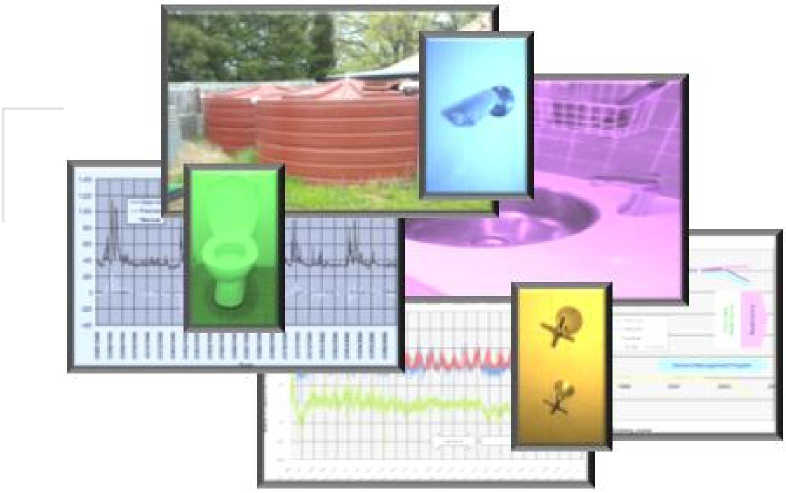

Project Report

Water Demand Analysis and Updating Decision Support System (DSS) Models for Wyong Shire and Gosford City Councils

- August 2012

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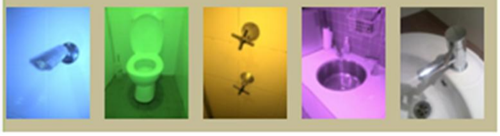

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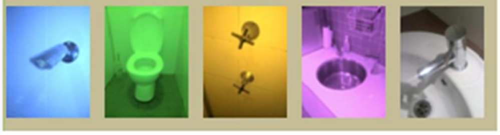


1. Introduction

1.1. Background

As part of their submission to the Independent Pricing and Regulatory Tribunal of NSW (IPART) for the 2013/14-2016/17 regulatory period, both Gosford and Wyong Council water businesses are to prepare demand forecasts. The forecasts of water sales for the previous regulatory period 2009/10 to 2012/13 were well above the sales that occurred. This has led to a shortfall in consumption-based water revenue. Both Councils are eager to firstly understand why water sales in the current 2009/10 to 2012/13 regulatory period have been lower than forecast and to use that understanding to improve the accuracy of forecasts for the next regulatory period.

The last 20 years has seen a significant change in the management of urban water supplies. The move to pay for use pricing in the mid to early 1990s resulted in significant reductions in urban water demand. Additional scrutiny of water prices was provided in the form of the economic regulation of water utilities to avoid monopoly pricing outcomes for consumers. Water businesses around Australia also embarked upon demand management programs.

Much of the Australian continent entered a severe drought over the period 2004 to 2010. The so-called "Millenium Drought" also affected the water supplies on the Central Coast.

This report outlines:

1) the analysis of changes in bulk water demands and metered water sales in recent years in an attempt to provide an increased understanding of the drivers of demand; and
2) The utilisation of the information generated in the analysis to prepare forecasts of demand for the next regulatory period.

1.2. Challenges in Preparing Forecasts of Water Sales

With a severe drought since the year 2002 triggering high levels of restrictions on water use, and a comprehensive demand management effort, it is difficult to separate trends in demand from the effects of water restrictions and the impacts of efforts by both Councils and the Central Coast Community to reduce demand.

Forecasts of water sales will be dependent on understanding:

1) What is the current level of water consumption in the residential and non-residential sectors?
2) What are the impacts of the demand management programs implemented during the recent drought?

3) How long will the water consumption take to “rebound” following the lifting of water restrictions?

1.3. Glossary

Bulk Water Demand is assumed to refer to water passing through bulk meters and treatment facilities into the reticulation system.

Water Consumption is assumed to refer to all water passing from reticulation mains into customer’s service line and billed as usage.

Non-Revenue Water (NRW) refers to the difference between water consumption and bulk water demand. Strictly speaking a system with no metering of consumption would have 100% NRW.

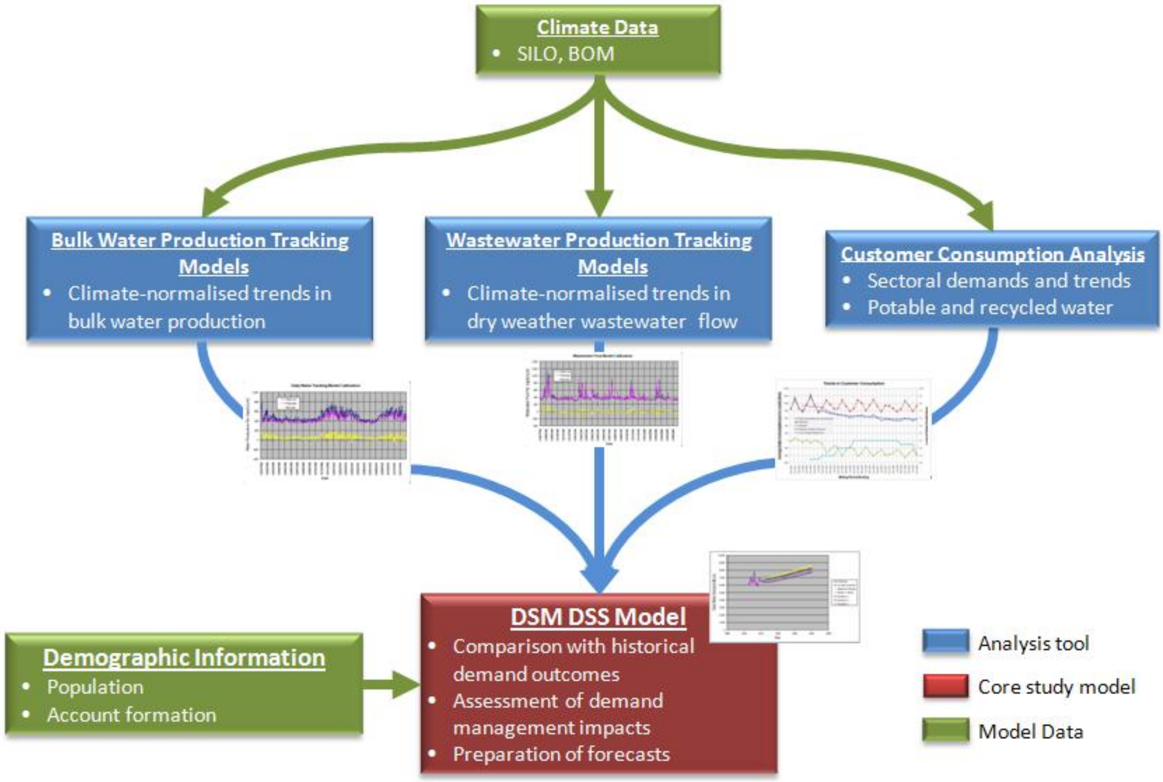
Internal Use refers to water used internally in buildings and would also encompass any other water consumption that is not influenced by climate. This demand is assumed to remain unchanged by seasonal effects during the year.

External Use refers to water used externally primarily for irrigation and cooling towers, but also for swimming pools, car washing and other outdoor uses.

Demand is a generic term that refers to any of the water usage terms above.

2. Demand Forecasting Approach

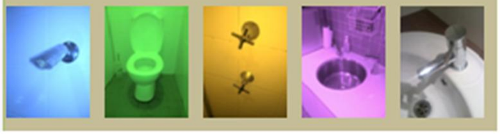
To assist in the analysis of historical water demands and the preparation of forecasts, a suite of analysis and forecasting tools has been used to examine trends in water demands and wastewater flows and to prepare demand forecasts (Figure 2-1). A description of each of the models is provided below.

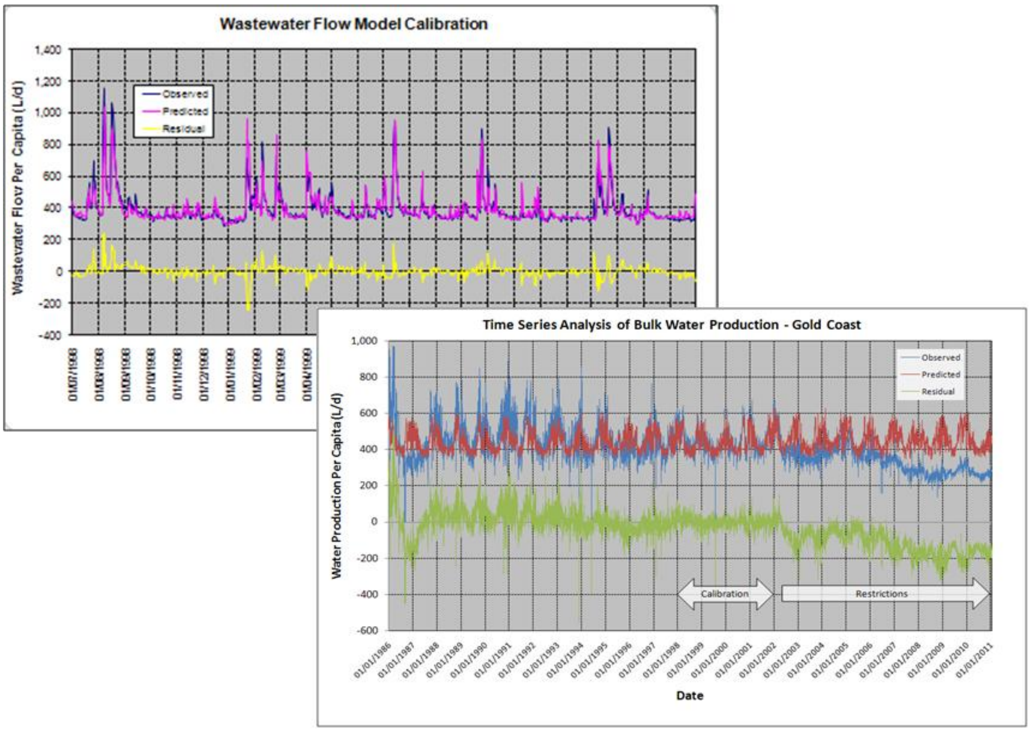


- **Figure 2-1: Demand Analysis and Forecasting Modelling Framework**

2.1. The Water and Wastewater Trend Tracking Model

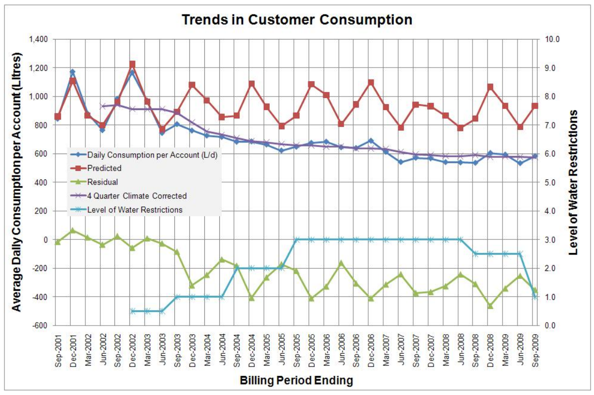
The daily water demand trend tracking model was originally developed by the NSW Office of Water for providing detailed information in climate-driven variations and underlying trends in water demands and wastewater flows. This model can be used to track changes in seasonal and non-seasonal water demands and dry weather wastewater flows.





- **Figure 2-2: Tracking of Bulk Water Demand and Wastewater Flows**

2.2. Customer Consumption Trend Tracking



- **Figure 2-3: Example Output from Customer Consumption Tracking Model**

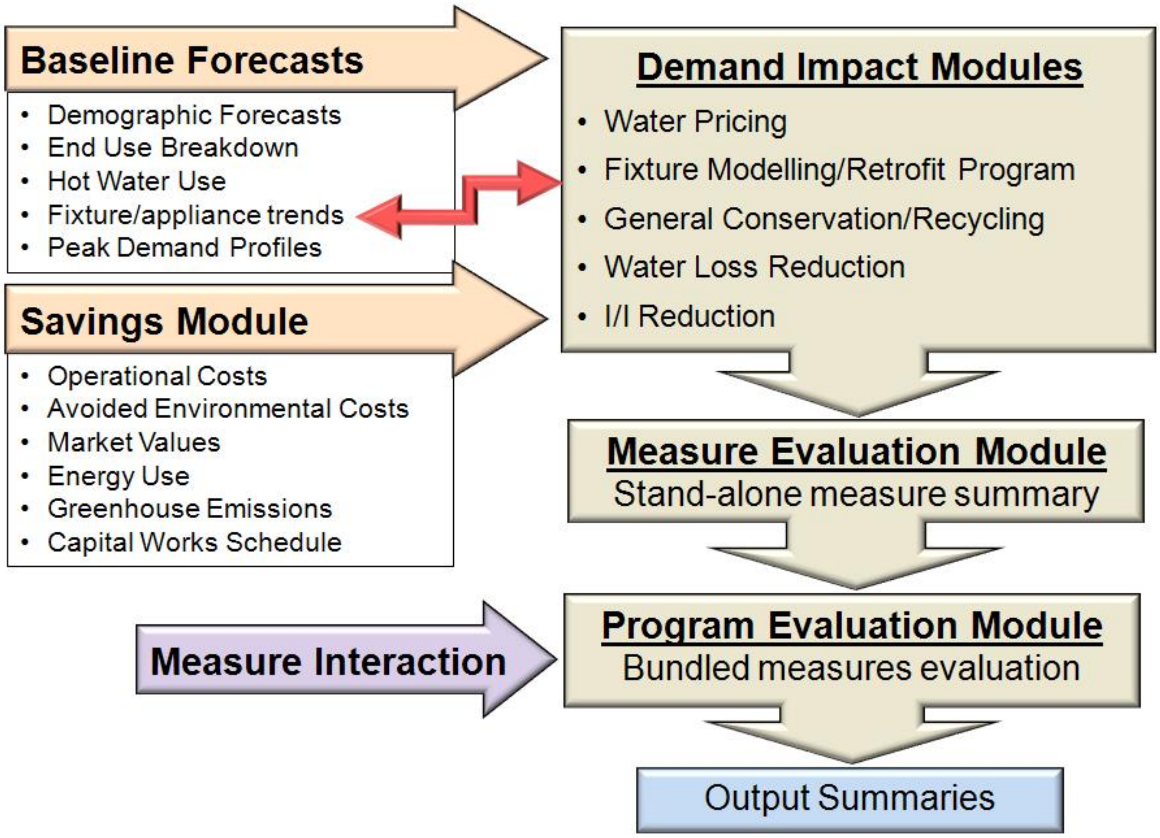
Another key aspect of understanding the impact of both demand management programs and water restrictions is the understanding of trends in customer consumption in different customer sectors. This analysis is undertaken using the Customer Consumption Trend Tracking tool, which examines the trends in quarterly water consumption. By understanding the customer sector origin of changes in water demand, we can better understand if those changes are due to temporary behaviour changes due to restrictions or more permanent behavioural or structural changes.

2.3. The DSM DSS Model

The DSM DSS model is an "end-use" urban water decision support model designed for use in preparing forecasts of water demand and assessing the impact of demand management options (Figure 2-4). The model prepares baseline forecasts of water demand and wastewater generation taking account of trends in:

- The propagation of water efficient fixtures and appliances;
- Account formation and household size;
- Employment;
- Discretionary water uses and the impact of income and lifestyle factors; and
- Demand management programs.

The model has a number of other economic and environmental impact functions that were not used in the preparation of demand forecasts for this project.



- **Figure 2-4: Structure of the DSM DSS Model**

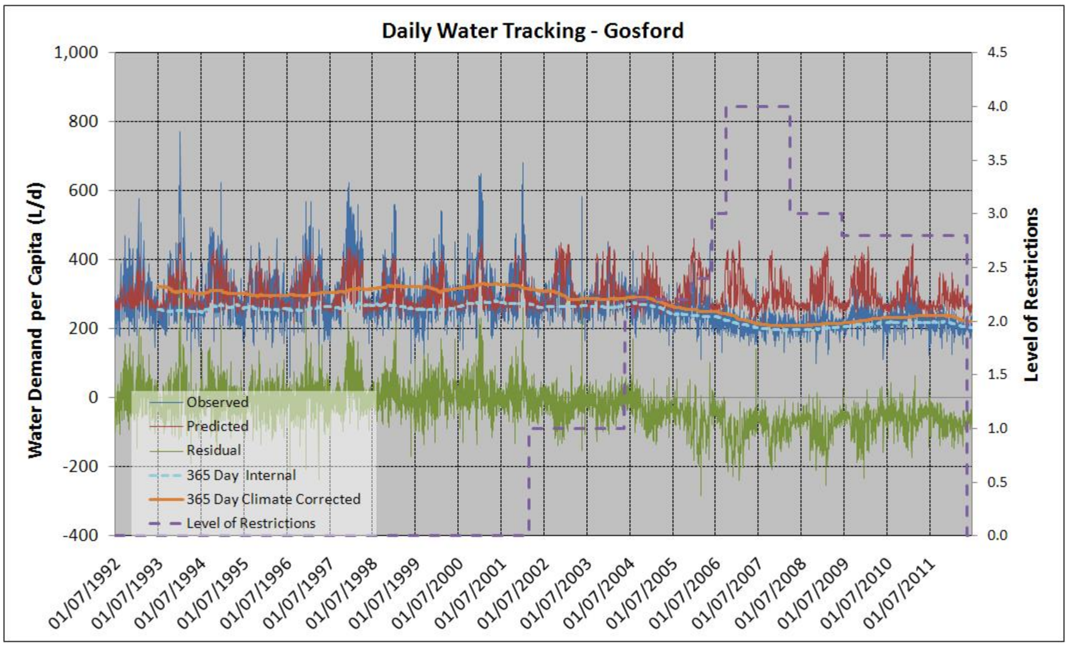
3. Supporting Analysis

3.1. Time Series Analysis of Bulk Per Capita Water Demand

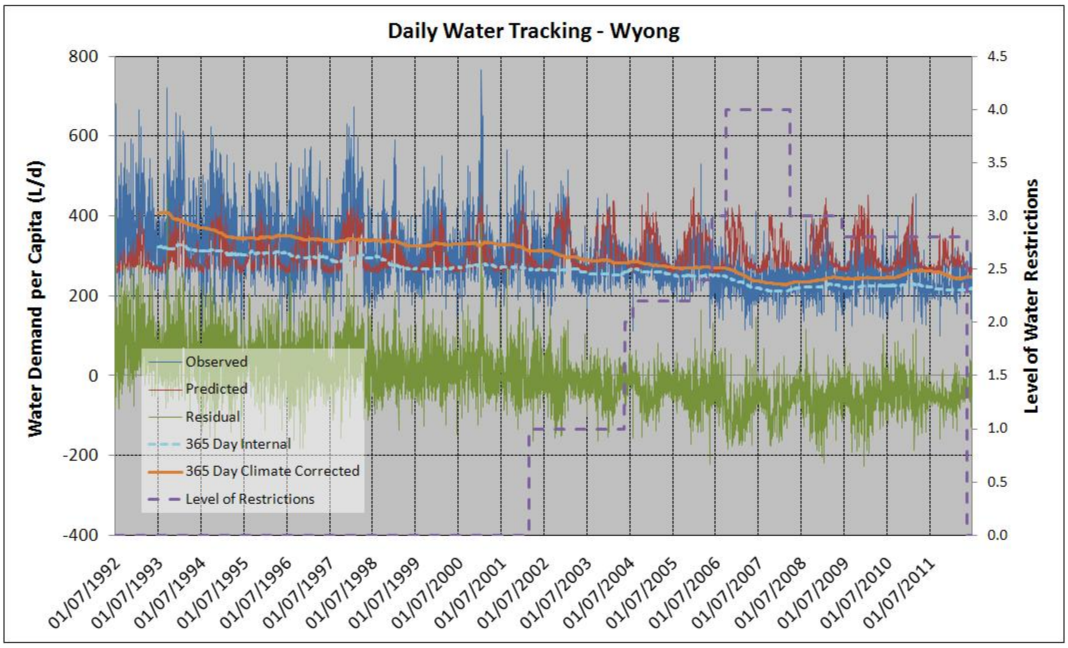
The Daily Water Tracking Model (NSW Department of Land and Water Conservation, 2002) was used to analyse the trend in bulk per capita water demand. The results of the analysis are shown in Figure 3-1 and Figure 3-2. To assist in identifying the level of reduction in internal or non-seasonal use, a 365 day moving average of the 30th percentile of demands is also plotted. The 30th percentile is a convenient level of bulk demand that effectively accounts for the daily variations in demand that occur in cool and wet winter periods (where little external water use is expected) and is not influenced by the impact of hotter and drier conditions on bulk demand. It is taken to be representative of internal or non-seasonal water use.

The change in the non-seasonal bulk water demand can act as a barometer for the overall response to water restrictions and reductions in the level of Non-Revenue Water (NRW). It essentially is an indicator of the eagerness of the community to reduce the level of their internal water use (that is, water being discharged to the sewerage system).

The reduction in non-seasonal demand coincides with the period of water restrictions in both Gosford and Wyong, and the peak reduction in bulk demand appears to be in the order of 75 Litres/person/day (25%) in Gosford and 55 Litres/person/day (21%) in Wyong. This reduction appears to have decreased with the easing of water restrictions, but interestingly has increased again in the last 12 months.



- **Figure 3-1: Daily Water Tracking – Gosford**



- **Figure 3-2: Daily Water Tracking – Wyong**

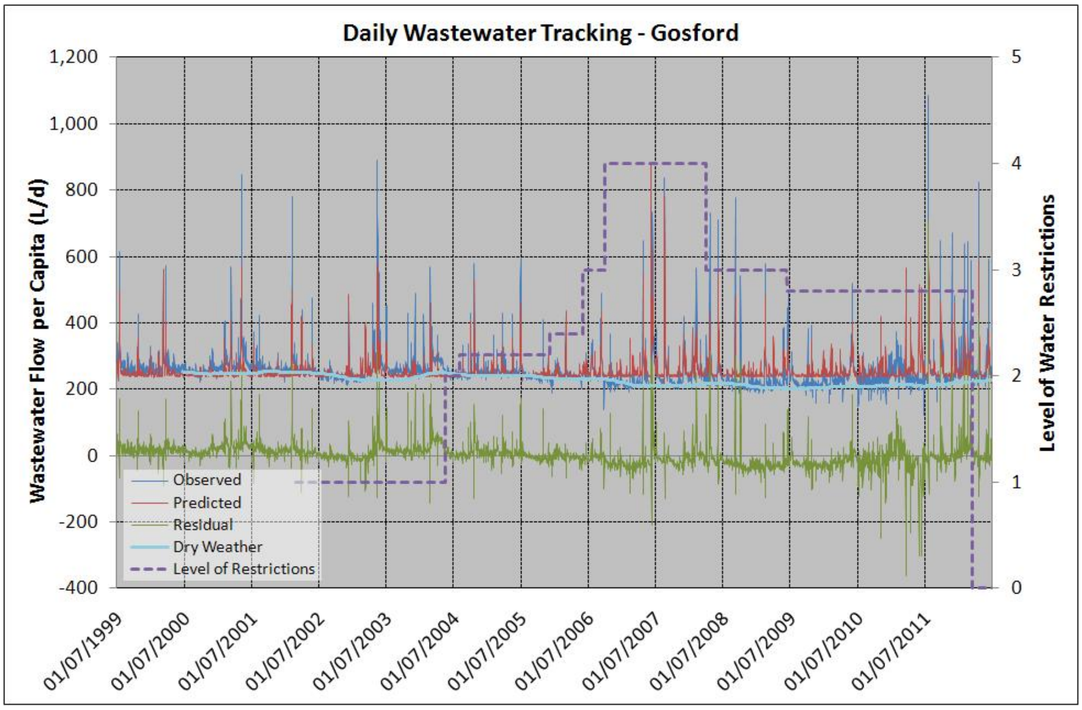
3.2. Time Series Analysis of Bulk Per Capita Wastewater Flows

The Daily Water Tracking Model was also utilised to examine the trends in per capita wastewater flows. The results of the analysis are shown in Figure 3-3and Figure 3-4. To assist in identifying the level of reduction in dry weather flow, a 365 day moving average of the 15th percentile of flows is also plotted. As with the 30th percentile used for bulk water demands, the 15th percentile is a convenient level of wastewater flow that effectively accounts for the daily variations in dry weather flow demand that occur in dry periods (where little wet weather sewerage system infiltration). It is taken to be representative of internal or non-seasonal water use.

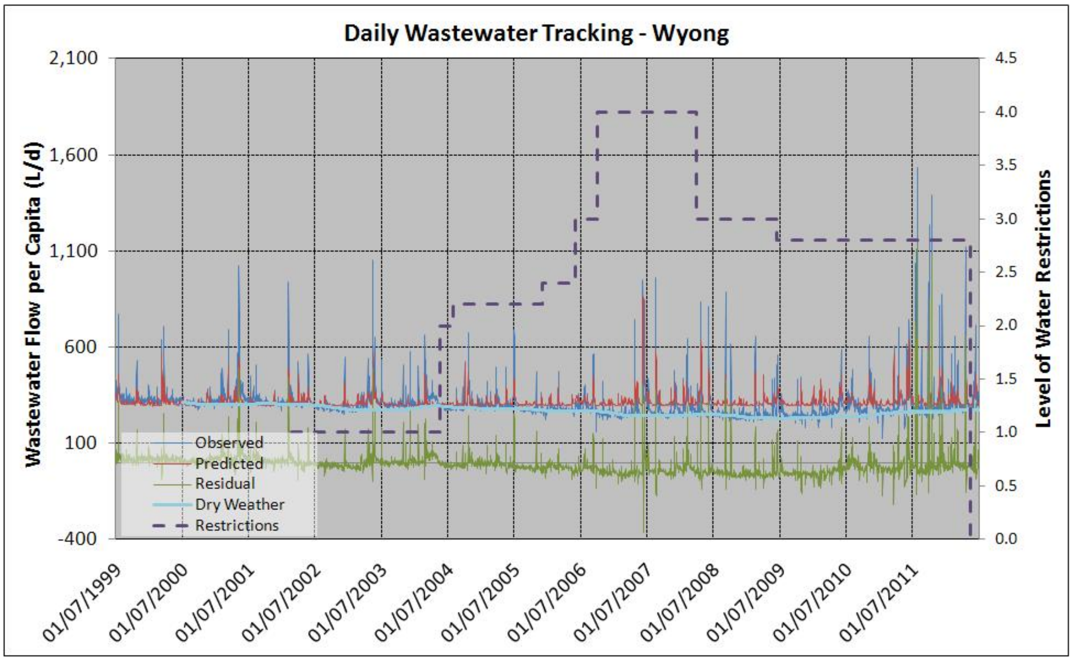
As with the non-seasonal water demand, the change in the non-seasonal volume of wastewater discharge can act as a surrogate for the overall response to water restrictions. It essentially is a barometer of the eagerness of the community to reduce the level of their internal water use (that is, water being discharged to the sewerage system).

The initial reduction in wastewater flows coincided with the introduction of water restrictions in both Gosford and Wyong, and the peak reduction in dry weather flows appears to be in the order of 50 Litres/person/day (20%) in Gosford and 75 Litres/person/day (23%) in Wyong.

Interestingly, the level of dry weather wastewater flow in both Gosford and Wyong has rebounded to almost pre-restrictions levels. This is in contrast to bulk water demand levels, which seem to be trending downward again.



▪ **Figure 3-3: Daily Wastewater Tracking – Gosford**

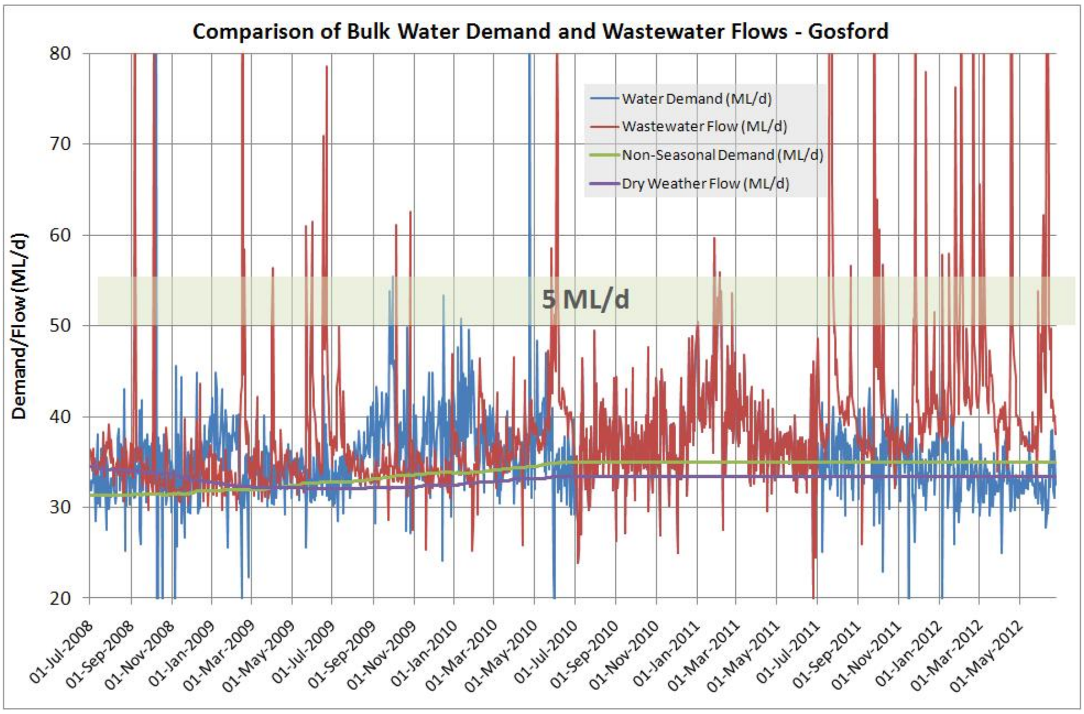


- **Figure 3-4: Daily Wastewater Tracking – Wyong**

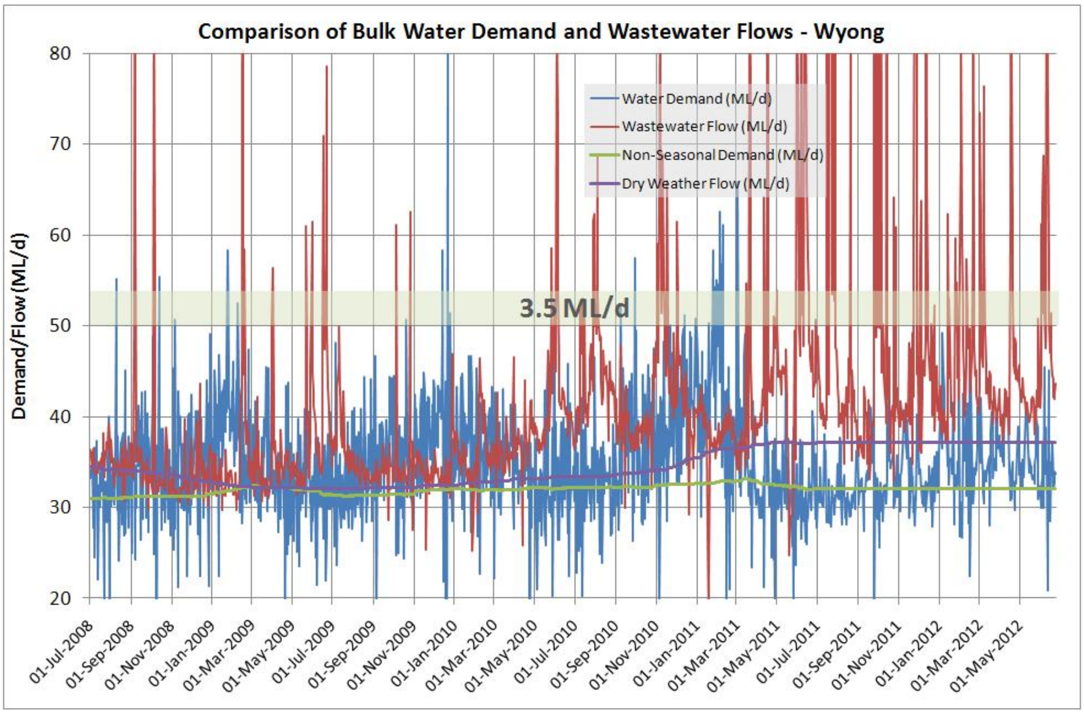
3.3. Comparison of Bulk Water Demand and Wastewater Flows

It is a useful process in the analysis phase to examine the difference between water demands and wastewater flows. In theory, in the cooler, wetter times of the year, the difference between the two should equate to the level of water supply system leakage, which is typically about 10% of the volume of bulk water demand. The results of the analysis for Gosford and Wyong are shown in Figure 3-5and Figure 3-6. Also shown are the approximate magnitudes of the NRW as the light green bands. The difference between the two is at times much lower than expected and at times the dry weather wastewater flow is higher than the non-seasonal water use. Once source of this discrepancy could be the dry weather infiltration from groundwater or ocean water. Another could be the propagation of rainwater use which is not sourced from potable water systems but still contributes to wastewater flows.

Recommendation: The source of the smaller than anticipated difference between bulk water demand and bulk wastewater flows be investigated further. This investigation should start with the wastewater flow records.



- **Figure 3-5: Comparison of Bulk Water Demands and Wastewater Flows – Gosford**



- **Figure 3-6: Comparison of Bulk Water Demands and Wastewater Flows – Wyong**

3.4. Time Series Analysis of Customer Consumption Data

In Gosford and Wyong, customer water consumption data is collected from most customers on a six monthly basis. This information is aggregated into annual water consumption figures that were made available for this project from the 1999/2000 to the 2010/11 fiscal years.

To undertake a meaningful time series analysis of annual data, there needs to be a sufficient length of data set upon which to calibrate a model. As climate is the most likely cause of annual demand fluctuations outside of periods of water restrictions, it is essential that a long record of consumption is available outside of periods of water restrictions (typically ten years). This is because during water restrictions the impact of these climate influences is suppressed making it difficult to calibrate statistical models. By using data from each billing period (six months), additional seasonal influences can be observed in the data and the length of data set required for meaningful analysis can be reduced (to typically five years).

Due to the short period of annual record available outside of the period of water restrictions, it was not possible to generate a statistically significant relationship between climate influence and annual consumption in any customer sector.

Recommendation: Both Councils download and analyse trends in water consumption data on a quarterly or six monthly basis in line with billing periods.

4. Departure from Previous Forecasts

For the previous demand forecasts submitted for the current 2009/10 to 2012/13 regulatory period, both Councils utilised the DSM DSS models that had been prepared for the IWCM Strategies. A transition from restricted demands to the medium term forecast was assumed to occur during the regulatory period.

The key drivers in demand over the current 2009/10 to 2012/13 regulatory period have been:

- Population growth;
- Climate;
- Demand management; and
- Water restrictions.

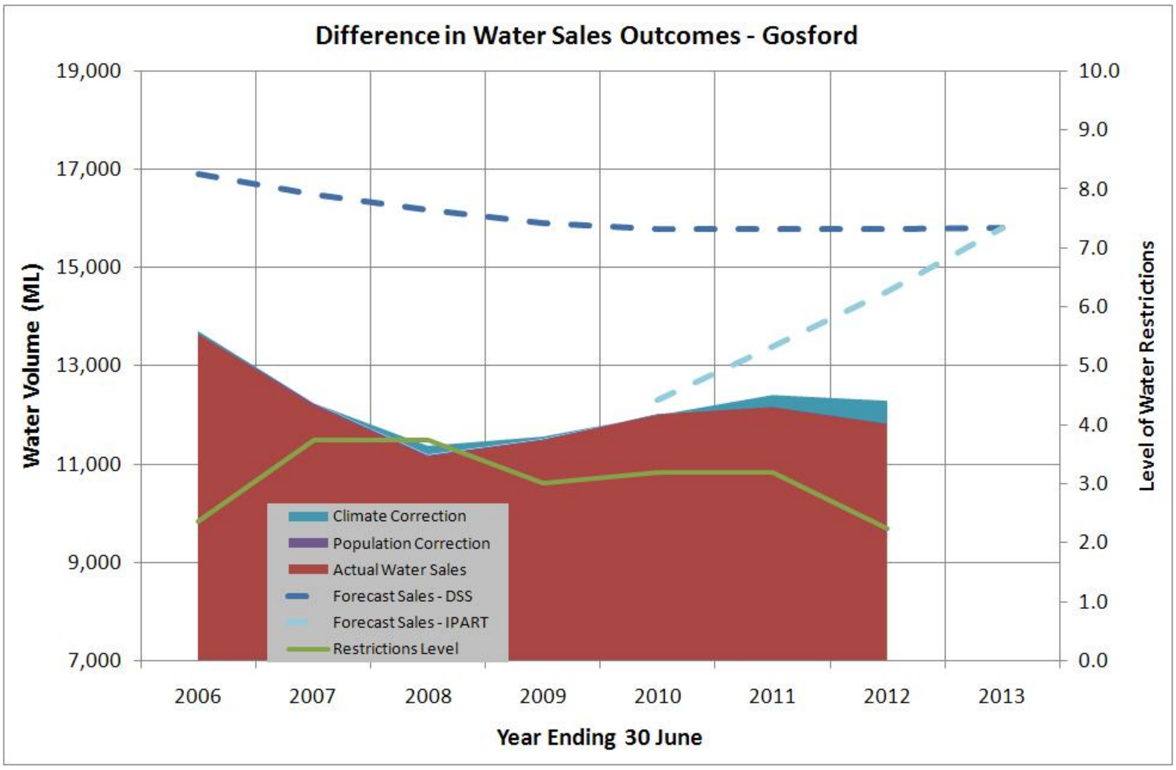
The current 2009/10 to 2012/13 regulatory period forecasts all had assumptions underlying each of these drivers. The most uncertainty in outcomes in the above four drivers is the impact of the demand management programs. The impact of climate can be assessing using the results of the water tracking models, the impact of differences in population forecasts is a relatively straightforward exercise in multiplication.

4.1. Impact of Population Forecast Changes and Climate

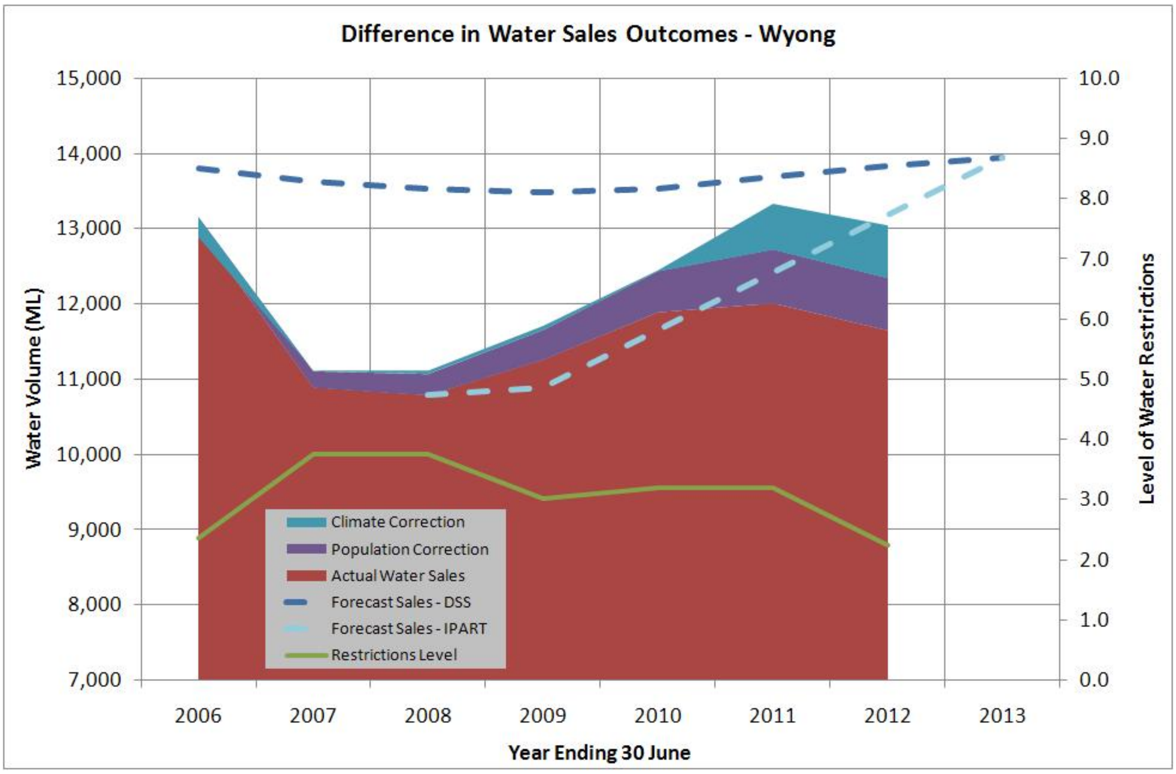
As a first step, the historical water sales records have been adjusted for the impact of climate and differences between population forecasts and compared with the water sales forecast by the previous DSM DSS model and those submitted to IPART for the current 2009/10 to 2012/13 regulatory period. As stated above, the forecasts submitted to IPART assumed a transition between the current levels of consumption under water restrictions to the DSM DSS model forecasts during the regulatory period. The results are shown in Figure 4-1and Figure 4-2. They show that for Wyong, differences in population forecasts (the actual population was lower than forecast) and climate (the wetter than average conditions suppressed demand) plus the fact that water restrictions were not eased as early as anticipated explain the lower than anticipated water sales. For Gosford, the persistence of water sales at levels much further below forecasts suggests that there is a different dynamic in play. It appears that the water restrictions and demand management are maintaining more downward pressure on sales than in Wyong. While Gosford experienced similar climate conditions to Wyong, demand in Gosford is significantly less sensitive to climate influences (see Section 5.3).

It is important to recognise that population forecasts are prepared based on census information that is available every five years. Preparing forecasts for a future regulatory period will require using census data that is some years old. The population forecasts used for preparing forecasts for the current 2009/10 to 2012/13 regulatory period were prepared in 2005, and were based on the 2001 census data. For this study, preparing forecasts for the 2013/14 to 1016/17 regulatory period will be based on the 2006 Census. So there is some uncertainty in population outcomes for a regulatory period when the forecasts are based on census data seven or eight years prior to the commencement of the period.

Recommendation: Population forecasts for the current 2009/10 to 2012/13 regulatory period should be updated as population forecasts based on the 2011 census data are available.



- **Figure 4-1: Correction of Historical Water Consumption – Gosford**



- **Figure 4-2: Correction of Historical Water Consumption – Wyong**

<u>Conclusion</u>: The major difference in water sales forecasts submitted for the current 2009/10 to 2012/13 regulatory period and actual sales outcomes has been:

- In Gosford, the continuation of reasonably high levels of water restrictions into the regulatory period;
- In Wyong, differences in population outcomes, the influence of cooler, wetter climate conditions and the continuation of water restrictions.
- Water sales in Gosford are less sensitive to climate influences that in Wyong.

4.2. Impact of Demand Management and Water Restrictions

To examine the potential impact of both Councils Demand Management efforts and the impact of water restrictions, the DSM DSS models were set up to as closely as possible replicate the impacts of the demand management programs. These programs and their forecast water savings are shown in Table 4-1. The table does not show the aggregated total water savings, because the aggregated savings need to take account of the interactions (reduced impact) of measures that target the same end uses

- **Table 4-1: Assumed Impact of Demand Management Programs**

Measure Name	Modelled Water Savings – Gosford (2012 - ML/a)	Modelled Water Savings – Wyong (2012 - ML/a)
National Water Efficiency Labelling Scheme (WELS)	82	83
Current Water Pricing Path	693	614
BASIX	273	401
Pre-BASIX Residential Development Controls	24	31
Residential Refit Program	72	64
Water Usage Audits of Non-Residential Properties (includes Water Plans)	251	601
All System Water Loss Programs	924	165
Storm Water Harvesting for Cricket Pitches	-	1
Public Education	1,367	1,462
Rainwater Tanks in Schools	11	1
Recycled and Groundwater User for Tankers	37	150
Rural Fire Services	5	5
Rainwater Tank Rebate – Residential	179	353
Washing Machine Rebate	38	33
Rainwater Tank for General Community Use	-	3
Groundwater	65	32
Stormwater Harvesting Projects	-	450
Rainwater Tanks for 95% New Non-Residential Development	25	-
Water Recycling Programs	187	2,408
Minor Programs	7	1
Rainwater Tanks for Council Fields and Facilities	35	4
Total Aggregate of Savings	4,275	6,862
Total Savings with Interactions	4,005	5,186

In addition, the water restrictions were assumed to impact on internal and external water uses as outlined in Table 4-2.

Two scenarios were tested for each Council:

1) The impact of the demand management program; and
2) The impact of the demand management program plus restrictions.

The impacts for Gosford are shown in Figure 4-3 and for Wyong in Figure 4-4. The results show that the modelling undertaken tends at times over-estimates and at other times under-estimates the reductions in water sales, with similar results for both Gosford and Wyong. One noticeable difference in the observed consumption is the increase in consumption following the easing of water restrictions in 2010. While residential consumption has increased slightly in Gosford there has been a much bigger increase in Wyong. The reason for this difference is unclear.

The exercise does highlight the difficulty in modelling consumption in two different supply areas with a consistent set of assumptions at the same time as typing to differentiate between the impact of more permanent demand management impacts and the temporary impact of water restrictions. In addition, the modelling assumes that the transition that occurs when customers move from one level of water restrictions to another is instantaneous, whereas when restrictions are easing, there will be a transition period that might make it difficult to simulate the impacts in any one year.

- **Table 4-2: Assumed Reductions in Water Use with Water Restrictions**

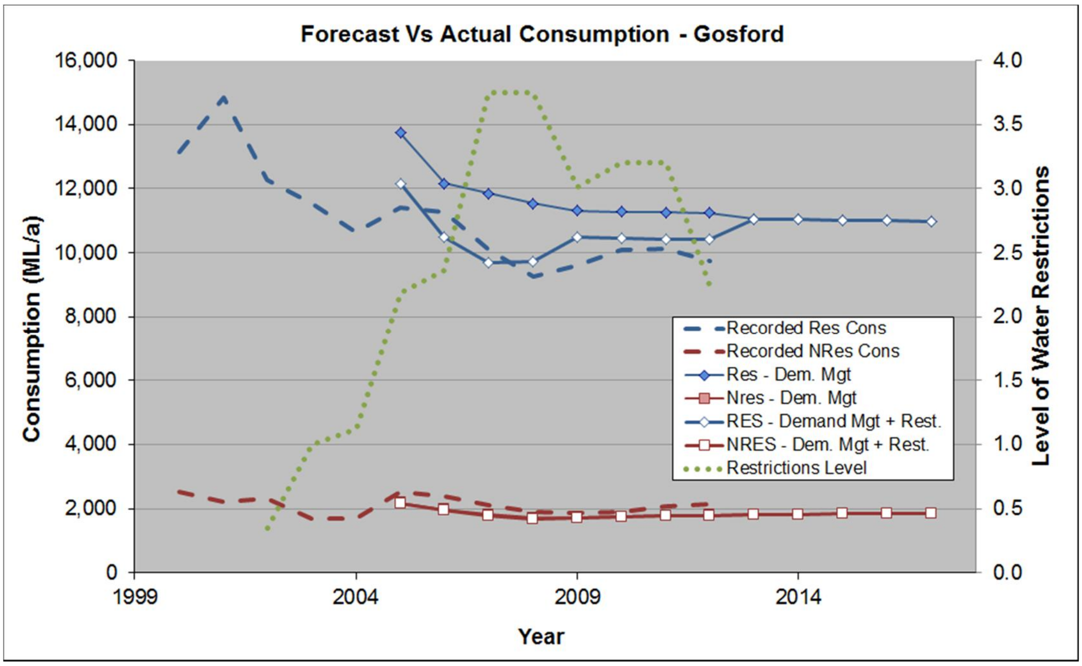
Level of Restrictions	Assumed to Apply in Year Ending June	Residential Reduction in Internal Use	Residential Reduction in External Use	Proportion of Residential Accounts Fully Complying	Non Residential - Reduction in Internal Use	Non Residential Reduction in External Use	Proportion of Non Residential Accounts Fully Complying
2.2	2005	5%	60%	50%	0%	15%	50%
3	2006	5%	60%	60%	0%	15%	60%
4	2007	5%	60%	80%	0%	20%	80%
3[1]	2008	5%	60%	70%	0%	20%	70%
2.8[2]	2009-2012	5%	40%	45%	0%	15%	40%

The recent drought was both lengthy (water restrictions in place for over ten years) and severe (water in surface water storages as low as 12%). In these circumstances may customers would have gone to great lengths to both conserve water (through the on-site re-use of greywater and harvesting of rainwater) and reduce their reliance on water for garden irrigation in the future (replacement of water-intensive gardens with more drought-resistant types). In addition, some

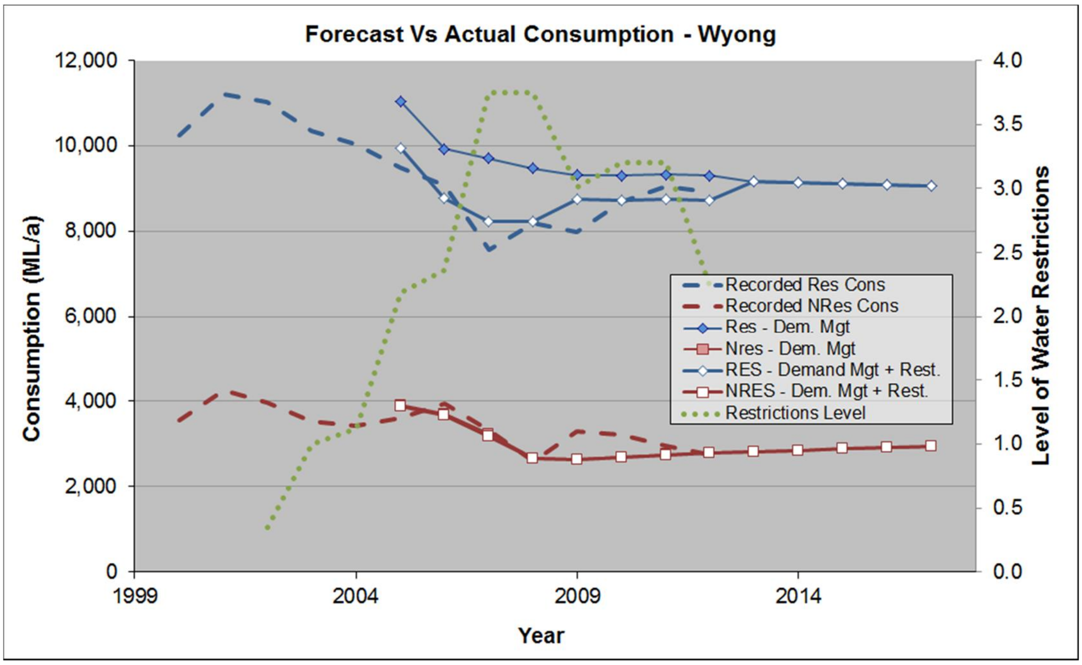
[1] The second round of Stage 3 water restrictions in 2008/09 involved slightly different measures to those in 2005/06.
[2] Level 2.8 water restrictions in force over the period 2008/09 to 2011/12 were considered slightly more lenient than the Level 2.2 restrictions in 2004/05.

customers may have abandoned their gardens or parts of their gardens altogether or the restrictions on watering may have taught them that their gardens would survive on far less water than previously thought. As a result, there is a real possibility that the level of garden watering will remain suppressed for some time, in spite of the recent lifting of water restrictions.

Conclusion: In both Gosford and Wyong cases, the assumptions utilised in the DSM DSS model to estimate the impact of demand management and water restrictions over-estimate the water savings impact of demand management and restrictions.



- **Figure 4-3: Impact of Demand Management and Restrictions on Metered Water Consumption – Gosford**



- **Figure 4-4: Impact of Demand Management and Restrictions on Metered Water Consumption – Wyong**

5. Forecasts of Bulk Demand and Consumption

5.1. Demand Scenarios

A key issue for previous consumption forecasts in both Council areas was the assumption that water restrictions would be progressively lifted during the current 2009/10 to 2012/13 regulatory period. Predictions of the outlook for water restrictions are dependent on the future climatic conditions and as such cannot be reliably predicted years in advance.

One parameter that can be estimated with some clarity is the current levels of residential and non-residential consumption. These, in concert with estimates of population growth, provide a baseline for consideration of demands. In addition, there is some validity in the estimates of the impact of the demand management programs. This will set the trajectory of the demand forecasts following the lifting of water restrictions. The only question therefore, is to the timing and duration of the transition between the two.

Work undertaken by Sydney Water suggests that the time frame for the transition to the unrestricted demand regime will be typically short (<2 years) (Sydney Water, 2012). Unfortunately, the analysis of impacts undertaken is based on the analysis of demands in a relatively short period following water restrictions, and there is a significant amount of uncertainty over the potential for rebound in the medium term (3 to 10 years).

The main issue for the medium term is that the data sets are of adequate length to pick up the short-term response to the easing and lifting of restrictions, but may be too short to pick up any medium-term transition. For both sectors, consumption will be assumed to transition between the restricted consumption and the managed demand consumption over a period of 4 years. This period of rebound is consistent with the transitions seen in Sydney following the drought of the mid 1990's.

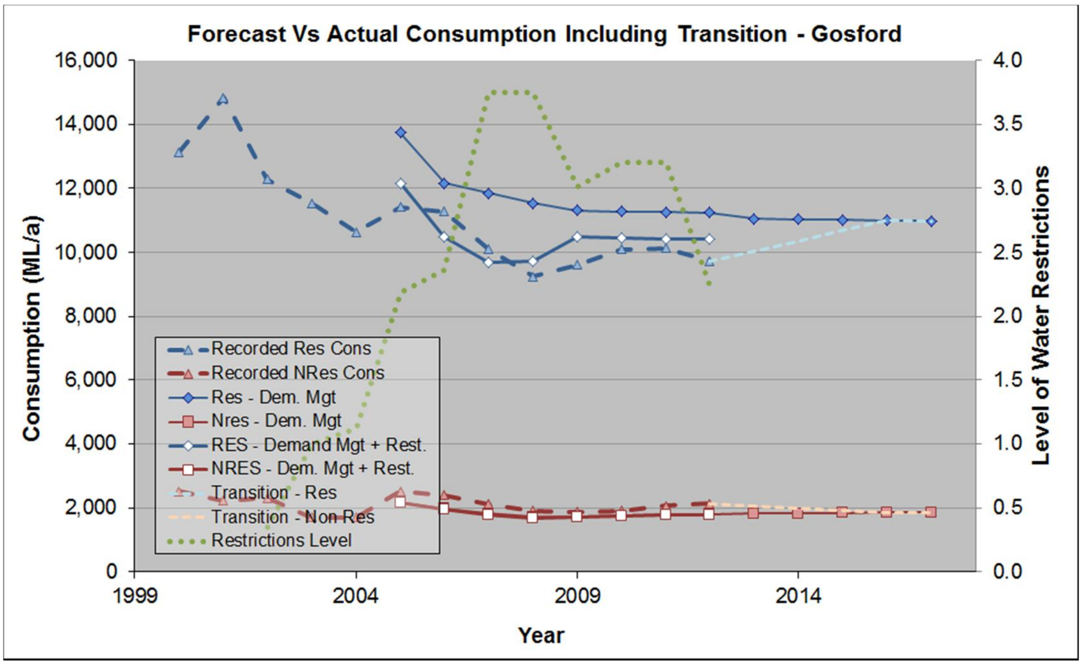
Conclusion: There is uncertainty on how fast the demand bounceback will be in the Central Coast in the event that water restrictions remain lifted, what the magnitude of any bounce back will be and whether the bounce back has already occurred.

5.2. Water Consumption Forecasts

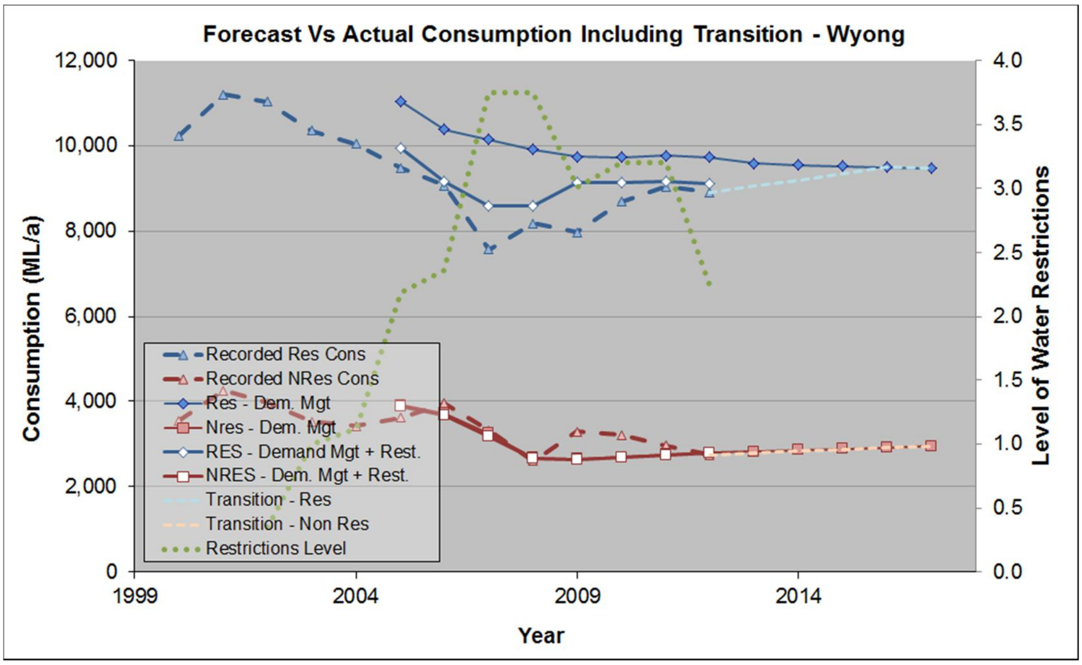
For the preparation of water sales forecasts for the 2013/14 to 2016/17 regulatory period, it has been assumed that:

- the starting point for projections is the 2011/12 consumption; and
- water sales in both the residential and non-residential sectors will transition from current levels to the estimated managed demand forecast in the four years from 2012/13 to 2015/16.

The resulting Forecasts of water sales are set out in Figure 5-1 and Figure 5-2, and Table 5-1. The noticeable drop in the managed demand forecast in 2012 is the result of the commencement of permanent water saving rules in 2012.



- **Figure 5-1: Water Consumption Forecasts – Gosford**



- **Figure 5-2: Water Consumption Forecasts – Wyong**

- **Table 5-1: Water Sales Forecasts (ML/annum)[1]**

Forecast	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Gosford – Res	9,722	10,040	10,358	10,676	10,994	10,974
Gosford – Non Res	2,134	2,062	1,991	1,919	1,847	1,857
Gosford - Total	***11,856***	***12,102***	***12,349***	***12,595***	***12,841***	***12,830***
Wyong – Res	8,904	9,052	9,199	9,347	9,494	9,473
Wyong – Non Res	2,743	2,773	2,803	2,833	2,863	2,882
Wyong Total	***11,647***	***11,825***	***12,002***	***12,180***	***12,357***	***12,355***

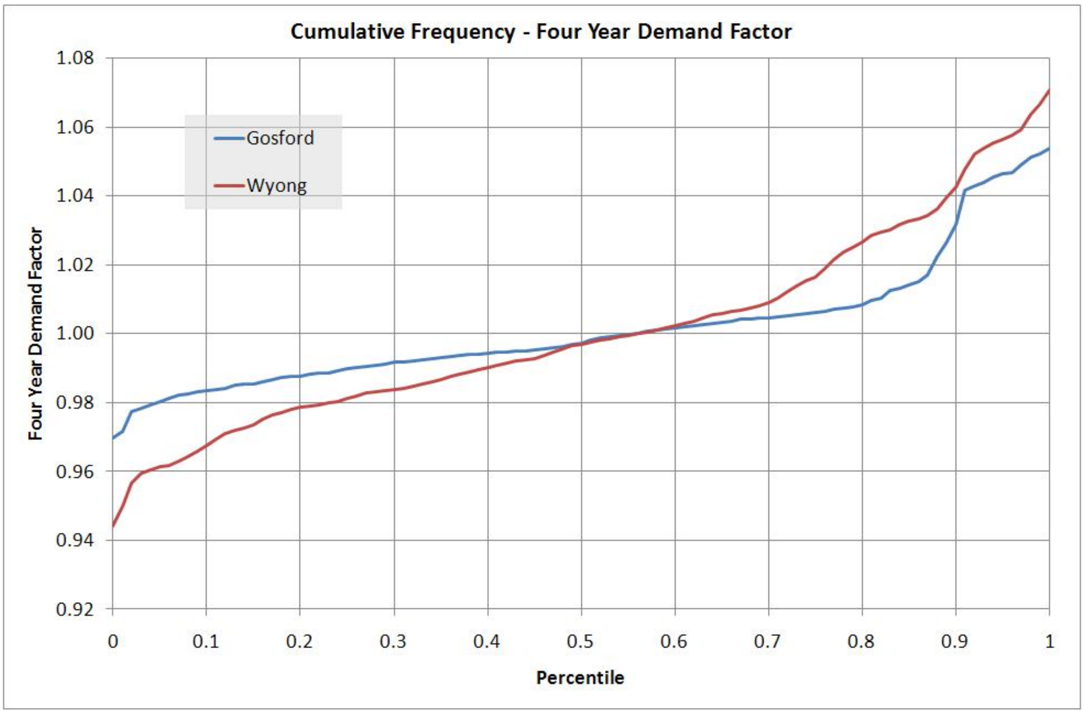
[1]Forecasts from the current model. Note that these differ from the forecasts previously provided to IPART in 2008.

5.3. Forecasts for Cool, Wet Periods

One concern of all water businesses preparing forecasts of water sales over a four year regulatory period is that deviations from "average" climate conditions will results in a shortfall in revenue. The Daily Water Tracking models provide detailed estimates of the different climate conditions that can impact on seasonal consumption. These can be applied to the seasonal consumption estimates from the DSM DSS model to generate scenarios for water sales.

The cumulative frequency of four yearly demand factors are shown in Figure 5-3. They show the likelihood of demands occurring over a four year period other than average. The resulting demand factors for selected percentiles are shown in Table 5-2. The results show that:

- The demand in Wyong is clearly more sensitive to climate than that in Gosford because the greater range over which the demand factors vary
- Over a four year period, water consumption outcomes are likely to be far less impacted by the prevailing climate conditions than it will be differences in population, demand management and water restrictions outcomes.



- **Figure 5-3: Cumulative Frequency of Four Year Demand Factor on Seasonal Use**

- **Table 5-2: Four Year Demand Outcomes at Different Demand Percentiles (at Pre-Restrictions Demand Levels)**

Demand Percentile	Gosford	Wyong
0.05	-2.0%	-3.9%
0.25	-1.0%	-1.9%
0.50	-0.3%	-0.3%
0.75	+0.6%	+1.7%
0.95	+4.6%	+5.7%

5.4. Bulk Demand Forecasts

The forecasts of bulk water demand for the regulatory period which is assumed to be the volume of water sales plus the forecast level of NRW is provided in Table 5-3.

- **Table 5-3: Bulk Water Demand Forecasts (ML/annum)**

Forecast	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Gosford – Sales	11,856	12,102	12,349	12,595	12,841	12,830
Gosford – NRW	938	945	953	960	967	972
Gosford – Total	***12,794***	***13,047***	***13,301***	***13,555***	***13,808***	***13,803***
Wyong – Sales	11,647	11,825	12,002	12,180	12,357	12,355
Wyong – NRW	1,249	1,255	1,261	1,268	1,274	1,280
Wyong Total	***12,896***	***13,080***	13,263	***13,447***	***13,631***	***13,636***

5.5. Stochastic Demand Generation

The WATHNET suite of models are used for simulating water supply headworks and distribution systems. Within the suite, support is provided for Monte Carlo analysis including generation of multi-site hydroclimatic data and probabilistic assessment of future performance, which was used for generating probabilistic demand data for use in this project.

Annual demands from the daily water tracking models hindcast were used to generate a synthetic series of demand estimates from 1970 to 2011. These demands were used as the basis for the simulation of 1,000 replicates of potential demand sequences from 2012 to 2021. Each replicate represents a potential demand outcome given observed demands in 2011. The WATHNET model output for the generation of the replicate data sets in provided in Appendix C.

The seasonal demand component in these replicates was applied to estimates of the seasonal demand from the DSM DSS model to generate a probabilistic distribution of future water sales. The results are outlined in Table 5-4 and shown in Figure 5-4 and Figure 5-5. They show the probability of the consumption in any one year exceeding the levels shown. The results provide an indication of the types of impacts that you will have from climate influences in any one year, and also that this variability will tend to increase as consumption rebounds from water restrictions.

Table 5-4: Total Probabilistic Water Sales Forecasts (ML/annum)

Probability of Exceedance	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Gosford – 0.01	10,829	11,110	11,335	11,549	11,803	11,762
Gosford – 0.05	11,148	11,403	11,694	11,902	12,182	12,226
Gosford – 0.25	11,602	11,898	12,209	12,498	12,808	12,817
Gosford – 0.50	11,891	12,235	12,565	12,897	13,230	13,283
Gosford – 0.75	12,245	12,616	12,906	13,347	13,666	13,687
Gosford – 0.95	12,724	13,151	13,471	13,883	14,349	14,241
Gosford – 0.99	12,998	13,599	13,877	14,350	14,863	14,766
Wyong – 0.01	10,636	10,787	10,911	11,089	11,144	11,174
Wyong – 0.05	10,891	11,023	11,235	11,333	11,556	11,521
Wyong – 0.25	11,289	11,482	11,667	11,819	11,995	12,032
Wyong – 0.50	11,594	11,818	11,961	12,148	12,337	12,381
Wyong – 0.75	11,911	12,133	12,284	12,524	12,680	12,700
Wyong – 0.95	12,377	12,599	12,783	13,008	13,207	13,214
Wyong – 0.99	12,693	13,012	13,115	13,247	13,658	13,494

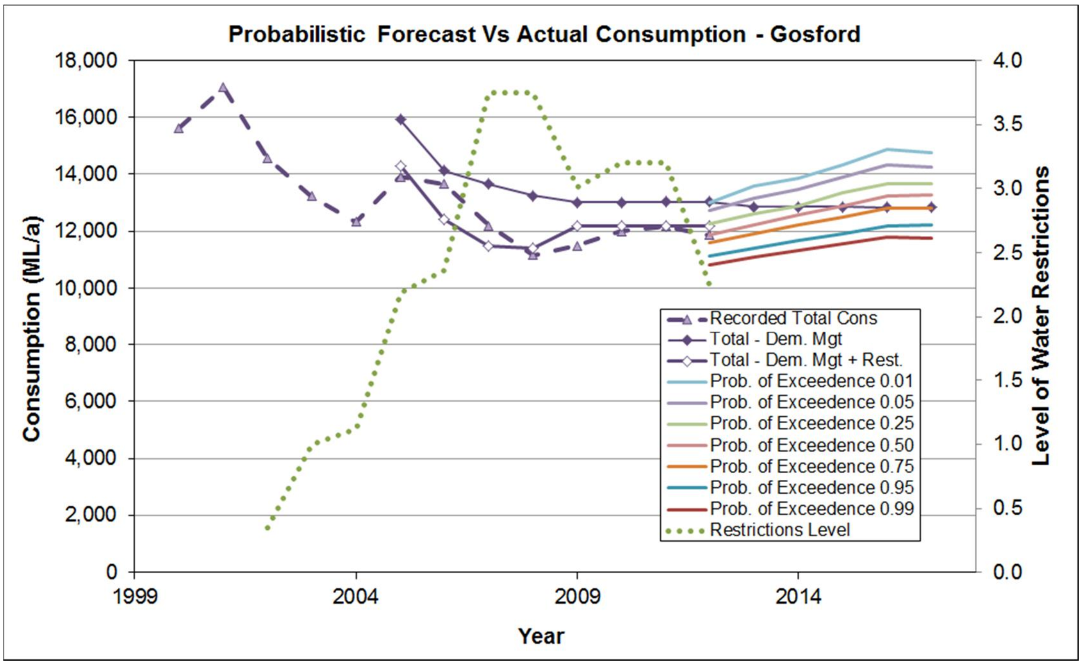
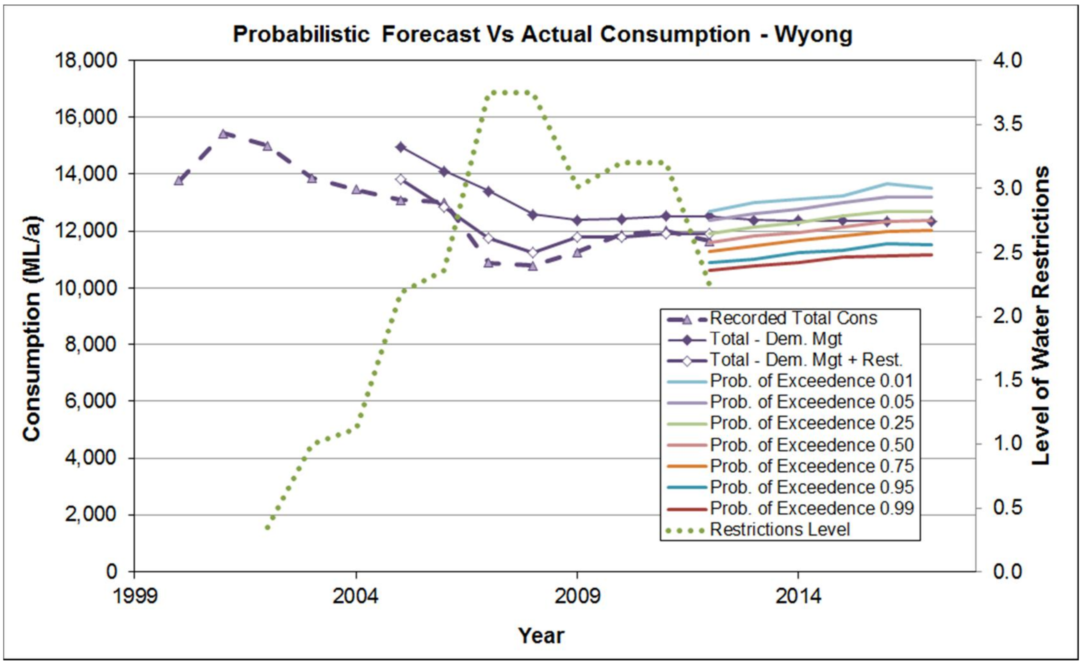


Figure 5-4: Probabilistic Sales Forecast – Gosford



- **Figure 5-5: Probabilistic Sales Forecast - Wyong**

6. References

NSW Department of Land and Water Conservation. (2002). *Daily Water Demand Trend Tracking and Climate Correction Model - Version 10 User Manual*. Sydney: NSW Department of Land and Water Conservation.

NSW Department of Planning. (2009). *Single Dwelling Outcomes 05-08 BASIX Building Sustainability Index*. Sydney: NSW Department of Planning.

Sydney Water. (2012). *Sydney Water submission to IPART's Review of prices for Sydney Water Corporation's water, sewerage, stormwater and other services.* Sydney Water.

Appendix A Demand Analysis – Detailed Outline of Results

The analysis of trends in water demand were supported by the analysis of trends in bulk water and wastewater demand using a multi-variable regression approach. The statistical results of the analyses are shown in Tables A-1 to A-3. Details on the use of the model and calibration procedures can be found in (NSW Department of Land and Water Conservation, 2002)

- **Table A-1: Soil Moisture Index Parameters**

Parameter	Gosford Bulk Water	Wyong Bulk Water	Gosford Bulk Wastewater	Wyong Bulk Wastewater
Rainfall multiplier	5.99	2.78	0.48	0.20
Evaporation multiplier	0.39	0.40	7.39	5.52
Evaporation power	3.26	2.55	1.00	1.00
Base flow co-efficient	0.00	0.00	0.100	0.100

- **Table A-2: Regression Model Calibration Output Summary**

Parameter	Gosford Bulk Water	Wyong Bulk Water	Gosford Bulk Wastewater	Wyong Bulk Wastewater
R Squared:	0.49	0.50	0.50	0.50
Standard Error of Y Estimate	47.97	53.21	37.89	36.99
F Statistic	444.65	270.78	1079.78	1433.20
Degrees of Freedom	1,822	1,091	4,378	4,379
Durban Watson Statistic	1.468	1.770	0.823	0.638

- **Table A-3: Regression Model Variable t-test Results**

Parameter	Gosford Bulk Water	Wyong Bulk Water	Gosford Bulk Wastewater	Wyong Bulk Wastewater
Intercept	22.9	-5.8	37.2	62.8
Soil Moisture Index	-28.4	-22.9	62.0	56.0
Maximum Temperature	6.6	5.4	Not used	Not used
Rainfall	-4.3		8.2	-7.7
Evaporation		2.3	2.3	-4.3
Weekday Index	4.3	-3.6	-2.8	Not used

Appendix B Demand Management Water Savings Estimates

In the process of the development of forecasts, both Gosford and Wyong Councils provided preliminary estimates of the water savings made under demand management programs. These were either replicated in the DSM DSS model, or replaced by estimates made within the DSM DSS. The assumed water savings are shown in Tables B1 and B2. These numbers are the initial water savings estimates and have been modified to provide a closer correlation with observed demand as outlined in Section **Error! Reference source not found.**.

▪ **Table B-1: Water Savings Estimates - Gosford**

Name	Water Savings (ML/a) (GCC Estimate)	DSM DSS Water Savings (2012)	Difference	Notes
National Water Efficiency Labelling Scheme	N/A	82.4	N/A	DSM DSS estimate used
Current Water Pricing Path	N/A	692.6	N/A	DSM DSS estimate used
BASIX	47.9	272.5	224.6	DSM DSS estimate used
Residential Refit Program	74.5	71.8	-2.7	DSM DSS estimate used
Water Usage Audits of Non-Residential Properties (includes Water Plans)	526.3	250.5	-275.8	
System Pressure Reduction Program	150.0	N/A	N/A	
Leakage Detection Programs	631.6	N/A	N/A	
All System Leakage Programs	781.6	924.4	142.8	
Public Education	1.0	1,367.0	1,366.0	DSM DSS estimate used
Rainwater Tanks in Schools	N/A	11.0	N/A	DSM DSS estimate used
Recycled and Groudwater User for Tankers	37.5	37.6	0.1	
Rural Fire Services	5.0	5.0	0.0	
Rainwater Tank Rebate - Residential (Gosford)	147.8	178.5	30.7	DSM DSS estimate used
Washing Machine Rebate	28.8	37.8	9.0	DSM DSS estimate used
Groundwater	64.6	64.6	0.0	
Rainwater Tanks for 95% New Non-Residential Development	0.0	25.2	25.2	DSM DSS estimate used
New Water Saving Rules	N/A	0.0	N/A	DSM DSS estimate used
STP Recycling	351.3	187.4	-163.9	DSM DSS estimate used
Minor Programs	7.3	7.3	0.0	
Rainwater Tanks for Council Fields and Facilities	34.9	34.9	0.0	
Pre-Basix Residential Development Code		24.1	24.1	DSM DSS estimate used
Aggregate of all Measures		4,274.7		
Total Savings (including interactions)		4,004.6		

Table B-2: Water Savings Estimates - Wyong

Name	Water Savings (ML/a) (GCC Estimate)	DSM DSS Water Savings (2012)	Difference	Notes
WELS - Total Program Savings	N/A	81.4	N/A	DSM DSS estimate used
Current Price Path	N/A	632.3	N/A	DSM DSS estimate used
BASIX - Total Program Savings	N/A	382.9	N/A	DSM DSS estimate used
Resdenitail Retrofit - Total Program Savings	67.6	64.2	-3.4	DSM DSS estimate used
Non Residential Audit- Total Program Savings	600.0	117.0	-483.0	
System Water Loss Management	163.6	167.3	3.7	
Existing Storm Water Harvesting for Cricket Pitches	1.0	1.0	0.0	
IWCM Education Program - Stepped Up	1.0	631.2	630.2	DSM DSS estimate used
Existing Rainwater Tanks in Schools	N/A	0.7	N/A	DSM DSS estimate used
Existing Rainwater Tank Rebate	213.0	369.1	156.1	DSM DSS estimate used
Rainwater Tanks for Council properties	3.5	3.6	0.1	
Pre-Basix Rainwater Tank Code	69.0	32.0	-37.0	DSM DSS estimate used
Rainwater Tanks for General Community Use	N/A	3.2	N/A	DSM DSS estimate used
Rainwater Harvesting for Commerical Use	N/A	6.5	N/A	DSM DSS estimate used
Permanent Water Savings Rules	N/A	0.0	N/A	DSM DSS estimate used
Aggregation of Minor Programs	1.8	1.8	0.0	
Residential Washing Machine Rebate	23.1	32.6	9.5	DSM DSS estimate used
Existing Stormwater harvesting Initiatives	150.0	153.0	3.0	
Stormwater Harvesting NSW Government Funding Application	300.0	306.0	6.0	
Groundwater Use	32.0	32.6	0.6	
Effluent Reuse for Rural Fire Service	5.0	5.1	0.1	
Effluent Reuse Tankers	150.0	151.5	1.5	
Existing Recycled Effluent Initiatives - Major Users	708.0	718.0	10.0	
Existing Recycled Effluent Initiatives - Other Users	1700.0	443.1	-1256.9	
Aggregate of all Measures		4,336.2		
Total Savings (including interactions)		3,619.2		

Appendix C Stochastic Generation of Demands

```
GENERATED DATA SUMMARY (Version 4.01)

 Generated data file: ../../dem/gos_wyo_dem.gen
 Historic data file:  ../../dem/gos_wyo_dem.bin
Estimation of Lag-one Annual Data Model Parameters
 The multi-site markov model has the form for year t:
     x(t) = a*x(t-1) + e(t)
 where x(t) is a vector of centralized transformed data
       obtained using the Box-Cox transformation
         x = (q**lambda-1)/lambda
       where q is the observed data, and
       e(t) is a disturbance vector distributed normally
       with zero mean and covariance sigma

 Std dev/correlation matrix of disturbances:
 -----------------------------------------------------------------------------------------------------------------------------------
   0.33936E-01
   0.92915      0.50577E-01

 There were NO missing data
 Full-data maximum likelihood estimators used

****************************************************************************************************
 Site name: GOSFORD (L/d)

 Mean of transformed data =     11.617
 Disturbance std dev      =      0.034
 Box-Cox lambda           =      0.000
 Prob[negative flow]      =     0.0000
 Annual data prior to generation set to 105627.000

 In  41 years there were   0 missing years

 Box-Cox lambda  Skew of transformed data
 ----------------------------------------
          1.500                  1.1233
          1.450                  1.1142
          1.400                  1.1052
          1.350                  1.0961
          1.300                  1.0871
          1.250                  1.0781
          1.200                  1.0691
          1.150                  1.0602
          1.100                  1.0512
          1.050                  1.0423
          1.000                  1.0334
          0.950                  1.0245
          0.900                  1.0157
          0.850                  1.0068
          0.800                  0.9980
          0.750                  0.9892
          0.700                  0.9804
          0.650                  0.9716
          0.600                  0.9629
          0.550                  0.9541
          0.500                  0.9454
          0.450                  0.9367
          0.400                  0.9280
          0.350                  0.9194
          0.300                  0.9108
          0.250                  0.9021
          0.200                  0.8935
          0.150                  0.8850
          0.100                  0.8764
          0.050                  0.8679
          0.000                  0.8594

                            Autocorrelation function

 Lag         Autocorrelation                -1.0  -.8  -.6  -.4  -.2  0.0   .2   .4   .6   .8  1.0
      Estimate  95% limits on white noise    |....|....|....|....|....|....|....|....|....|....|
   1   -0.003         0.316        -0.316     |                <       *       >                |
   2    0.032         0.320        -0.320     |                <       |*      >                |
   3    0.211         0.324        -0.324     |                <       |*****  >                |
   4   -0.167         0.329        -0.329     |                <   ****|       >                |
   5   -0.123         0.333        -0.333     |                <    ***|       >                |
   6   -0.010         0.338        -0.338     |                <       *       >                |
   7    0.051         0.343        -0.343     |               <        |*       >               |
   8   -0.011         0.348        -0.348     |               <        *        >               |
   9    0.116         0.354        -0.354     |               <        |***     >               |
  10   -0.140         0.359        -0.359     |               <     ***|        >               |
  11    0.249         0.365        -0.365     |               <        |******  >               |
  12   -0.016         0.371        -0.371     |               <        *        >               |
  13   -0.252         0.378        -0.378     |               <  ******|        >               |
  14    0.063         0.385        -0.385     |              <         |**       >              |
  15    0.072         0.392        -0.392     |              <         |**       >              |
                                             |........................|........................|
 Note < and > denote approximate 95% limits on the white noise autocorrelation function
```

```
                     Partial autocorrelation function

 Lag     Partial autocorrelation          -1.0  -.8  -.6  -.4  -.2  0.0   .2   .4   .6   .8  1.0
      Estimate  95% limits on white noise   |....|....|....|....|....|....|....|....|....|....|
   1   -0.003         0.316      -0.316     |                <       *       >                |
   2    0.032         0.320      -0.320     |                <       |*      >                |
   3    0.211         0.324      -0.324     |                <       |*****  >                |
   4   -0.173         0.329      -0.329     |                <   ****|       >                |
   5   -0.144         0.333      -0.333     |                <   ****|       >                |
   6   -0.042         0.338      -0.338     |                <      *|       >                |
   7    0.150         0.343      -0.343     |               <        |****    >               |
   8    0.023         0.348      -0.348     |               <        |*       >               |
   9    0.076         0.354      -0.354     |               <        |**      >               |
  10   -0.242         0.359      -0.359     |               <  ******|        >               |
  11    0.318         0.365      -0.365     |               <        |********>               |
  12   -0.049         0.371      -0.371     |               <       *|        >               |
  13   -0.193         0.378      -0.378     |               <   *****|        >               |
  14   -0.140         0.385      -0.385     |              <     ****|         >              |
  15    0.282         0.392      -0.392     |              <         |*******  >              |
                                            |........................|........................|
 Note < and > denote approximate 95% limits on the white noise partial autocorrelation function
```

```
Cumulative periodogram (assumes constant error variance)
       ...........................................
   1.000                                    + +  +.
       .                                          .
       .                                  +       .
       .                                +         .
       .                              +           .
   0.764                            +             .
       .                                          .
       .                                          .
       .                         +                .
       .                       +                  .
   0.527                     +                    .
       .                                          .
       .               + + +                      .
       .          + +                             .
       .        +                                 .
   0.291                                          .
       .      +                                   .
       .    +                                     .
       .  +                                       .
       .+                                         .
       !.........!.........!.........!.........!...
     0.0       0.1       0.3       0.4       0.5
                      Frequency

 Hypothesis: errors are time-independent - test statistic =  0.0924
                                         - 5% Exceedance value of test statistic =  0.3041
```

```
 Plot of standardized residuals against time
       ...........................................................................................
   3.504                    +                                                                     .
       .                                                                                          .
       .                                                                                          .
       .                                                                                          .
       .                                            +                                             .
   2.027                                                                                          .
       .                                                                                          .
       .                 +                                                                        .
       .             +                                     +                         +            .
       .                      + +                                +                                .
   0.551+   +   +                        +                                  +    +          +     .
       .--+-----------------------+---------------------------------------+----+------------------.
       .      +                            +    +              +    +                             .
       .               +                     +          +               +          +    +         .
       .                            +  +          +          +                                    .
  -0.926           +                                                                          +   .
       .                                                                                  +      +.
       .                                                              +                           .
       .                                              +                                           .
       !.........!.........!.........!.........!.........!.........!.........!.........!...........
     0.0       4.5       9.0      13.5      18.0      22.5      27.0      31.5      36.0

 Runs test Z-statistic =  0.194
```

```
Plot of standardized residuals vs N(0,1) variate
        .............................................
    3.504                                           +.
        .                                            .
        .                                            .
        .                                            .
        .                                            .
    2.168                                       +    .
        .                                            .
        .                                            .
        .                                    +       .
        .                                ++ +        .
    0.832                            +++             .
        .                        +2++2               .
        .                      +2                    .
        .--------------------+++---------------------.
        .                +2+2+                       .
   -0.504             +2+                            .
        .          +++                               .
        .       + +                                  .
        .   +  +                                     .
        .                                            .
   -1.840+                                           .
        !.........!.........!.........!.........!.....
     -2.1      -1.1      -0.1       0.8       1.8
                          Normal variate

Hypothesis: Errors are normally-distributed - test statistic =  0.0827
                                            - 5% Exceedance value of test statistic =  0.1371

****************************************************************************************************

Site name: WYONG (L/d)

Mean of transformed data =     11.771
Disturbance std dev      =      0.051
Box-Cox lambda           =      0.000
Prob[negative flow]      =     0.0000
Annual data prior to generation set to 120649.000


In  41 years there were   0 missing years


Box-Cox lambda  Skew of transformed data
----------------------------------------
         1.500                    0.4482
         1.450                    0.4405
         1.400                    0.4328
         1.350                    0.4252
         1.300                    0.4175
         1.250                    0.4098
         1.200                    0.4022
         1.150                    0.3946
         1.100                    0.3869
         1.050                    0.3793
         1.000                    0.3717
         0.950                    0.3641
         0.900                    0.3566
         0.850                    0.3490
         0.800                    0.3415
         0.750                    0.3339
         0.700                    0.3264
         0.650                    0.3189
         0.600                    0.3114
         0.550                    0.3039
         0.500                    0.2964
         0.450                    0.2889
         0.400                    0.2815
         0.350                    0.2740
         0.300                    0.2666
         0.250                    0.2592
         0.200                    0.2518
         0.150                    0.2444
         0.100                    0.2370
         0.050                    0.2296
         0.000                    0.2222

                            Autocorrelation function

Lag         Autocorrelation               -1.0  -.8  -.6  -.4  -.2  0.0   .2   .4   .6   .8  1.0
     Estimate  95% limits on white noise    |....|....|....|....|....|....|....|....|....|....|
  1   -0.004         0.316       -0.316     |                <       *       >                |
  2    0.054         0.320       -0.320     |                <       |*      >                |
  3    0.065         0.324       -0.324     |                <       |**     >                |
  4   -0.110         0.329       -0.329     |                <    ***|       >                |
  5   -0.160         0.333       -0.333     |                <   ****|       >                |
  6   -0.126         0.338       -0.338     |                <    ***|       >                |
  7    0.028         0.343       -0.343     |               <        |*       >               |
  8   -0.108         0.348       -0.348     |               <     ***|        >               |
  9   -0.010         0.354       -0.354     |               <        *        >               |
 10   -0.035         0.359       -0.359     |               <       *|        >               |
 11    0.233         0.365       -0.365     |               <        |******  >               |
 12   -0.034         0.371       -0.371     |               <       *|        >               |
 13   -0.189         0.378       -0.378     |               <   *****|        >               |
 14    0.118         0.385       -0.385     |              <         |***      >              |
 15   -0.001         0.392       -0.392     |              <         *         >              |
                                            |........................|........................|
Note < and > denote approximate 95% limits on the white noise autocorrelation function
```

```
                     Partial autocorrelation function

Lag     Partial autocorrelation           -1.0  -.8  -.6  -.4  -.2  0.0   .2   .4   .6   .8  1.0
     Estimate  95% limits on white noise    |....|....|....|....|....|....|....|....|....|....|
  1   -0.004         0.316       -0.316     |                <       *       >                |
  2    0.054         0.320       -0.320     |                <       |*      >                |
  3    0.066         0.324       -0.324     |                <       |**     >                |
  4   -0.113         0.329       -0.329     |                <    ***|       >                |
  5   -0.172         0.333       -0.333     |                <   ****|       >                |
  6   -0.127         0.338       -0.338     |                <    ***|       >                |
  7    0.061         0.343       -0.343     |               <        |**      >               |
  8   -0.083         0.348       -0.348     |               <      **|        >               |
  9   -0.041         0.354       -0.354     |               <       *|        >               |
 10   -0.094         0.359       -0.359     |               <      **|        >               |
 11    0.234         0.365       -0.365     |               <        |******  >               |
 12   -0.041         0.371       -0.371     |               <       *|        >               |
 13   -0.270         0.378       -0.378     |               < *******|        >               |
 14    0.040         0.385       -0.385     |              <         |*        >              |
 15    0.118         0.392       -0.392     |              <         |***      >              |
                                            |........................|........................|
Note < and > denote approximate 95% limits on the white noise partial autocorrelation function
```

```
Cumulative periodogram (assumes constant error variance)
        ...........................................
    1.000                                      +  +.
        .                                    +     .
        .                                          .
        .                                  +       .
        .                              + +         .
    0.756                            +             .
        .                                          .
        .                         +                .
        .                       +                  .
        .                     +                    .
    0.513                                          .
        .               + + +                      .
        .            +                             .
        .        + +                               .
        .                                          .
    0.269      +                                   .
        .    +                                     .
        .                                          .
        .  +                                       .
        .+                                         .
        !.........!.........!.........!.........!...
      0.0       0.1       0.3       0.4       0.5
                          Frequency

Hypothesis: errors are time-independent - test statistic =  0.0836
                                        - 5% Exceedance value of test statistic =  0.3041
```

```
Plot of standardized residuals against time
        ...........................................................................................
    2.522                    +                       +                                             .
        .                                                                                          .
        .                                                                                          .
        .                                                                         +                .
        .                                                                                          .
    1.322             +   +                                                                        .
        .                                                                                          .
        .                      + +                          +                         +            .
        .    +   +                                                +          +               +     .
        .  +                              +                   +            +    +   +              .
    0.123+----------------------------------+-------------------+----------------------------------.
        .      +                   +                                 +                             .
        .               +               +                                                          .
        .                            +           +       +               +               + +       .
        .                                     +                                                    .
   -1.077           +                              +                                              +.
        .                                                                                     +    .
        .                                                                                          .
        .                                             +               +                            .
        !.........!.........!.........!.........!.........!.........!.........!.........!...........
      0.0       4.5       9.0      13.5      18.0      22.5      27.0      31.5      36.0

Runs test Z-statistic = -0.442
```

```
Plot of standardized residuals vs N(0,1) variate
        .............................................
    2.522                                       +   +.
        .                                            .
        .                                            .
        .                                            .
        .                                    +       .
    1.437                                 + +        .
        .                                            .
        .                               ++           .
        .                            2++             .
        .                         +++                .
    0.351                      +2++                  .
        .--------------------2++---------------------.
        .                  +2                        .
        .                +                           .
        .            +2+++                           .
   -0.734           ++                               .
        .                                            .
        .       + ++                                 .
        .      +                                     .
        .                                            .
   -1.820+  +                                        .
        !.........!.........!.........!.........!.....
     -2.1      -1.1      -0.1       0.8       1.8
                          Normal variate
```

Hypothesis: Errors are normally-distributed - test statistic = 0.0668
- 5% Exceedance value of test statistic = 0.1371

Data generation option summary:

Site Name	Code	Group	Ksite	kNN	Ksite2	Cl_ch	Year
1 GOSFORD (L/d)	Generate	1	y	1	1	0	42
2 WYONG (L/d)	Generate	1	n		2	0	42

>>> NO parameter uncertainty

Replicate Annual Data Statistics
Number of replicates = 2022 Number of years =   10

Statistic	Site name	Mean	Std dev	Skew	5%	25%	50%	75%	95%
Mean	GOSFORD (L/d)	111036.591	1235.707	0.006	109042.082	110155.912	111041.373	111865.646	113054.968
Mean	WYONG (L/d)	129635.327	2286.517	0.096	126057.865	128052.728	129629.655	131184.522	133445.277
Std dev	GOSFORD (L/d)	3681.430	892.049	0.365	2312.096	3048.424	3602.185	4253.429	5245.789
Std dev	WYONG (L/d)	6357.158	1535.255	0.353	3982.082	5252.890	6266.662	7367.182	8934.865
Skew	GOSFORD (L/d)	0.063	0.497	0.007	-0.776	-0.250	0.061	0.393	0.878
Skew	WYONG (L/d)	0.068	0.503	0.026	-0.769	-0.243	0.063	0.379	0.914
Lag-1 cor	GOSFORD (L/d)	-0.097	0.321	0.016	-0.620	-0.325	-0.102	0.139	0.433
Lag-1 cor	WYONG (L/d)	-0.054	0.318	0.061	-0.566	-0.283	-0.052	0.169	0.475