Appendix H

ACIL Allen Demand model audit

ACIL ALLEN CONSULTING

REPORT TO
SA WATER

8 FEBRUARY 2019

WATER DEMAND MODEL REVIEW

VERIFYING AND VALIDATING SA WATER'S NEW DEMAND FORECASTING MODEL

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1 INTRODUCTION

South Australia Water Corporation (SA Water) is the sole provider of water services in South Australia. It is owned by the South Australian Government and services around 1.6 million customers through its ten metropolitan and six regional reservoirs.

SA Water is subject to independent economic regulation administered by the Essential Services Commission of South Australia (ESCOSA) with the broad objective of ensuring that water is supplied at efficient prices and at service levels that are valued by customers.

In its previous regulatory determination, ESCOSA used a cost-based (building blocks) approach to determine a revenue cap for drinking water and sewerage services. [1] This allows SA Water to recover a return on the prudent and efficient costs of its operations.

In November 2017, ESCOSA published its draft framework and approach paper for the forthcoming regulatory period, which will be from 1 July 2020 to 30 June 2024 (SAW RD20).[2] In that paper, ESCOSA says that its objectives in regulating SA Water's revenue are to ensure that:

- SA Water:
  - understands what its customers value
  - develops proposals for services and prices that respond to customer's needs
  - incurs (only) efficient expenditure
  - takes a long-term approach to its decision making to ensure that its service provision is sustainable
- customers receive the benefits of SA Water's improved efficiency through the prices they pay.

As part of the cost-based approach to regulation, ESCOSA will "*determine forecasts of drinking water demand and sewerage connections that can impact SA Water's costs.*"[3]

Previously, SA water submitted demand forecasts prepared by ACIL Allen Consulting (ACIL Allen) in 2012.[4]

On this occasion, SA Water has internally prepared a water demand model and engaged ACIL Allen to undertake a peer review of this water demand model to ascertain:

- the reasonableness of SA Water's forecasting approach
- whether the model reasonably produces fit for purpose demand figures for water planning and calculation of revenue and pricing for regulatory purposes
- whether the outputs are relatively accurate.

[1] The various other services SA Water supplies will be regulated using a pricing principles approach.
[2] SA Water Regulatory Determination 2020 – Draft Framework and Approach, November 2017.
[3] ESCOSA Draft framework and approach paper, November 2017, available at www.escosa.sa.gov.au, p. 11
[4] We were known as ACIL Tasman when that model was prepared.

That review is summarised in this report, which is structured as follows:

— chapter 2 describes our approach to conducting this review
— chapter 3 outlines SA Water's proposed water demand model
— chapter 4 presents model validation results
— chapter 5 presents model verification results.

This report should be read in light of the fact that our task was to review the modelling methodology and structure, but not the model inputs. Therefore, we have not considered issues such as:

— whether the water usage data upon which the model is based are accurate reflections of the amount of water used in South Australia from time to time and, in particular, whether meter improvement programs may have changed the level of accuracy
— whether one weather station or another offers a better 'fit' to the data, or whether the best fit could be achieved by using data from a combination of stations

The key findings of our review are that, based on our review:

1. we are satisfied that SA Water's forecasting model is fit for purpose as a forecasting model for regulatory purposes. It conforms sufficiently to the *Better Regulation* principles
2. we are satisfied that the spreadsheet supplied to us is an accurate implementation of the model described in the modelling report.

2 REVIEW APPROACH

As inputs to this review, SA Water provided:

— a report titled *RBP Demand forecasting review 2017 – DRAFT* (the modelling report)
— a spreadsheet titled *RBP2020_MonthlyBulkWaterUseModel.xlsx* (the spreadsheet)
— a walk-through of the newly developed water demand model.

In our review we assessed both the conceptualisation and operation of SA Water's water demand model. There are two components:

1. model validation – in which we considered whether SA Water's forecasting methodology is appropriate/ the best choice given the various constraints that apply
2. model verification – in which we consider whether the spreadsheet accurately and efficiently implements the forecasting methodology.

Our conclusions are based on our review of the modelling report and the spreadsheet and on our previous experiences in creating and reviewing demand forecast models. We are regularly engaged by regulated utility businesses either to produce demand forecasts or to review forecasts prepared by others.

2.1 Model validation

We validated SA Water's modelling methodology by comparing it with best practice forecasting principles published by the Australian Energy Regulator (AER). The AER uses the same principles for when assessing the reasonableness of energy (electricity and gas) demand forecasts proposed by regulated network service businesses, which corresponds directly to the task at hand.

We recognise that some of the issues that apply to water demand forecasting differ from those in the energy sector. However, our view is that the principles that define good forecasting are consistent across both sectors.

We also note that while the AER's views are not binding on ESCOSA in any way, the two regulators work together closely. Therefore, the principles endorsed by the AER are a good guide to ESCOSA's likely concerns or interests.

The AER published 12 best practice forecasting principles in its *Better Regulation* materials in 2014. Those which relate to forecasting demand for water are summarised in Box 2.1.

BOX 2.1 BEST PRACTICE DEMAND FORECASTING

Demand forecasts should conform to the following principles:

— **Accuracy and unbiasedness**: demand forecasting approaches should produce demand forecasts that are unbiased and meet minimum accuracy requirements.
— **Transparency and repeatability**: demand forecasting approaches should be transparent and reproducible by independent sources.
— **Incorporation of key drivers**: a best practice forecasting approach should incorporate all key drivers either directly or indirectly and should rest on a sound theoretical basis.
— **Weather normalisation**: corrections for abnormal weather conditions is an important aspect of demand forecasting.
— **Use of most recent input information**: the most recent input information should be used to derive demand forecasts.

SOURCE: AER BETTER REGULATION PRINCIPLES

We adapted these principles into four main questions to answer when validating SA Water's demand forecasts:

1. Does SA Water's forecasting model incorporate the key drivers of water demand?
2. Are independent forecasts of water demand in South Australia available and, if so, how do SA Water's forecasts compare to them?
3. Has the calibrated model been subjected to diagnostic checking and is it free from statistical bias?
4. Is SA Water's forecasting model likely to produce forecasts that are sufficiently accurate for regulatory purposes?

2.2 Model verification

Model verification is primarily about ensuring that the spreadsheet produces the intended outputs using the intended methodology.

The core task in verifying the model was to reproduce it. As we verify our own internal models, we often repeat the model in a slightly different manner as a mechanism for checking that all inputs and assumptions are appropriately used in calculations and produce the correct and intended outputs.

We also considered model design, which relates to the 'transparency and repeatability' principle above.

In our view a demand forecasting model should be designed such that all steps outlined in the accompanying documentation are easy to follow and can be reproduced by another party. For Excel-based models, we prefer worksheets to be laid out in a logical manner and follow a clear structure (usually) left to right. Models should:

— begin with a 'Cover Page' that sets out the purpose of the model, as well as a description of all sheets within the Excel model
— be followed by inputs and assumptions. To minimise errors, these should be recorded once only and then referenced in formulae when used.
— include calculation sheets where all calculations can be checked and reproduced
— have outputs/ modelling results reported on a separate sheet or sheets.

Having a well-designed model provides the transparency for ESCOSA to verify that the Spreadsheet indeed accurately and efficiently implements the forecasting methodology described in the Modelling Report.

3 WATER DEMAND MODEL

SA Water's model is an econometric model that relates bulk water usage to demographic, economic and climate drivers.

SA Water's demand model is built from historical data stretching back a period of ten years (from 2007-08 to 2016-17). Through a process of trial and error, the 'best' model is identified and used for forecasting from financial year 2017-18 to 2023-24.

This chapter summarises the approach SA Water took to arrive at its final water demand model, which is described in section 3.4.

We also discuss, in section 3.5, SA Water's choice to use only the data that have been collected since water restrictions were lifted in 2010 to calibrate its model.

In any econometric forecasting process, the choice of explanatory variables should be decided empirically through the modelling process. The objective is to identify variables that:

1. have a theoretical relationship with water consumption such that they can be incorporated into a properly specified econometric model
2. are measured and reported appropriately
3. are projected appropriately or are amenable to being projected by SA Water.

There should then be a process of estimating regression models with different variables to identify the model that best fits the data. In this process variables should be tested using appropriate statistical techniques and other requirements, such as the need for coefficients to have the appropriate sign and magnitude should be considered.

Consistent with this approach, SA Water tested three main groups of drivers to include in the final water demand model. These were:

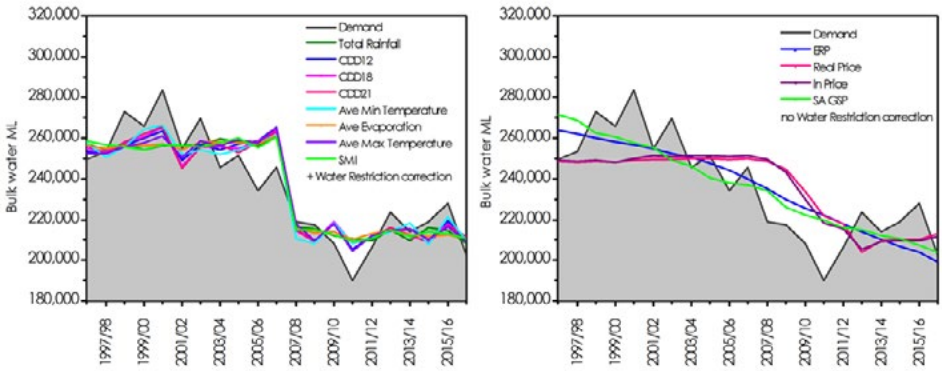
1. climate patterns
2. economic and demographic patterns
3. water restrictions and forced efficiencies.

It then embarked upon a testing process in which it tested a range of variables from each of these groups.

The testing process involved running individual regressions of annual bulk water usage on each variable individually.

The results are shown in Figure 3.1, which is a reproduction of Figure 9 from the modelling report, and discussed in turn below.

FIGURE 3.1 ANNUAL BULK WATER MODEL RESPONSE TO INDIVIDUAL VARIABLES



SOURCE: MODELLING REPORT FIGURE 9

3.1 Testing climate patterns

Figure 3.1 shows that demand for water fits reasonably well with the various weather/climate variables shown in the left hand pane.

The theoretical relationship is simple: warmer and/ or drier days warrant higher water consumption. Therefore, we would expect demand to be positively related to temperature and negatively related to rainfall, which is borne out in Figure 3.1.

To improve the final model, SA Water examined different time periods. In particular it compared water usage levels in summer with those in winter.

For these purposes:

— summer is defined as to November, December, January and February
— winter is defined as the other months.

Analysis of water usage on a monthly basis showed that water usage in *summer* tends to fluctuate from year to year. However, on the contrary, water usage in *winter* tends to be stable from year to year.

This led SA Water to construct separate models of water usage for summer and winter (as defined).

Having established that there is a relationship between water demand and climate, the next step is to identify the appropriate explanatory variable, or measure of weather.

SA Water's analysis led it to choose SMI and CDD_{15}.

3.2 Testing economic and demographic patterns

Figure 3.1 shows that demand for water does not fit particularly well with economic variables when these are considered in isolation. This observation led SA Water to the conclusion that demand for water is not well explained by economic variables.

Economic and demographic variables are often used in water demand models. They can have substantial impacts on water usage.

SA Water considered a range of economic and demographic drivers of water demand. A summary of these, along with their theoretical effect on water demand is provided in Table 3.1.

TABLE 3.1 THEORETICAL RELATIONSHIPS WITH WATER DEMAND

Variable	Data source	Theoretical effect
Gross State Product (GSP)	ABS	Positive relationship
Population	ABS	Positive relationship
Price	SA Water	Negative relationship
Water restrictions	SA Water	Negative relationship

SOURCE: ACIL ALLEN

On this occasion SA Water was concerned by the fact that when it fit regressions between water usage and the various economic variables (individually), the results were contrary to theoretical expectations. In particular, SA Water identified that the regression coefficient on economic activity was negative, suggesting that water usage would *decrease* with *increases* in economic activity.

As discussed below, our expectation is that this problem is due to the lack of a 'water restrictions' variable in these models. Nonetheless, based on this observation SA Water chose not to include economic variables in its final model.

That said, as discussed below SA Water's final model is expressed in per capita terms, which has the effect of making population an explanatory variable. This is very similar in effect to including economic activity (GSP) as an explanatory variable because these two variables are typically strongly correlated. In our experience, it is common to see residential consumption models that incorporate population, and commercial models that incorporate economic activity. Given that most of SA Water's sales are to residential customers it is not surprising that its modelling process led it to using population as an explanatory variable.

3.3 Water restrictions

Following the millennium drought and beginning in July 2003,[5] South Australia experienced an extended period in which water use was restricted. The details varied from time to time until December 2010 when they were lifted.

Level 2 water restrictions were the least stringent. They were as follows:

— hand held hoses, watering cans and buckets could be used to water gardens at any time be used at any time but sprinkler systems could only be used twice a week from 8pm to 8am.
— drip irrigation systems could be used at any time
— cars could be washed using buckets and sponges for washing and a trigger hose or high pressure cleaner were permitted for rinsing
— cleaning paved areas was prohibited at all times except for fire and emergencies
— a permit was required to fill a new pool or outdoor spa and a permit was required to refill an existing pool or outdoor spa.
— fountains or ponds that did not recycle water could not be operated or topped up. The water in fountains or ponds that recycled water could only be topped up with water from a hand held hose or bucket

During the time that Level 3 water restrictions were in place they were varied a number of times. In summary:

— use of sprinkler systems for watering outdoor trees, shrubs, plants and lawns was prohibited
— gardens could be watered anytime with a hand held bucket or watering can and for a limited number of hours using a hose fitted with a trigger nozzle. Hose watering was only permitted at certain times of the day
— external paved areas could only be hosed down in limited circumstances

[5] Restrictions began around 6 months earlier on the Eyre Peninsula.

- topping up of fountains and ponds was limited
- existing pools and spas that were empty could not be refilled and new pools could only be filled if they were fitted with an approved cover. There were limitations on topping up the level of all pools
- hoses were not permitted to be used in washing cars or boats other than for specified circumstances
- there were a number of restrictions on the commercial use of water for dust suppression and in nurseries, garden centres and farms

In December 2010, level 3 restrictions were lifted. Water usage would not be expected to return to 'pre-restrictions' levels, though, because permanent water wise measures have been in place since December 2010 and are expected to remain in place indefinitely. In summary, [6] water wise measures:

- prohibit the use of overhead sprinklers between 10:00am and 5:00pm
- require that cars and boats can only be washed using a hose with trigger nozzle, a bucket or a high pressure low volume water cleaner
- permit external paved areas to be hosed down only in limited circumstances
- require proof of purchase of an approved pool cover before issue of a permit to fill new swimming pools

The effect of water restrictions is clearly evident in water usage as shown by the down sloping arrow in Figure 3.2.

FIGURE 3.2 BULK WATER DEMAND AND WATER RESTRICTIONS 1996/97 TO 2016/17

SOURCE: ACIL ALLEN ANALYSIS OF SA WATER DATA

It can be challenging to model the effect of water restrictions on water usage because it is difficult to measure the difference in intensity between 'types' of water restrictions. To illustrate, the challenge facing SA Water here is to find a variable that quantifies the difference, in terms of water usage, between the 'basket' of limits in, say, level 2 and level 3 restrictions. It is possible to use discrete (dummy) variables although this must be done carefully as excessive use of dummy variables can lead to overfitting.

We note from the modelling report that SA Water used a correction for water restrictions in the climate models on the left hand side of Figure 3.1, but not in the economic models depicted on the right hand

[6] This is a summary only.

side of that figure. In our view, based partly on our experience in preparing demand forecasts for SA Water in 2012, this is likely to be the key reason for the unintuitive coefficients in the economic model.

3.4 Final forecasting model

SA Water's process of model testing identified a 'best' regression model to be used for forecasting water demand. As discussed above, SA Water has used SMI, CDD and population as explanatory variables for its final regression model, but did not included other economic or demographic variables.

Due to the seasonal pattern of water demand, SA Water's final water demand model also incorporates separate regression models for summer and winter.[7] To further account for climate variability within seasons, regressions are conducted using monthly SMI and CDD measures as explanatory variables for predicting monthly bulk water usage *per capita*.

From a technical perspective, the final regression model used for forecasting is summarised in the following equation.

$$Bulk\ Water\ Usage\ per\ Capita_{s,t} = \left(\alpha + \beta_1 \times CDD15_{s,t} + \beta_2 \times SMI_{s,t} + \epsilon_{s,t}\right)$$

Where:

— Bulk water usage per capita is measured in kilolitres per person (as measured by ERP)
— CDD15 relates to the CDD metric using 15 degrees as the base temperature
— s: season being summer or winter
— t: month of the year
— α, β_1, β_2: regression coefficients to be estimated.

A post-model adjustment was then made to account for improvements to water efficiency. In arriving at its estimate of water efficiency, SA Water considered:

— the uptake of more water efficient products of toilets, washing machines and showerheads from its household appliance efficiency models for South Australia
— the changing household densities and housing types in South Australia.

SA Water's analysis concluded that an efficiency per capita rate of 0.2 per cent per annum should be applied to the forecasts of the regression model.

Therefore, the final model used to produce forecasts is of the form:

$$Bulk\ Water\ Usage\ per\ Capita_{s,t,y} = \left(\alpha + \beta_1 \times CDD15_{s,t} + \beta_2 \times SMI_{s,t} + \epsilon_{s,t}\right) \times (1 - 0.02 \times y\ \ )$$

Where:

— *y*: 1, 2, …*y*

The final forecasting model relies on a number of key forecasting and input assumptions. These are summarised in Table 3.2.

[7] Note that the models do not align with the conventional definitions of these seasons. See section 3.1 for details.

TABLE 3.2 FORECASTING AND INPUT ASSUMPTIONS

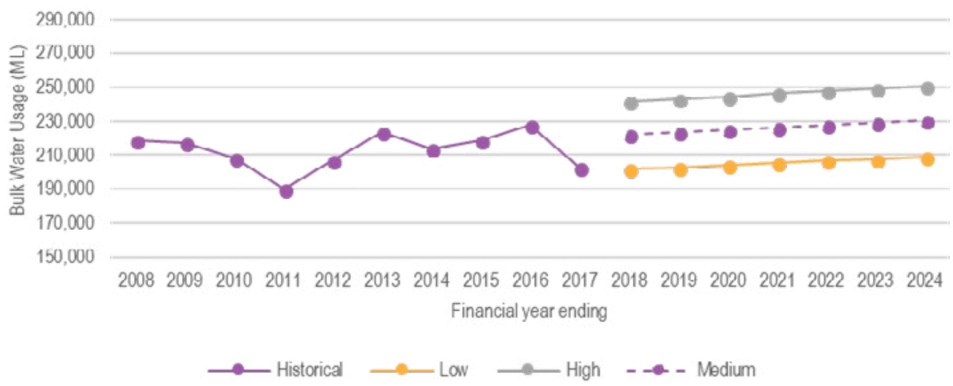
Forecasting assumptions	
Forecast period	Financial year 2017-18 to 2023-24 (7 years, or 84 months)
Low scenario	90th percentile values for SMI 10th percentile for and CDD15
Medium scenario	50th percentile (median) values for SMI and CDD15
High scenario	10th percentile values for SMI, 90th percentile forCDD15
Non-revenue water proportion	13.50% of bulk water usage is attributed to non-revenue water. The remaining proportion is attributed to billed water.
Input assumptions	
Population	Projected from starting base of 1,723,548 in June 2016-17 by 0.60 per cent per annum
CDD15	Mean, 10, 50 or 90th percentile of monthly total between 2007-08 to 2016-17
SMI	Mean, 10, 50 or 90th percentile of monthly average from 2007-08 to 2016-17

SOURCE: SPREADSHEET

Forecasts of bulk water usage per capita are produced for low, medium, average and high scenarios of climate. Monthly bulk water usage values are then deduced by multiplying by projected population figures using a 0.60 per cent annual growth rate.

The monthly forecasts are then aggregated for annual forecasts and these are presented in Figure 3.3. Applying the non-revenue water proportion of 13.50 per cent then provides the split of water demand into billed water and non-revenue water demands.

FIGURE 3.3 ANNUAL BULK WATER USAGE FORECASTS



SOURCE: SPREADSHEET

3.5 The historical data that were used

SA Water had access to water usage and other data extending back to the late 1992. However, in calibrating its demand model it chose not to use data collected before December 2010 when water restrictions were lifted and replaced with permanent water wise measures.

Generally speaking we would encourage the use of all available data in preparing forecasting models. However, in this case the decision to use a truncated dataset appears to be a reasonable response to the difficulty of quantifying the changing impact of water restrictions. As noted above, the impact of restrictions could potentially be accounted for using discrete variables in the model, though this may lead to overfitting.

In the circumstances it does not seem unreasonable to truncate the historical data used as SA Water chose to do.

4 OUR REVIEW – MODEL VALIDATION

As described in section 2.1, we compared SA Water's demand model and process with a set of demand forecasting principles adapted from those published by the AER following its *Better Regulation* review. Our adaptation of those principles led us to consider the following questions:

1. Does SA Water's forecasting model incorporate the key drivers of water demand?
2. Are independent forecasts of water demand in South Australia available and, if so, how do SA Water's forecasts compare to them?
3. Has the calibrated model been subjected to diagnostic checking and is it free from statistical bias?
4. Is SA Water's forecasting model likely to produce forecasts that are sufficiently accurate for regulatory purposes?

These questions are addressed in the following sections. Based on our review, we have formed the view that SA Water's forecasting model is fit for purpose as a forecasting model for regulatory purposes. It conforms sufficiently to the *Better Regulation* principles.

We have not checked the accuracy of the input data. However, if they are accurate it is reasonable to expect the demand model we reviewed to produce forecasts that are adequate for regulatory purposes.

Notwithstanding this overall view, we have identified a number of areas in which the model might be improved. Those are identified in the following sections. We note, though, that it was beyond our scope to test whether those suggestions will *actually* improve SA Water's model. Therefore, they should be regarded as no more than suggested areas for further development of the model.

KEY FINDING 1 WHETHER THE DEMAND MODEL SATISFIES THE BETTER REGULATION PRINCIPLES

Based on our review, we are satisfied that SA Water's forecasting model is fit for purpose as a forecasting model for regulatory purposes. It conforms sufficiently to the *Better Regulation* principles.

4.1 Incorporation of key drivers

In developing the model SA Water considered a variety of drivers of water demand and tested models based on many of them. These included different specifications of climate and weather variables, water efficiency and different demographic and economic variables.

In our view, SA Water's application of the model testing process, which is described in the modelling report and summarised in chapter 3 of this report, was comprehensive and thorough in identifying the 'best' drivers of water demand.

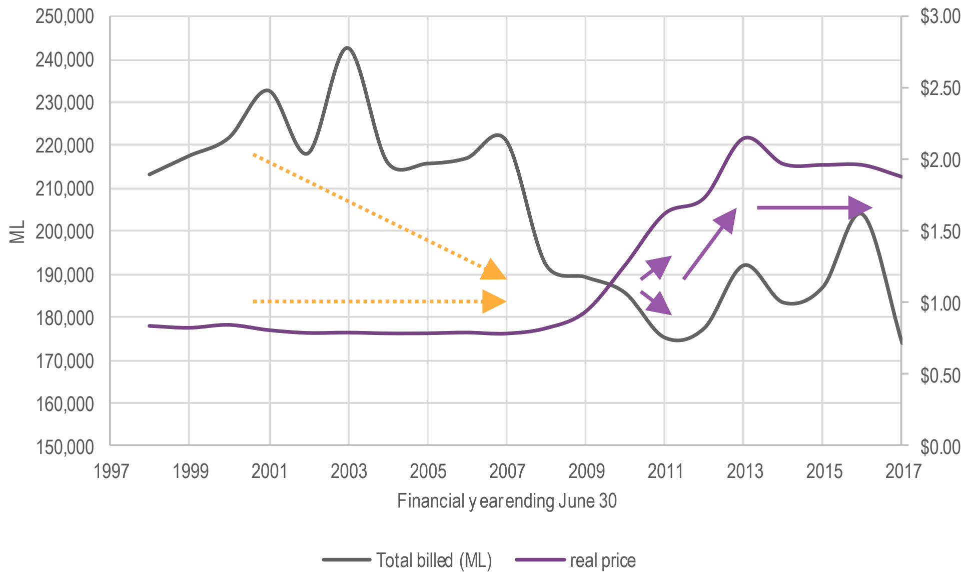
We note that the final model does not include the price of water as an explanatory variable. As a general proposition we consider the price of a product to be a key driver of demand for it.

With regard to water efficiency, SA Water applied the post-model adjustment described in section 3.4 above to the regression forecasts, using an efficiency per capita rate of 0.2 per cent per annum. Without details of the household appliance efficiency model used by SA Water, we cannot comment on validity of the efficiency rate though the conceptual process is sound.

We note that there are other methods to capture water efficiency. In particular, SA Water considered how changing household densities could lead to additional water efficiencies. An alternative could be to capture water usage patterns separately for new and existing customers to allow for differences in water efficiencies in different types of users.

SA Water examined the relationship between price and water usage. That analysis, which is illustrated in Figure 4.1 below, suggests that there was a positive relationship between these two things throughout the period in which the model coefficients were estimated.

FIGURE 4.1 BULK WATER DEMAND, WATER RESTRICTIONS AND PRICE



SOURCE: SA WATER

The arrows on Figure 4.1 show two 'regions' in the relationship between water price and quantity demanded. In the first region, illustrated by the dashed gold arrows, water price remains mostly constant while quantity demanded falls. There is no apparent relationship between the two.

The second region is illustrated by the solid purple arrows. This region is in three parts in which the two variables:

1. moved in opposite directions from 2009/10 to 2010/11
2. increased together from 2010/11 to 2012/13
3. remained approximately constant from 2012/13 to 2016/17, with small movements in the same direction within the period.

Therefore, for most of the period in which the model was estimated, price and quantity demanded moved together, both increasing or decreasing at the same time. If price was added to SA Water's demand model, the result would almost certainly be a *positive* coefficient. Such a coefficient would be inconsistent with economic theory and should not be accepted.

As we understand it, this was part of SA Water's rationale for omitting price from the forecasting model.

The second part was that SA Water's current expectations are that price will be more or less constant (in real terms) during the forthcoming regulatory period. SA Water argues that this means that price changes are not likely to cause substantial changes in water usage during that time and that, for this reason, it is not important to include price in the model.

In almost all cases we expect the price of a product and demand for it to be inversely, or negatively, correlated. That is, as price increases, quantity demand decreases and vice versa.

Any sensible econometric model must conform to the applicable theoretical expectations, so we accept SA Water's view that price should not be included in the forecasting model with a positive coefficient.

To be clear, we do not consider the presence of a positive coefficient to be evidence that there is a positive relationship between water price and quantity demanded. Nor is it evidence that there is no relationship.

It is much more likely, in our view, that the increase in water usage observed between 2010/11 and 2012/13 is attributable to other factors. It is beyond the scope of this project to identify those factors, but one candidate explanation is that this is the effect of 'bounce back' in water usage following the relaxation of water restrictions. This problem could be overcome using discrete variables as long as care is taken to avoid overfitting.

We also note that the data shown here are not weather normalised so some of the variability is attributable to weather conditions (as shown the left hand pane of Figure 3.1).

The problem with omitting price from the model is that it will affect the magnitude of the other coefficients.

If price had not risen as it did between 2010/11 and 2012/13 we expect that water usage would have been higher, and still would be. However, in this model, this effect has been 'mopped up' by the weather and population variables.

Therefore, while we do not consider this to be a 'fatal flaw' in the model, we would encourage SA Water to revisit the question of including price in future forecasting models. In particular it may be appropriate to examine lagged structures of price to allow for the possibility that it takes time for price changes to 'flow through' to water usage.

It is also possible that the model could be improved by adding a variable, or system of discrete variables, to account for 'bounce back' following the relaxation of water restrictions. Again, we note that SA Water explored this issue and we accept that it is difficult to measure this effect, meaning that it may turn out to be impossible to account for this effect in the forecasting model. Nonetheless the literature suggests that it is likely to have occurred.

4.2 Comparability of forecasts

One of the best practice forecasting principles is that forecasts should be compared with forecasts produced by others and that any differences should be explained. In other words, that forecasts should be subjected to peer review.

We raised this with SA Water's forecasting team who were receptive to the idea, but are not aware of comparable forecasts produced by others. For this reason the forecasts have not been contrasted with other forecasts produced independently.

In the absence of suitable forecasts with which to compare we recommend that SA Water consider comparing its forecasting method with forecasts prepared by water utilities in other regions. In making this recommendation, though, we acknowledge the importance of climatic differences in forecasting water usage and the differences in climate of other parts of Australia.

4.3 Model diagnostics and accounting for potential biases

The modelling report provides only limited detail regarding diagnostic testing of the final forecasting model, which reflects its purpose. As discussed in chapter 5, though, we replicated the model and, in doing that, performed relevant diagnostic tests.

SA Water used the ordinary least squares method to estimate its regression coefficients.

For the most part the statistical tests that go along with that method indicated no problems. However, there was some evidence of autocorrelation. To test for this we re-estimated SA Water's model using the robust least squares model which yielded similar coefficients. On this basis we are satisfied that SA Water's original model is sufficiently free of statistical problems of this type.

4.4 Accuracy of forecasting results

The final question we considered was whether we can reasonably expect SA Water's demand forecasts to be sufficiently accurate to use as inputs to the forthcoming regulatory determination.

As discussed above, we are satisfied that the model incorporates the key drivers of water demand other than price and that it is free from statistical bias. We also note that it fits the historical data well. The R-squared statistic, which measures the proportion of variation in the data that is explained by the model, is 93.1 per cent in the winter model and 80.7 per cent in the summer model.

It follows from this that the model can be expected to produce forecasts with this level of accuracy as long as:

1. there is no significant change in the price of water or in tariff structure.
2. there is no substantial change in the underlying relationship between the three explanatory variables and water usage
3. SA Water uses accurate forecasts of the three explanatory variables in its model, namely:
   a) Population
   b) CDD
   c) SMI.

We cannot comment on the future level or structure of water tariffs other than to say that we have been told by SA Water that these are not expected to change substantially and that SA Water acknowledges that a substantial change of this type would require the model to be revised.

Similarly, we are not able to comment on whether there will be a substantial change in the relationship between demand for water and its drivers in the forecast period. Perhaps the best example of the type of change we have in mind here would be a change in the extent of water restrictions/ water saving measures. We see no particular reason to expect a change of this type and we understand that SA Water does not either. The most we can say is that if a change of this type occurred, the forecasts would need to be adjusted to take it into account.

The remaining issue to consider is whether SA Water's choice of inputs is sufficient to generate accurate forecasts.

From this perspective, the inputs to SA Water's model are:

— population data and projections
— weather data and projections, which are used to calculate historical and projected SMI.

As discussed:

— in section 4.4.1, our analysis suggests that SA Water's projection of population growth, and therefore water usage, is reasonable
— in section 4.4.2, we were initially concerned that SA Water's decision to use only ten years of historical weather data might harm its forecasts, but subsequent analysis alleviates this concern to some extent.

4.4.1 Population data and projections

Australia's population, and that of the States and Territories is an important statistic with a wide number of uses including analysis and projection of demand for water.

However, population changes substantially over time and is difficult and time consuming to measure. This is apparent from the fact that our Census is conducted on a six-yearly cycle.

Between the six yearly census cycle the Australian Bureau of Statistics produces quarterly estimates of our population, known as *Estimated Resident Population,* published in ABS publication number 3101.0. At the time of writing this report, the most recent edition of *Estimated Resident Population* was the December 2017 edition. This was published on 21 June 2018, *after* SA Water's model was produced.

There are numerous editions of *Estimated Resident Population* with small changes in the values between each edition. One recommendation is that SA Water update its historical model to make use of the most recent edition as it currently appears to be using older data. This would lead to small changes in the model coefficients and fit, but not, we expect, to substantial changes in the forecasts.

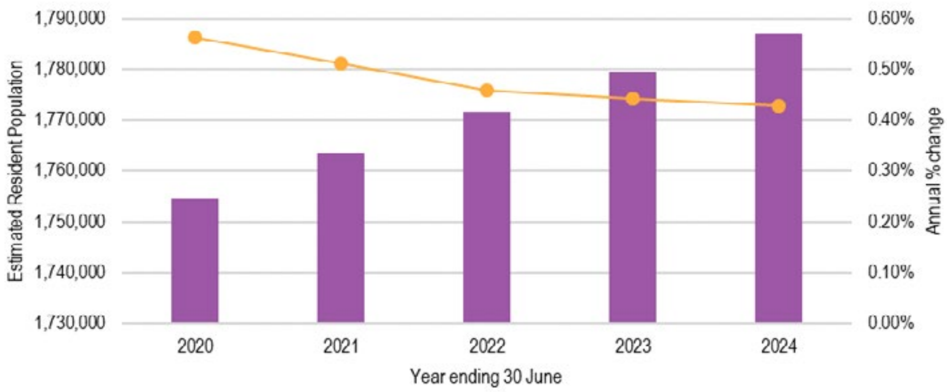
A more substantial recommendation relates to SA Water's choice of South Australia's projected population.

In the model we reviewed forecasts are based on the expectation that South Australia's population will grow in line with the low projection series produced by the Department of Planning, Transport and Infrastructure (DPTI) in 2015, which is shown in **Figure 4.2**. This implies a projected population growth rate of 0.48 per cent per annum for the regulatory period.

Generally speaking we would expect forecasts such as these to be based on the 'neutral' or central projection of a suitably independent forecaster. Therefore, SA Water's choice of the low series led us to examine historical growth in South Australia's population more closely.

The result of that examination, which is discussed further below, is that the recent slowdown in population growth supports SA Water's choice, which is reasonable in our view.

FIGURE 4.2 POPULATION PROJECTIONS FROM 2020 TO 2024



SOURCE: DPTI POPULATION PROJECTIONS – LOW PROJECTION SERIES

Figure 4.3 shows the estimated resident population (ERP) of South Australia as published by the ABS in December 2017 (ABS cat 3010.0).[8] The figure shows the change in ERP on a year on year basis as well as the average calculated from each year to the end of the dataset (December 2017). From the

[8] ERP is presented on a quarterly basis, but year on year growth is always the same in any given pair of years regardless of which quarter is considered. In this figure the December values are plotted, but the choice of quarter makes no difference.

figure it is evident that, in the 36 years for which data are shown, year on year growth in South Australia's population:

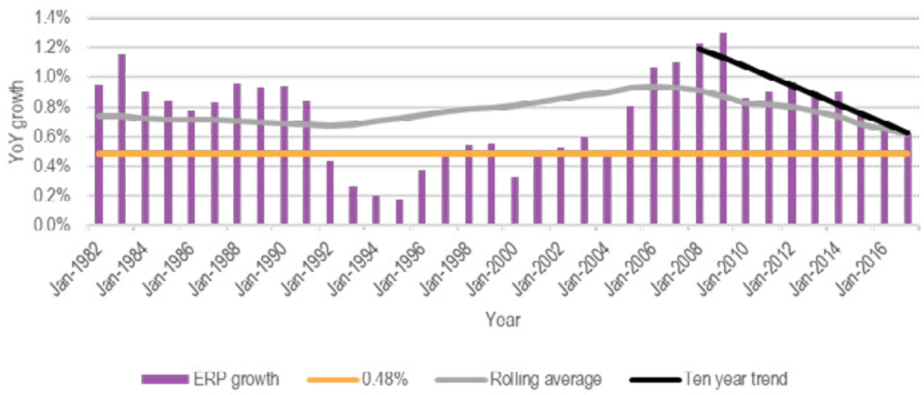
— exceeded 0.48 per cent approximately 81 per cent of the time (on 29 occasions)
— been less than 0.48 per cent approximately 19 per cent of the time (on 7 occasions)
— has never equalled 0.48 per cent.

In other words, in the last 36 years, South Australia's population growth is more than four times as likely to have been faster than 0.48 per cent than slower.

However, in the last ten years the picture is different. Population growth in South Australia has slowed and trended downwards over this period.

Therefore, notwithstanding that the long term average growth in South Australia's population, depicted by the grey curve, has *never* been as low as 0.48 per cent per annum, it appears reasonable to expect that this will be the experience in during the regulatory period.

FIGURE 4.3 ANALYSIS OF ESTIMATED RESIDENT POPULATION, SOUTH AUSTRALIA



SOURCE: ACIL ALLEN ANALYSIS OF ABS CAT 3010.0, DECEMBER 2017

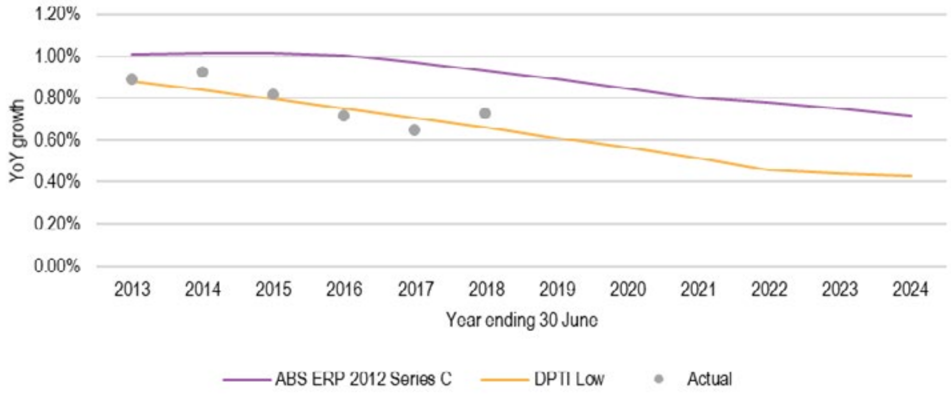
It is also relevant to note that the low series has matched actual outcomes closely in the last five years as illustrated in **Figure 4.4**.

The figure shows that historical growth in ERP has been tracking the low DPTI projection series reasonably closely, lending further support to the idea that this will continue to be the case.

The best practice forecasting criteria in **Box 2.1** require that forecasts are prepared using suitably independent forecasts of key drivers and call for the use of the most recent information available. This suggests that, in principle preference should be given to the ABS projections, which are more recent.

However, given that the DPTI low series has been the best historical predictor of population growth in South Australia, it seems perfectly reasonable for SA Water to adopt that series here.

FIGURE 4.4 COMPARING POPULATION PROJECTIONS



Note: DPTI – low and ABS Series C both assume a low natural rate of population growth, low net overseas migration and small interstate flows. The difference is in the magnitudes assumed under each of the underlying trends.

SOURCE: ABS, DPTI

4.4.2 Weather data and projections

SA Water uses weather data in its model to calculate SMI, which is a composite index drawing on rainfall and evaporation. It also uses weather data to calculate CDD, which is a function of temperature.

The use of historical data is not in question. We note that SA Water has used data from Adelaide Airport whereas it has previously used data from Kent Town. The change was a result of the Bureau of Meteorology's decision to move its 'central' weather station away from Kent Town in mid 2017. We do not have a particular view as to whether one or another of these two weather stations is better suited to forecasting demand for water in South Australia, but we see no problem with changing.

We note that SA Water's forecasts include high medium, average and low scenarios, which are driven entirely by differences in the weather/ climate inputs. Further, we understand that these three scenarios relate to the mean, 10th, 50th and 90th percentile of weather outcomes as observed in the last ten years.

This raises a conceptual challenge. In many cases we would argue that ten observations is not sufficient data from which to form a view as to the variability in a data series. Statistically, the 10th and 90th percentile levels can be expected to be observed once in ten observations. However, there is no particular guarantee that this will happen.[9]

Ordinarily, we would advocate the use of more data to establish expectations as to the likely high, medium and low weather/ climate conditions and, therefore, demand for water.

The problem in this instance is climate change. There are plenty of weather data that could be used to provide a robust understanding of the true level of variability in South Australia's weather outcomes. However, due to climate change, data that are 'old' might no longer be relevant as, from a statistical perspective, they might have been generated by a different process.

It is beyond the scope of this assignment to test this issue thoroughly, but our preliminary testing supports the notion that CDD in Adelaide has increased. This is illustrated in Figure 3.1, which shows the level of CDD calculated using SA Water's preferred base 15 from data measured at both the Kent Town and Adelaide Airport weather stations. In this case the figure related to February, though we examined the other months as well.

[9] This is exactly the same as saying that if a coin is tossed twice, we *expect* to see one head and one tail, but there is no guarantee that this will actually happen.

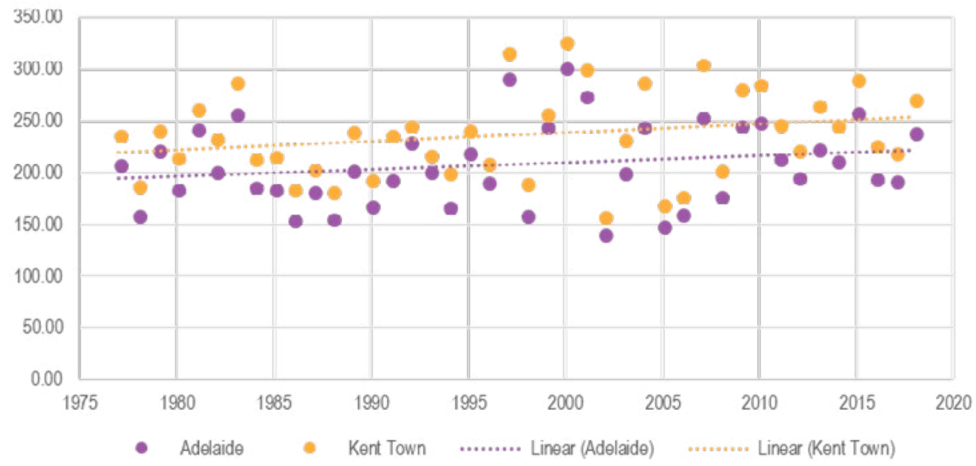
The figure shows an increasing trend in CDD, which is consistent with a warming climate, though also with the Urban Heat Island effect. The latter is also consistent with the fact that the trend is more rapid in Kent Town.

This analysis, though preliminary, provides some support for SA Water's decision not to use more than 10 years weather/ climate date in projecting weather conditions for its forecasts.

However, it leaves the question of whether the last ten years provide a thorough enough understanding of the potential variability of weather conditions in future unanswered. To address this question in a preliminary fashion we detrended the CDD data and tested the hypothesis that the number of occasions on which the number of CDD15 observed at Adelaide Airport at the last ten years exceeded the 10th percentile level so frequently as to suggest that there has been an increase in the *variability* of the CDD measure *in addition* to a trend increase in the level of CDD.

The number of CDD we would expect to observe varies month by month, so a test of this kind must be conducted separately for each month. The results of the test provide reasonably strong evidence that variability has increased in March, July and October and more limited evidence that it has increased in other months. The analysis is only preliminary, but it supports SA Water's decision not to use 'old' weather data for this purpose.

FIGURE 4.5 CDD IN ADELAIDE IN FEBRUARY, 1977 TO 2018



SOURCE: ACIL ALLEN ANALYSIS

5 RESULTS – MODEL VERIFICATION

Model verification refers to reviewing whether the Spreadsheet accurately and efficiently implements the final demand model as described in the Modelling Report. As described in section 2.1, we have completed this component of the review in two steps:

1. assessing model design, as described in section 5.1
2. assessing the reproducibility of the forecasts, as described in 5.2.

KEY FINDING 2 WHETHER THE SPREADSHEET IS AN ACCURATE IMPLEMENTATION FO THE INTENDED MODEL

Based on the review we have conducted we are satisfied that the spreadsheet supplied to us is an accurate implementation of the model described in the modelling report.

5.1 Model design

SA Water's spreadsheet is well-designed.

It begins with a home page that details the purpose of the model. This is followed by a contents page that describes how the overall model is laid out. Links are also provided to individual spreadsheets for ease of navigation. All of these links have been verified and lead to the correct worksheets.

Worksheets are numbered in a logical manner from left to right, starting with an inputs and assumptions sheet. Inputs such as population growth rate and the proportion of non-revenue water are also named to provide ease of reference in later calculation sheets. All named cells follow a naming prefix "k_SHEET NUMBER". These named inputs and assumptions are then easily referred to in later calculation worksheets.

Regression outputs and associated calculations and charts then follow. All calculations can be easily tracked, without any indication of hard-coded cells. There is also a separate sheet for charting which reduces unnecessary clutter and adds to the overall aesthetics of the Spreadsheet.

Projections of the climate variables and population are next. We have been unable to trace the calculations within these sheets because they are presented as hard-coded numbers. However, we recognise that our scope of works does not extend to assessing the inputs – we have taken them for granted in our review of SA Water's forecasting methodology.

The Spreadsheet ends with forecasting results and final outputs for presentation in reports or presentations. Again, all calculations can be easily traced back to their sources.

Overall, the model is designed in a format that can be easily followed. It is laid out transparently and will be relatively simple for ESCOSA to audit.

5.2 Reproducibility of results

We have repeated the final forecasting model provided to us by SA Water, albeit in a slightly different manner. This yielded essentially the same results as those contained in SA Water's spreadsheets, which verifies that SA Water's spreadsheet works as intended and is free from error.

To reproduce SA Water's model we took the historical SMI, CDD_{15}, ERP and monthly bulk water per capita to use in our own regression analysis.

One difference between our regression model and the final one used by SA Water is that our dependent variable was expressed in megalitres per person rather than kilolitres per person. This leads to small differences in the results.

We have made the decision to work our regressions in megalitres per capita purely for ease of calculations. Bulk water usage, as provided by SA Water, was reported in megalitres so completing the regressions in those units limits the chances of errors in units conversion in the preparation of data.

From a technical standpoint, our scaling down of the dependent variable by a factor of 1000 means that the estimated model coefficients should be scaled down by the same factor. Similarly, the standard errors should also be lower and so should the residuals. However, important econometric diagnostics such as t-statistics, p-values and model fit should remain the same.

The other main difference between our model and SA Water's final model is that we completed our regressions in R, which is a specialist statistical programming language that uses discrete methods to calculate statistical results. In contrast, SA Water's regression was computed using a macro in Excel. Therefore, there may be slight differences in statistical diagnostics in our regression results and the ones from SA Water.

Table 5.1 compares our regression results with the ones used by SA Water. As hypothesised, our model coefficients have been scaled down due to the difference in units used in the two models. Additionally, there are slight differences in t-statistics. These reflect a combination of using different software packages to conduct regressions, as well as the difference in units used.

TABLE 5.1 COMPARISON OF REGRESSION RESULTS

Variable	Summer regression coefficients	Winter regression coefficients
	ACIL Allen regression model	
Intercept	0.01252*** (17.84316)	0.01134*** (31.30382)
Average SMI	-0.00006*** (-7.15943)	-0.00003*** (-9.35801)
CDD15	0.00001*** (4.79697)	0.00001*** (9.73664)
R-squared	80.7%	93.1%
	SA Water regression model	
Intercept	12.526*** (17.855)	11.337*** (31.288)
Average SMI	-0.056*** (-7.166)	-0.034*** (-9.353)
CDD15	0.013*** (4.796)	0.014*** (9.732)
R-squared	80.7%	93.1%

Note: Numbers in brackets refer to the associate t-statistics on the estimated coefficients. One star means the coefficient is statistically significant at the 10 per cent level. Two stars means statistically significant at the five per cent level. Three stars means statistically significant at the one per cent level.

SOURCE: ACIL ALLEN

From a forecasting perspective, our final forecasts will be lower than SA Water's because our overall regression results have been scaled downwards. This is confirmed in Table 5.2, which summarises the differences in forecasts produced by SA Water and our forecasts after aggregating to the annual level. We note that in every financial year and every given scenario, SA Water's forecasts are higher than ours. However the differences are immaterial and are due entirely to our choice to work with different units.

TABLE 5.2 DIFFERENCE BETWEEN SA WATER FORECASTS AND ACIL ALLEN FORECASTS

Financial year ending	Low scenario (ML)	Medium scenario (ML)	Average scenario (ML)	High scenario (ML)
2018	6.84	9.80	9.39	11.32
2019	6.88	9.86	9.44	11.38
2020	6.92	9.92	9.50	11.45
2021	6.96	9.98	9.56	11.52
2022	7.00	10.04	9.62	11.59
2023	7.05	10.10	9.67	11.66
2024	7.09	10.16	9.73	11.73

SOURCE: ACIL ALLEN

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