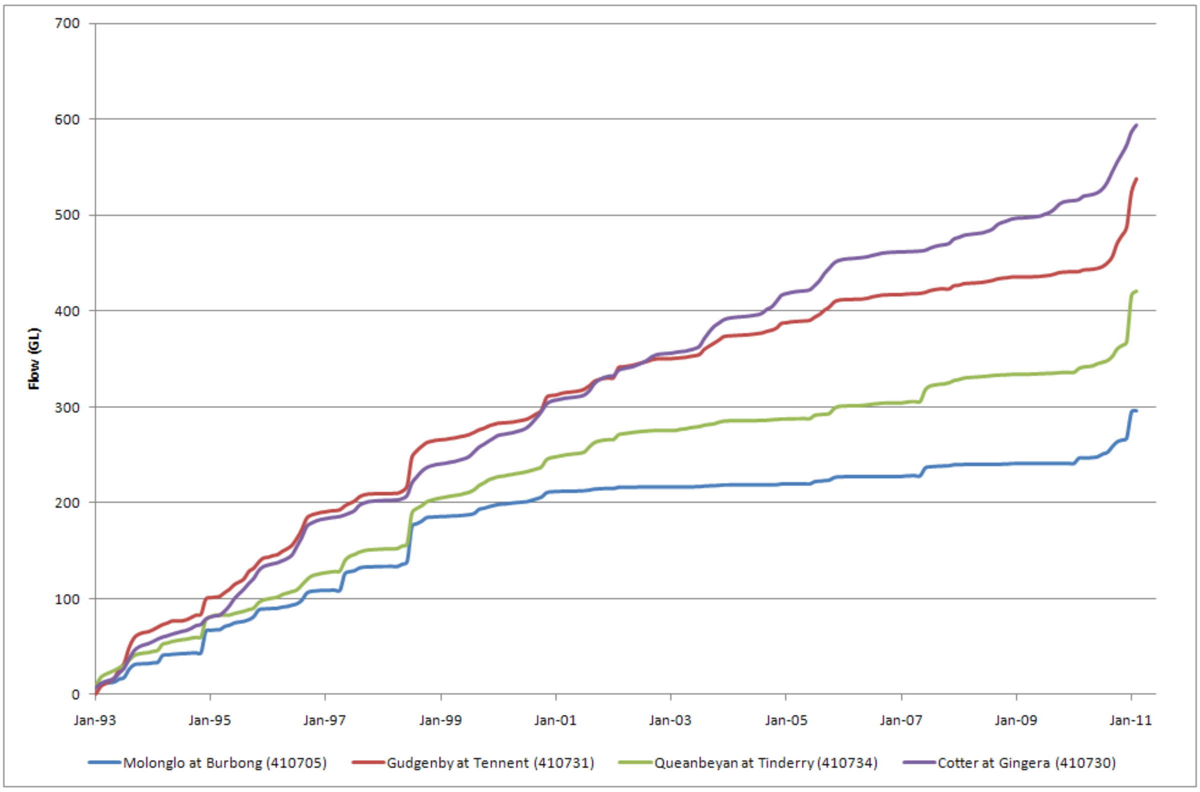

Figure 8 – Comparison of Cumulative Flows Since 1993 in Unregulated Catchments

Table 6 – Comparison of Average Inflows Before and Since 2000

	August 1966 to December 1999 (GL/year)	January 2000 to Feb 2011 (GL/year)	Reduction
Molonglo at Burbong (410705)	43.8	9.0	79%
Gudgenby at Tennent (410731)	68.6	23.2	66%
Queanbeyan at Tinderry (410734)	76.3	18.1	76%
Cotter at Gingera (410730)	46.5	29.3	37%

While the recent reduction in rainfall explains at least some of this reduction, the full cause is a matter of debate amongst hydrologists. ActewAGL has developed a new Googong Dam Rainfall Runoff Model that will be implemented in modelling from late 2011.

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.[42]

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.[43]

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

	Average Googong Inflow from January 2002 to December 2010 (ML/month)	Error
Observed	2298	
Current SimHyd Rainfall Runoff Model	3772	64%
SimHyd Rainfall Runoff Model Used in 2004/05 Future Water Options Work	5421	136%

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;[44] and
- Creating an in-house rainfall runoff model.[45]

In 2010 and 2011 ActewAGL performed a significant review of the SimHyd model to incorporate changes in the catchment. Simultaneously, ActewAGL was involved in the development of an integrated water resources-catchment modelling toolkit. As part of this toolkit, ActewAGL developed a rainfall-runoff model using Sacremento.

A comparison of these two models (the Sacremento model and the 2010/11 SimHYD model) with the SimHYD model currently in place[46] showed that both of these models outperformed the current model on both the long-term (1967-2009) basis and for the more recent 1997 – 2009 low-flow period.

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.

[42] 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
[43] ActewAGL, *Performance Of Existing SimHyd Models During Recent Drought Flows* (ActewAGL Document No. 322867), October 2007
[44] ActewAGL, *Performance Of Existing SimHyd Models During Recent Drought Flows* (ActewAGL Document No. 322867), October 2007
[45] ActewAGL, *Excel Rainfall Runoff Model for Googong Catchment* (ActewAGL Document No. 341454), April 2008
[46] ActewAGL, *Comparison of Googong Catchment Rainfall-Runoff Models* (ActewAGL Document No. 473644), May 2010

Conclusions

Given the recent drought and the potential impact of climate change, it is important to include climate change in water supply modelling. As new data and predictions relating to climate change become available, they will be incorporated into water supply modelling. However, assumptions relating to climate change have significant impacts upon results.

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.

6 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*[47]. A draft of the 2011 Environmental Flow Guidelines was released in June 2011. This has no changes from the current guidelines.[48]

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

Table 8 – Current 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	Smallest of inflow or 20 ML/day, plus riffle and pool flows; riffle flows to be managed on an adaptive management basis
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	Smallest of inflow or 20 ML/day, plus riffle and pool flows; riffle flows to be managed on an adaptive management basis
Cotter Below Cotter Dam (supplied from Cotter Dam)	15 ML/day (only supplied when M2C not operating)	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, Riffle flow required annually	Smaller of Inflow or 10 ML/day, 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.
2. Pool Flows are required once a year between mid-July and mid- October. Pool Flows may count as part of a Riffle Flow.

As part of the Infrastructure improvement program, it is now possible to provide base-flow environmental flow from the base of the Cotter Dam with water from the Murrumbidgee (known as the M2C), via recirculating pumps. There are four modes of operation of the M2C relating to the flow in the Murrumbidgee and any outflow (due to planned discharges or flooding events) from Cotter Dam. These guidelines are summarised in Table 9.

[47] Environment ACT, *2006 Environmental Flow Guidelines*, January 2006
[48] Environment ACT, 2011 *Environmental Flow Guidelines*, June 2011

Table 9 – Environmental Flow Requirements for the Murrumbidgee to Cotter

Operation Mode		**Discharge Requirements**
Standard Operation	Flow at Mount MacDonald >80ML/d	40ML/d for 28 days and 20ML/d for 1.5 to 2 days.
Low Flow (Murrumbidgee) Operation	Flow at Mount MacDonald greater than 20ML/d but less than 80ML/d	Daily Discharge to be ½ the flow at Mount MacDonald
Drought Flow (Murrumbidgee) Operation	Flow at Mount MacDonald less than 20ML/d	M2C is not operational.
High Flow (Cotter) Operation	Cotter is releasing water	As per standard operations
	Cotter is releasing Water >100ML/d	M2C can be shutdown, but must operate for 24 hours while Cotter is releasing water to allowing shandying of water.

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.* [49]

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 difficulty in differentiating between climate change and climate variability. For simplicity, and to be conservative, all modelling uses the specified historical 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 allows 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).[50]

From 2006 - 2010 *Licence to Take Water* significantly increased the volumes of water that can be taken from the Murrumbidgee River at the Cotter pump station during water restrictions, as shown in

[49] Environment ACT, *2006 Environmental Flow Guidelines*, January 2006
[50] Environment ACT, *2006 Environmental Flow Guidelines*, January 2006

Table 10[51]. Modelling has shown that this Murrumbidgee environmental flow rule significantly influences water supply system performance.[52] Environment ACT has advised that the environmental flow drought measures introduced from 2006 will not be continued long-term. Additionally, they have specified requirements for utilising the Murrumbidgee to substitute environmental flows downstream of Cotter Dam. These were outlined in Table 9.

Table 10 – Current Environmental Flow Requirements for the Murrumbidgee River at Cotter

	Normal	**Stage 1 Restrictions**	**Stage 2 Restrictions and Above**
Required Environmental Flow at Cotter Pump Station	the 80th percentile from November through May, 90th Percentile from June through to October.	the 80th percentile from November through May, 90th Percentile from June through to October	the 80th percentile from November through May, 90th Percentile from June through to October

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. ActewAGL and ACTEW have assumed in all modelling that the environmental flow requirements will be unchanged by the new infrastructure. A change in this assumption could significantly affect water supply security.

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, meaning that review is due in 2011.

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

[51] ACT Environment Protection Authority, *Licence to Take Water Under the* Water Resources Act 2007, 4th December 2008

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

7 Ongoing Bushfire Impact

Severe bushfire events modify catchment vegetation and have significant short and long-term impacts on catchment hydrology. Immediate impacts 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 9 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.

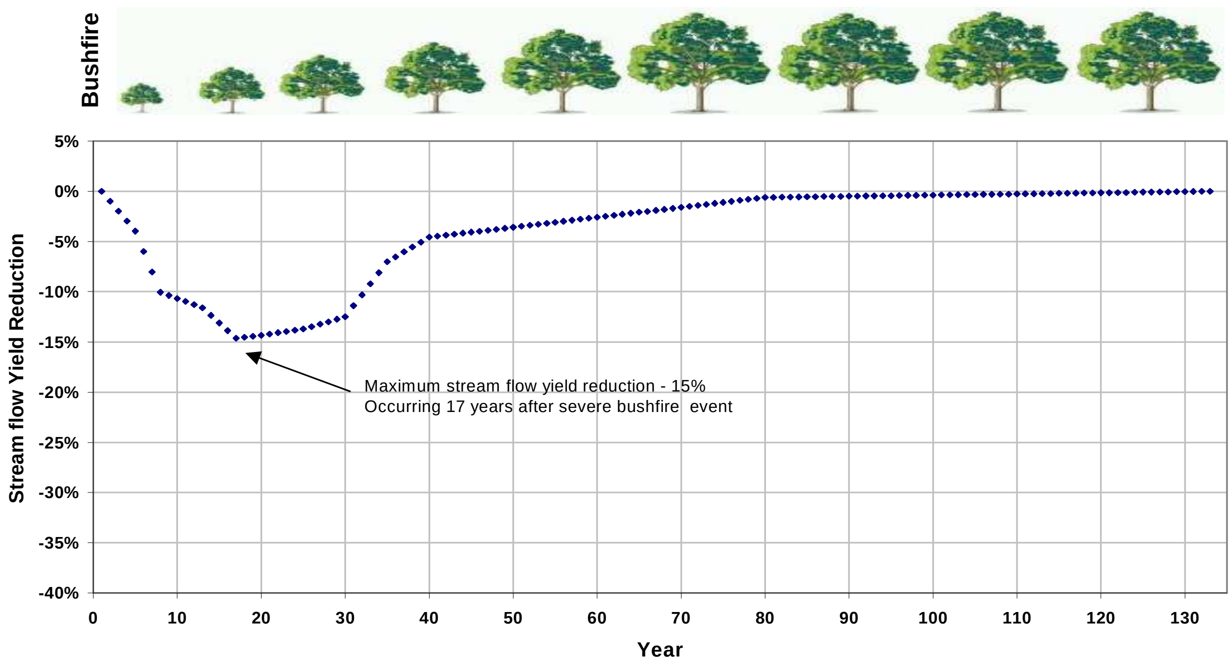

Figure 9 – Predicted ACT Severe Bushfire Yield Reduction Relationship

Ecowise Environmental was commissioned by ACTEW in 2008 to undertake a review of satellite imagery to assess the recovery of the vegetation types in the bushfire affected catchments and determine if the predicted yield reduction had taken place. The review found that the reduction in yield could not be ascribed to bushfire, because during the same period there had been a significant reduction in rainfall. ActewAGL and ACTEW have therefore concluded that at this stage there should be no change to current bushfire modelling yield reduction.

An opportunity to repeat this analysis may exist in 2011-12. The most discriminating satellite imagery can be obtained in the autumn, after a wet spring and summer. These conditions were satisfied with the 2010 inflows. However, the predicted yield reduction is greatest between 10 and 20 years after the fire and the long-term average effect of bushfires on total system performance within the model is small. Therefore, postponement of this analysis to sometime closer to 2013 may be more useful.

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 9. The time that has passed since the bushfires is taken into account: for example, a run starting in 2011 would begin 8 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 11 outlines the frequency with which each catchment experiences bushfire potential conditions and the recurrence interval of actual triggered bushfires for current climate and 2030 climate stochastic sequences.

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

Table 11 – 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 2-3 years after a fire are not directly representative of the yield reduction in later years. This occurs because the amount of tree regrowth does not peak until a significant time has elapsed since the fires. 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.[53]

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 10 is an indication of how the yield recovery could be influenced by this possible delay in regrowth. 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.

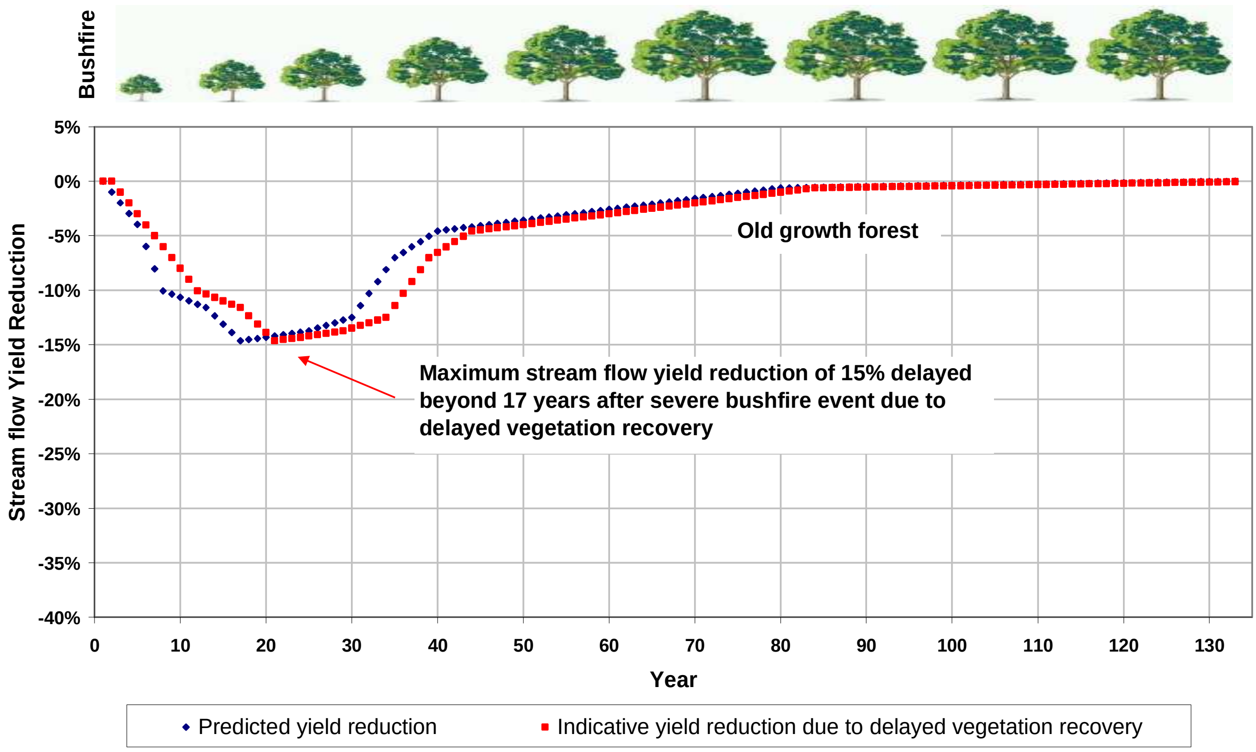

Figure 10 – Predicted ACT Severe Bushfire Yield Reduction Relationship

ActewAGL compared the bushfire trigger model with spatial based fire frequency modelling by ANU.[54] 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.

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

[54] ActewAGL, *Comparison between bushfire trigger model used by ActewAGL and ANU model (FIRESCAPE)* (ActewAGL Document No. 375489), December 2008

Conclusions

While 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, current assumptions regarding catchment yield reduction have been found to adequately predict actual yield, within the margin of error of observation. System performance is not impacted as significantly by bushfires as by other variables, such as climate change and variability, so the majority of resources should be directed to quantifying variables with more critical impacts.

8 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.[55] 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 11 displays the distributions of historical and stochastic annual demand.

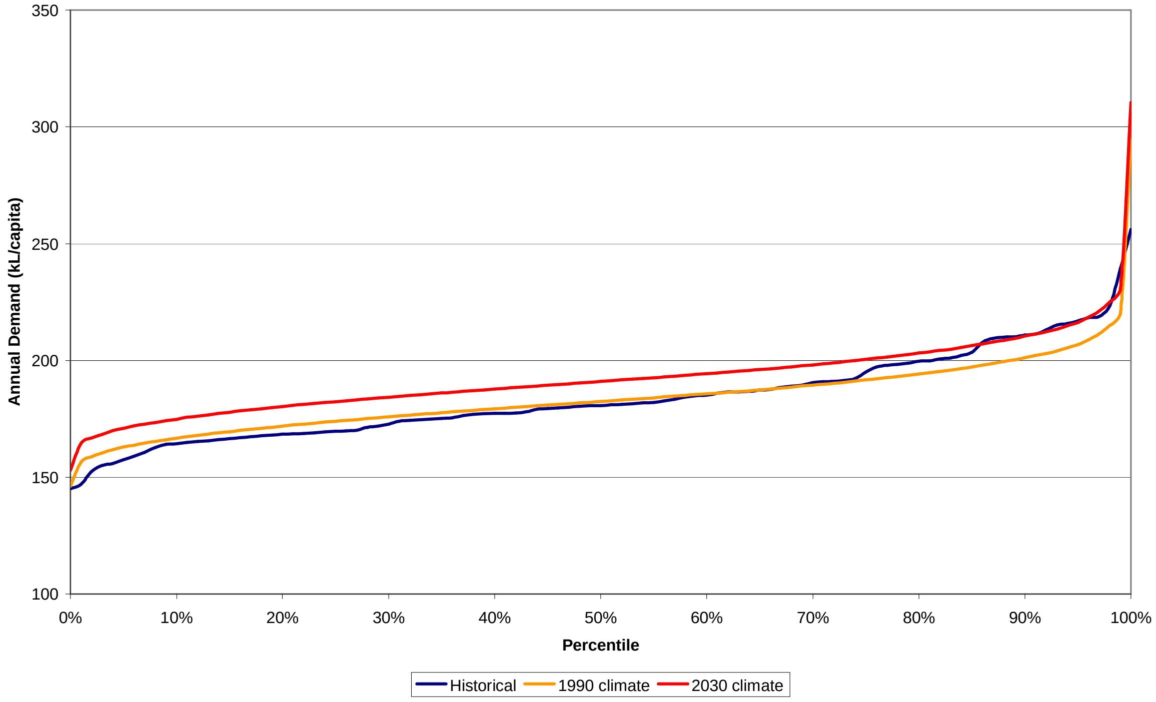

Figure 11 – Comparison Between Historical, Stochastic and Climate Change Stochastic Demand

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;
- effluent reuse;
- stormwater harvesting;

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

- 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 (e.g. rainwater tanks, greywater reuse, effluent reuse, stormwater harvesting) will be required to reach the 25% target.[56, 57] It should be noted, that water use to date under enhanced PWCMs has exceeded the 25% target. However, this is not expected to be maintained in the long term as some of this reduction is the residual effect of demand reduction after drought and a particularly wet summer.

The latest ACT Government progress report estimates that initiatives already implemented or committed to will deliver the demand reductions specified in Table 12.

Table 12 – Expected Demand Reduction from Measures Already Implemented or Committed to by the ACT Government[58]

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."[59]

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

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

ActewAGL and ACTEW have interpreted the demand reduction targets as meaning that the measured per capita consumption in (say) 2013 will be compared to the predicted consumption for 2013, and should be 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; and
- 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 and in place until the end of October 2006 where they were replaced with Temporary Water Restrictions. 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 12 months when PWCMs were in place, 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.

PWCM have been reviewed and enhanced by ACTEW. This review mainly focuses on the non-residential water sectors, unlike the initial measures, which mainly targeted residential consumption. The intention of the PWCM review is to achieve percentage savings in the non-residential sectors that are similar to the percentage savings in the residential sector. Enhanced PWCMs have been in place since November 2010. There is still insufficient data to determine if the water savings made to date are due to PWCMs (and the other permanent water saving measures) or are a result of behavioural change after eight years of temporary water restrictions.

It is assumed that this change, along with various other measures, will help achieve the overall 25% reduction target set by the ACT Government. This target is already included in water resources modelling. It is not worthwhile explicitly modelling the impact of the PWCM review because consumption reductions cannot be accurately quantified until water restrictions have been removed for some years. It is therefore difficult to gauge the impact of the PWCM review or other demand management programs implemented by the ACT Government.

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 determine the consumption reduction associated with each water restriction level.

Table 13 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 13 – 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%[2]
Enhanced PWCM's		12%	36%[1]
1	10%	17%	
2	25%	31%	27.7%*
3	35%	40%	39%
4	55%	59%	

* Limited data, as Stage 2 only in place for 107 days over two separate events.

[1]Limited Data, only in place for 180 days to date, wet conditions

[2] Limited Data, in place for 11 months

Modelling adjusts for water restrictions as the volume of water stored increases or decreases and applies the relevant target reduction as shown in Table 13. The trigger levels for introducing and removing water restrictions increase proportionally with the projected increase in demand over time and also vary with each season. The trigger levels for removing each restriction level are around 10 to 20% higher than the triggers for introducing restrictions to avoid continual restriction level changes.

This approach for selecting the restriction level is suitable for modelling because the model must select a level based upon the available information (storage and average demand). However, in reality, the decision to select a restriction level will also consider a number of other factors, such as:

- Climate outlook
- Community expectations
- Political concerns, such as the level of water restrictions in surrounding regions

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 highly resistant to new restrictions.

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 Australian Bureau of Statistics (ABS) 2008 projections the revised Canberra – Queanbeyan population estimate is now slightly over 390,000 people. This is a 7% increase over the 2005 population estimation. In April 2009 new consumption restriction targets for stages 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.

Stage 5 restrictions are now modelled in the water supply scenario modelling, so the corresponding consumption target for stage 5 is included, although these targets are not currently used.

Average consumption June 2010 – May 2011

2010 and 2011 experienced a remarkable turnaround in storage levels from 60% to 100% at the beginning of December. Storage levels remained at 100% for all of summer. This led to a dramatic lifting of temporary water restrictions from Stage 3 (May to September), to Stage 2 (October) and the introduction of Enhanced Permanent Water Conservation Measures in November of 2011. This change in storage levels was due to significant rain events precipitated by one of the strongest La Ninã events on record. This contributed to lower than expected consumption over much of summer.

From June 2010 to May 2011, average daily consumption did not exceed the published or calculated target consumption for any of the stages of water restrictions or during water restrictions.

The various levels of water restrictions that were in place during this period were effective in reducing the total consumption from the expected consumption by approximately 20.4 GL to 33%.

The biggest savings were obtained during the months of Jan to Feb 2011 with savings of 2.8 to 3.8 GL as the wet spring and early summer kept the expected consumption low. For all other months the savings ranged from 1.0 GL during the winter months of June and July 2010 to 1.8 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[60]. 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.

The EUM uses annual customer meter data, and information from water audits and water appliance manufacturers to model potable water demand in the absence of temporary water restrictions. This model will continue to be refined as more information becomes available, and there is an extended period of time without temporary water restrictions.

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

ActewAGL has performed an initial calibration on the model for the ACT. It is intended to include the impacts of seasonality, climate change and climate variability on potable water demand. ActewAGL has also used the EUM for answering policy questions related to water conservation. The EUM will take into account the recently revised PWCM and the new temporary restriction scheme when finalized.

In early 2011, ISF in conjunction with the National Water Commission and WSAA released an updated End-User Model and integrated Supply Demand Planning Tool. ActewAGL will investigate merging their calibrated EUM with the updated software in 2011. The ACT Government also maintains an end-use model. ActewAGL will work with the ACT Government to ensure both models utilize the same base data and assumptions.

Conclusions

All water resource modelling currently assumes 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). The revision of PWCM will help towards achieving the 25% demand reduction.

ActewAGL will continue developing the End Use Model by updating with additional data as it becomes available. 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.

9 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.

ACT Government Target

The ACT Government has specified[61] that no more than 1 year in 20 should be spent in water restrictions[62]. ACTEW had interpreted this target to mean that over a modelled 20 year period, on average no more than 12 months should be in any level of water restrictions. Future climate is highly uncertain because of both climate change and variability, so it is not desirable to guarantee that the target will be achieved. ACTEW will ensure that the average model output meets this target, after allowing for climate change in all modelling. ActewAGL and ACTEW have interpreted this to mean that for any year, there is less than a 5% probability of any level of temporary water restrictions.

Current method

During FWO (2004/05) ACTEW set a series of service level targets relating to water restrictions. The water supply system would be deemed failed if these targets were not met, and augmentation would be required. 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 augmenting. 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.[63] The objective of system performance criteria can be summarised as a trade off between the social, economic and environmental costs of supplying water and benefits of not restricting the water supply. This is shown in Figure 12.

[61] Corbell (2009) (ACT Minister for the Environment, Climate Change and Water) (2009), ministerial statement on water security for the ACT, Legislative Assembly for the ACT, Debates, Weekly Hansard, 26 March, p. 1434, http://www.hansard.act.gov.au/hansard/2009/week04/1434.htm

[62] Independent Competition and Regulatory Commission, *Enlarged Cotter Dam Water Security Project*, June 2010

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

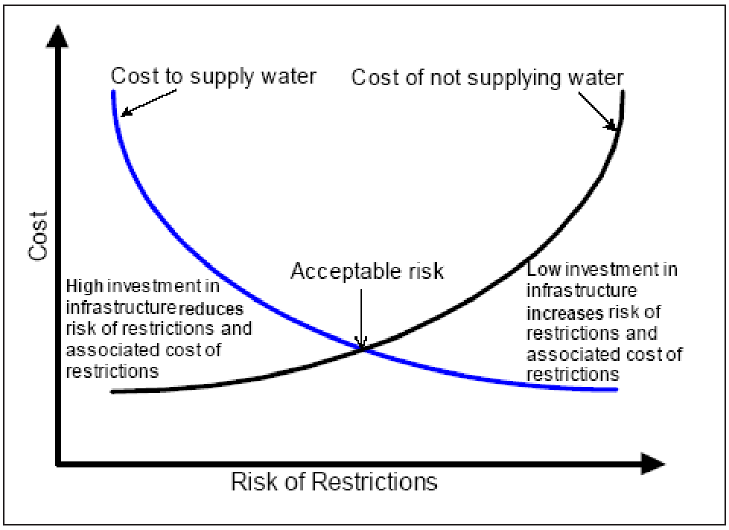

Figure 12 – Trade-off for Setting Level of Service Objectives[64]

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

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 then 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 + (operating cost of 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.

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

The 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 13. In this distribution, 77% of the replicates produce a small economic loss (driven by the capital cost of the project), however a number of replicates produce a substantial economic gain, sometimes in the hundreds of millions.

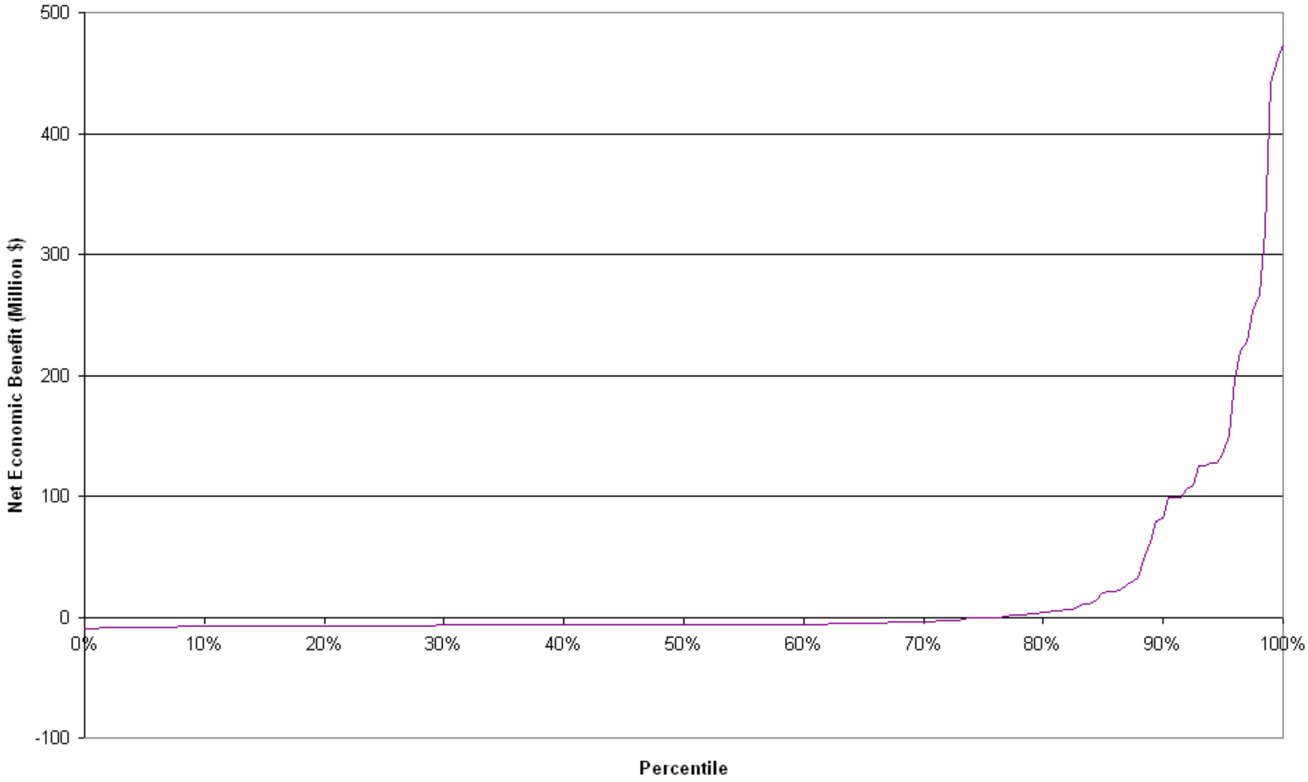

Figure 13 – Cumulative Probability Distribution of Net Economic Benefits

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[65] 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);

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

- Tourism costs;
- Urban environment costs (such as loss and replacement of street trees); and
- 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.

The estimated costs for each stage of water restrictions for 2011 are shown in Table 14. The costs are projected to gradually increase over time in real terms.

Table 14 – Estimated Cost of Water Restrictions in 2011

Water Restriction Stage	Cost of Restrictions for 2011
Stage 1	$8.4 million/year
Stage 2	$59.0 million/year
Stage 3	$150.0 million/year
Stage 4	$419.0 million/year
Stage 5*	$460.9 million/year

* Stage 5 is only used for water modelling purposes.

Proposed review of System Performance Criteria

ACTEW has recently commissioned ActewAGL to commence a program of work under the “Sustainable Supply Strategy”. Part of this strategy will include a review of the level of service requirements, and the development of a multi-criteria tool for options analysis. Additionally, ActewAGL and ACTEW will move to a more “Scenario driven” strategy. This approach will mean projects will not just be assessed on the “average” response, but on the benefits they bring in particular scenarios. Projects which perform robustly across multiple scenarios will be developed in preference to projects which are only beneficial in certain scenarios. In particular, “Readiness Options” will be identified as part of contingency planning. This approach will explicitly align with the Council of Australian Government’s National Urban Water Planning Principles. [66]

[66] http://www.environment.gov.au/water/policy-programs/urban-reform/nuw-planning-principles.html

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)[67]. 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.

Capacity of the Cotter Pump Station – addition of Pump 10

The capacity of the Cotter Pump Station (CPS) has recently been upgraded with the addition of a sixth pump (Pump 10). This has upgraded the capacity to a peak of 150ML/d if all pumps are available. However, this value is considered to overestimate the reliable medium term ability to extract from the CPS.

Operational advice has suggested that a long-term capacity of 2,745ML/month (90ML/day) would be more appropriate even with the additional pump. Previous modelling at the Cotter Pump Station had assumed that any augmentations would increase the capacity to 4,275ML/month. Using the higher figure will overestimate any benefit from sources that are dependent on the Cotter Pump Station. The model has now been adjusted to the lower figure of a capacity of 2,745ML/month.

This has a number of effects on the modelling. It leads to:

- A reduction in total water supplied on average of 0.2 GL/year;
- A small increase in the average time spent restrictions 1, 2 and 3 with the changes in restrictions occurring in the first few years of the model, and post 2030;
- A small increase in probability of being in water restrictions 4 and 5 particularly post 2030;
- A small increase in the average total cost of operations and water restrictions of $24 million (net present value over 47 years of model time); and

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

- An increase in the 95th percentile total cost of operations and water restrictions of $63 million (net present value over 47 years of model time).[68]

Introduction of an Annual Shutdown at Stromlo Water Treatment Plant

It can be necessary to conduct maintenance on the water supply infrastructure from time to time. However, it is often desirable to supply water from Stromlo Water Treatment Plan continuously for extended periods. It is therefore sometimes necessary to shut down the plant even at times when it would be preferable to continue supplying water from Stromlo. To model this interruption to the supply capacity, the capacity of STWP has been set to zero for one month annually.

This has a number of effects on the modelling. It leads to:

- A small reduction in total water supplied on average of 0.3 GL/year;
- A small increase in the average time spent restrictions 1, 2 and 3 with the changes in restrictions occurring in the first few years of the model, and post 2030;
- No change in probability of being in water restrictions 4 and 5;
- A small increase in the average total cost of operations and water restrictions of $14 million (net present value over 47 years of model time); and
- An increase in the 95th percentile total cost of operations and water restrictions of $28 million (net present value over 47 years of model time).[69]

Murrumbidgee to Stromlo Turbidity Limitations

Previously in the REALM model, there was no reduction in the capacity at Stromlo Water Treatment Plant when sourcing turbid water from the Murrumbidgee River, although the supply rate from the Murrumbidgee was limited or set to zero under certain circumstances. Sourcing highly turbid water is problematic as treatment and sludge handling facilities may be severely stressed, and high turbidity levels may correlate with the presence of large pathogen counts. Previous modelling will therefore have overestimated the amount of water that can be extracted from the Murrumbidgee and the amount of water that can be treated at Stromlo when extracting water from the Murrumbidgee.

The model has been modified in the following ways:

- Water will only be supplied from the Murrumbidgee River to STWP if the turbidity is less than 50NTU (The previous limit was 100 NTU, with supply halve if above 40 NTU)
- A "blended turbidity" calculation is used to estimate the overall turbidity loading of the plant.
- A relationship between "blended turbidity" and "Monthly capacity" has been developed which progressively reduces the capacity of STWP when the "blended turbidity" is between 10 and 20 NTU.

When the operating rules have been fully optimized, this has a number of effects on the modelling. It leads to:

- A small reduction in total water supplied on average of 0.2 GL/year;
- A small increase in the average time spent restrictions 1, 2 and 3 with the changes in restrictions occurring in the first few years of the model, and post 2030;

[68] *Cotter Pump Station Capacity*, MCP 1011-10, ActewAGL, 10 Aug 2010
[69] *Annual Shutdown at Stromlo WTP*, MCP 1011-12, ActewAGL, 10 Aug 2010

- A small increase in the probability of being in water restrictions 4 and 5, particularly post 2030;
- An increase in the average total cost of operations and water restrictions of $30 million (net present value over 47 years of model time); and
- An increase in the 95th percentile total cost of operations and water restrictions of $110 million (net present value over 47 years of model time)[70].

Inclusion of Water Quality Rules for Murrumbidgee to Googong Transfers

It has become apparent that the discharge of water into Burra Creek from the proposed Murrumbidgee to Googong (M2G) pipeline will be limited by water quality requirements. For modelling purposes, ACTEW has interpreted the ANZECC Guidelines for fresh and marine water quality. Only rules that are likely to impact on a monthly time step have been modelled, although it is likely there will be additional rules applying on a daily timestep basis.

Using historic data, ActewAGL has generated a probability of falling into one of three water quality categories. The probability is dependent on season and flow tercile. These are applied to synthetic stochastic data by sampling a random number and comparing it to the relevant season and flow tercile. This will either flag the month as a "Do Not start pumping" month, where the model will not allow any pumping from the river, or as an "Additional Monitoring Required" month which will allow pumping at the normal rate (if the other conditions are suitable) with an additional monitoring cost, or as a "Good Water Quality" which will allow pumping at the normal rate.

When the operating rules have been fully optimized, this has a number of effects on the modelling. It leads to:

- A small reduction in total water supplied on average of 0.2 GL/year;
- An increase in the average time spent in restriction levels 1, 2 and 3 with the changes in restrictions occurring in the first few years of the model, and post 2030;
- An increase in the probability of being in water restriction levels 4 and 5, particularly post 2030;
- An increase in the average total cost of operations and water restrictions of $41 million (net present value over 47 years of model time); and
- An increase in the 95th percentile total cost of operations and water restrictions of $111 million (net present value over 47 years of model time).[71]

Enlarged Cotter Dam Impoundment Dates

The previous model of the water supply system assumed that progressive impoundment during the construction of the Enlarged Cotter Dam was possible. The Bulk Water Alliance has advised that progressive impoundment will not be possible. Additionally, the more recent water quality modelling has suggested that the water quality in the ECD will take two years to recover before it can be used as a water supply dam.

The model has been changed to set the storage of Cotter Dam at 3856ML until November 2011, when it is set to 78 000ML. Additionally, the model assumes that no extraction from the dam will take place until December 2013.

[70] *Murrumbidgee to Stomlo Turbidity Limitations*, MCP 1011-13, ActewAGL, 10 Aug 2010
[71] *Inclusion of Water Quality Rules for Murrumbidgee to Googong (M2G) Transfers*, MCP 1011-14, ActewAGL, 10 Aug 2010

When the operating rules have been fully optimized, this has a number of effects on the modelling. It leads to:

- A small reduction in total water supplied on average of 0.1 GL/year;
- An increase in the average time spent restrictions 1, 2 and 3 with the changes in restrictions occurring in the first few years of the model;
- No change in probability of being in water restrictions 4 and 5;
- A small decrease in the average total cost of operations and water restrictions of $1 million (net present value over 47 years of model time); and
- An increase in the 95th percentile total cost of operations and water restrictions of $50 million (net present value over 47 years of model time).[72]

Conclusions

There are a number of criteria that can be used to measure water supply performance including probability of water restrictions, lowest cost, greenhouse gas, public health and environmental outcome. ACTEW will consider all of these and focus on:

- Meeting the ACT Govt target
- Maximising NEB for the community
- Developing scenarios to ensure that our planned water supply system performs robustly in a range of possible future conditions

This analysis may also be used to determine the optimal timing of future augmentations.

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

[72] *Enlarged Cotter Dam Impoundment Dates*, MCP 1011-15, ActewAGL, 3 Dec 2010

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