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# water

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## Unconventional Gas Mining: What Can Australia Learn From The US Experience?

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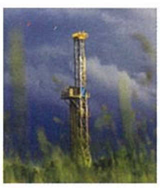

### Cover

A hydro-fraccing rig in a field in North Pennsylvania. On page 4, Dr Ian Duncan, Research Scientist at the University of Texas and keynote speaker at AWA's recent Unconventional Gas Thought Leadership Seminar Series, compares CSG and shale gas and discusses how Australia can benefit from the US experience.

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# MODELLING BOUNCE-BACK IN WATER CONSUMPTION POST-DROUGHT

## A comparison of a custom-built regression model for forecasting total customer water demand and end-use based water projections using the integrated Supply Demand Planning (iSDP) model.

D Giurco, S Mohr, J Fyfe, P Rickwood, M Teng, J Franklin

SMART SYSTEMS/METERING

## ABSTRACT

Focused on a case study of Geelong, Victoria, this paper presents the results of a unique comparison of (i) a custom-built regression model for forecasting total customer water demand and (ii) end-use based water projections using the integrated Supply Demand Planning model (iSDP) model. The regression model used historical data for calibration based on level of restrictions, evapotranspiration, temperature, and rainfall. By selecting a future climate scenario (and any anticipated restriction periods) for the next 10-year period, demand can be projected by the model.

By contrast, the end-use model was calibrated to consumption data during drought (rather than long-term averages) to determine the extent to which end-use consumption was suppressed and how much each end-use may be expected to rebound under a range of scenarios. Results from both approaches are contrasted and reflections of the relative strengths of each approach are discussed.

## INTRODUCTION

Major population centres in Australia have experienced significant periods of drought over the last decade. As a result, restriction regimes were put in place that resulted in significant water savings. In the case of Geelong, with a population of over 250,000 people, Level 3 and 4 restrictions were in place from late 2006 to early 2010 and were progressively lifted as the drought eased.

Determining the effect of restriction periods on urban water consumption is an important modelling exercise that can be used to more effectively manage scarce water resources. Not only is it important to determine the reduction of water consumption during periods of restrictions, it is also important to determine the longevity of reductions after the stages of restrictions are lifted. This has given rise to the term *bounce-back*, which is the extent to which water consumption levels will rise toward pre-restriction levels following the lifting of restrictions. To date, limited research has been published on bounce-back in Australia.

This paper contrasts two approaches to modelling future water demand following the lifting of restrictions – a regression-based model and an end-use model. Each has strengths and weaknesses and the combination of techniques offers complementary insights.

The paper is structured in three main sections. The first introduces the regression model for estimating the effect of historical restrictions and future water demand proejctions based on different *climate scenarios*. The second introduces results from the end-use model/integrated Supply Demand Planning (iSDP) model and explores future water demand projections based on different *customer behaviour scenarios*. The iSDP model also has the capacity to run scenarios of low or high uptake of water-efficient technologies. Finally, in the third section, results and modelling approaches are contrasted.

## REGRESSION MODEL

In the literature, regression modelling has been used to determine water savings associated with periods of water restrictions. Such models may be fitted on pre-restriction data and used to derive estimates of water consumption during restrictions periods, which are subsequently compared with observed consumption in order to generate estimates of water savings (Hansen and Narayanan, 1981; Kenney *et al.*, 2004; Kidson *et al.*, 2006; Neal *et al.*, 2010; Spaninks, 2010).

The effect of restrictions may also be determined by incorporating one or more additional variables into the regression model to reflect the implementation of restrictions (Anderson *et al.*, 1980; Roberts, 2008). Simple dummy variables reflecting when a given stage of restrictions is in force are often used (Anderson *et al.*, 1980; Roberts, 2008), although more complex specifications can be applied. In a similar manner, the long-lasting effects of restrictions may also be determined, using a simple dummy variable that defines the post-restrictions period.

For Geelong, a 10-year forecast model was built and forecasts bulk water demand under user-specified climate scenarios and bounce-back from the 2007–2010/11 water restrictions. The model applies linear regression to historical data between 2001 and 2011. It predicts bulk water demand based on temperature and rainfall under varying levels of restrictions (to allow for climate variability).

Future forecasts can then be made for 'wet' or 'dry' climate years under varying levels of anticipated future restrictions or bounce-back.

The regression model is:

$$D = a_0 + a_1E + a_2W - a_3R + E\sum_{i=1}^{4} x_i r_i + (1-B)E\sum_{i=1}^{4}(1-x_i)r_i$$

where the per capita water demand $D$ is a function of:

- a constant term $a_0$
- evapotranspiration (more evap. leads to higher water usage) $a_1.E$

- the number of days in the month over 20°C (more warm days, higher water use) $a_2.W$
- the amount of rain (more rain, less demand) $a_3.R$
- the level of restrictions (i.e. Level 1, Level 2, Level 3, Level 4) $E.(x_1.r_1+...+x_4.r_4)$
- the degree of bounce-back specified/ expected [used for future projection scenarios] $(1\text{-}B).E.((1\text{-}x_1).r_1+...+(1\text{-}x_4)r_4$

The regression model is run using calibration data from 2001 to 2011 to determine:

- the constants $a_0$, $a_1$, $a_2$, $a_3$

which are then also used for the future projection.

To calculate the 10-year projection, for each year, the user specifies:

- Any expected level of restriction for the given year [default = none; and all projections in this paper use the default of no anticipated restriction periods];
- The level of progress back towards unrestricted demand for each year in the future projection period, specified on a zero (0) to one hundred (100) scale
  - 0 = litres per capita per day (LCD) demand as per under Stage 4 restrictions (no bounce-back)
  - 100 = LCD demand as per pre-restriction levels (full bounce-back);
- The specific climate reference year to be used as the basis for the projection (e.g. we expect the next 10 years to have a climate like 1985, or 2010, etc). The model then uses the evapotranspiration, rainy days and warm days data from the specified year as a basis for the future projections.

As an alternative to specifying a specific climate reference year, a percentile figure from zero to one can be used, i.e. 0.5 is a neutral climate, 0.01 is an extremely wet-cold climate (lowers projected water use), or 0.99 is an extremely dry-hot climate (increases projected use).

To illustrate, Figure 1 shows the influence of climate; three scenarios are run, each goes to 50% bounce-back over six years (i.e. 0% bounce-back in year one, 10% in year two, 20% in year three, 30% in year four, 40% in year five, 50% in years 6–10):

I. is for a 90th percentile climate (dry-hot) [indicated by a long dash in Figure 1] and

II. is for a 50th percentile climate (average) [indicated by a solid line in Figure 1]

III. is for a 10th percentile climate (wet-cold) [indicated by a dotted line in Figure 1].

The calibration data is shown in Figure 2 – note that at the time of analysis, only actual water consumption data to 2011 were available.

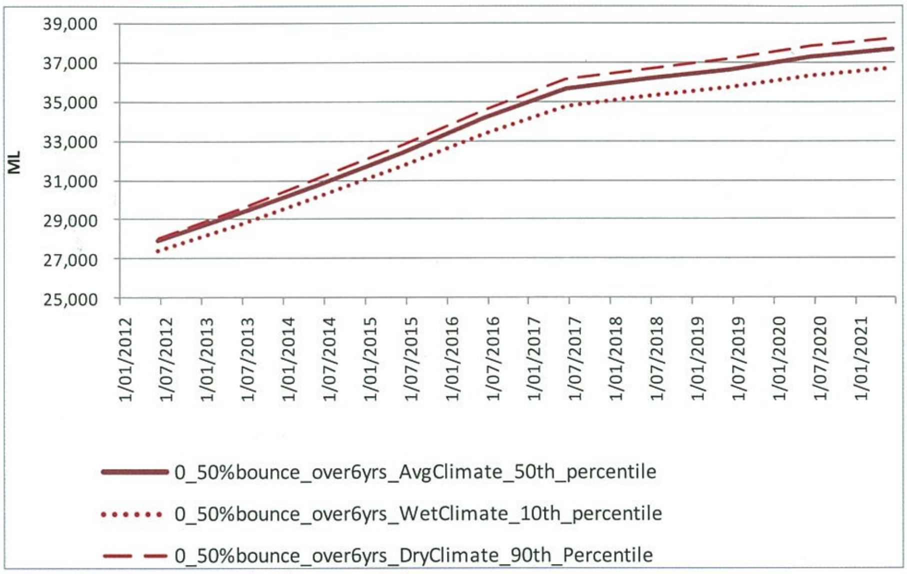

**Figure 1. Illustration of influence of climate.**

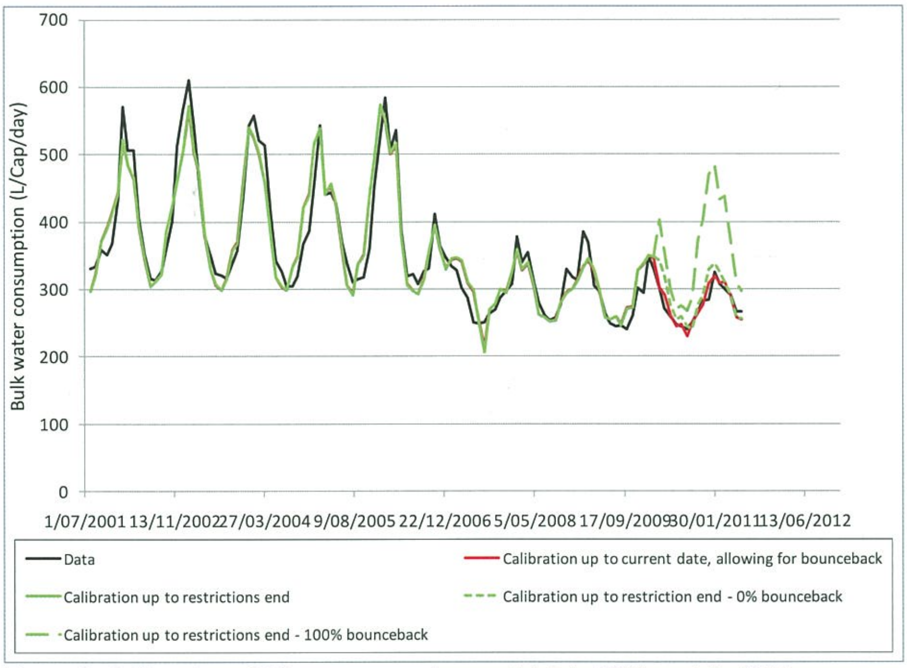

**Figure 2. Calibration of 10-year regression model July 2001 to July 2011.**

## ISDP/END-USE MODEL

Another approach to projecting demand is to use an end-use model. Unlike regression, which tries to find a relationship between a small number of explanatory variables, an end-use model takes explicit account of water consumption by different end uses (residential shower use, toilets, irrigation, industrial, etc) and, because of this, knowledge of particular trends (such as the trend to more water-efficient appliances) can be explicitly included in the model. By contrast with the regression model, whose calibration period is 2001 to 2011, the calibration period for the End-Use Model (also called iSDP or integrated Supply Demand Planning model) is June 2000 to June 2006.

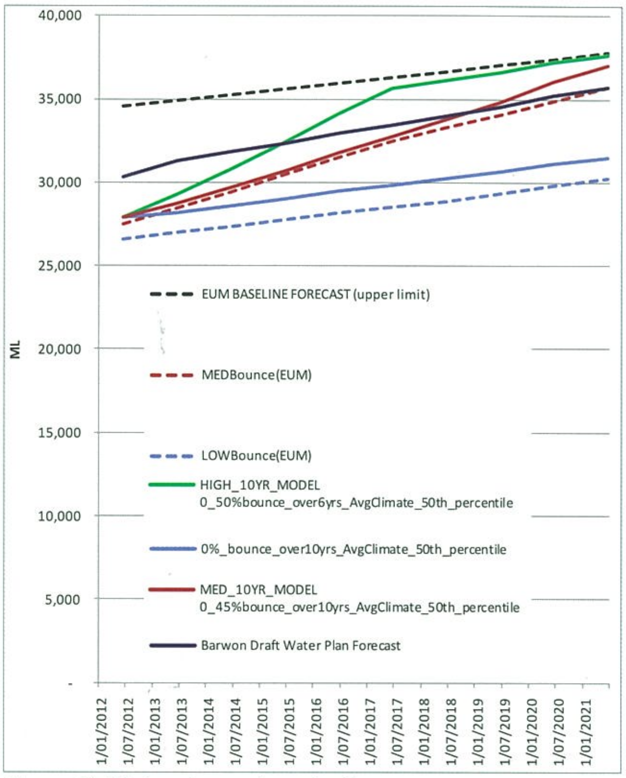


**Figure 3. Water demand projections.**

Under the end-use modelling approach, in addition to the baseline forecast (black dash) two scenarios are developed, one of which is presented here:

- Low demand projection (low bounce-back/high savings) (red dash);
- Medium projection (medium water use/bounce-back) (blue dash).

The purpose of describing these plausible scenarios to the end-use level is to show how relative changes in end-use consumption affect projections. They take into consideration the work of Beatty (2011), who estimated significant indoor savings of up to 44% in Sydney under Stage 3 restrictions, where previously it was commonly assumed that savings from restrictions were overwhelmingly from outdoor savings.

The projection in Table 1 (overleaf) shows that residential showers and residential landscapes are the dominant areas of use and uncertainty. While toilets and clothes washers are also big uses, use in these appliances is influenced by technology (i.e. is the toilet or clothes washer efficient or inefficient?). Usage and behaviours do play a part and could relax following lifting of restrictions (e.g. washing clothes without a full load, or using full-flush instead of half-flush); however, these behaviours have a lesser impact on usage than shower length and watering gardens. The length of time people stay in the shower or water the garden are things that can easily be extended and contribute significantly to bounce-back. The accelerated introduction of efficient showerheads helps limit this bounce-back (a 20-minute shower under a low-flow showerhead uses approximately half the water of an inefficient showerhead) and has been allowed for.

It should be recognised that there is a lack of published literature on bounce-back by end-use, therefore this paper has cross-checked projections with the regression model. Approaching the projections from two starting points and comparing results strengthens the insights derived from the results.

## RESULTS

The results of the scenarios for future demand projections using the end-use model (dotted) and regression model (solid lines) are presented in Figure 3. This figure shows the mid-range prediction in dotted red based on end-use assumptions and medium bounce-back of 5% per year from the 10-year regression model as a solid red line, assuming a 50th percentile climate) with a low bounce-back scenario in blue (again, the dotted line from the end-use model and solid line in light blue representing 0% bounce-back for a 50th percentile climate). The high scenario from the 10-year regression model (green) could occur if there is 50% bounce-back over six years, which is then maintained (i.e. 0% in the first year, 10% in the second year, 20% in the third year, 30% in the fourth year, 40% in the fifth year, 50% in the sixth–10th years). This LCD demand is a little less than that seen under Level 2 restrictions.

The solid dark blue line uses actual 2011/12 data showing consumption in this year. It is higher than other projections (except the black dotted line). The most recent data used in the 10-year regression model and end-use model were 2010/2011 data. The dotted black line is the baseline forecast from the End-Use Model and would be equivalent to all the values in Table 1 being 100% of pre-restrictions levels across the projection period.

Future projections could also be sensitive to significant (unexpected) changes in population or industry demand over the period – these have not been explicitly explored, however, both the 10-year forecasting model and the end-use model have the capacity to do so.

It is important to note that the baseline demand for the end-use model (represented as a black dotted line in Figure 3) DOES NOT consider future climate variability (i.e. hot-wet or cold-dry); however, it does consider changes to stock efficiency made during the four years of restrictions and over the 10-year projection period (i.e. further introduction of water-efficient showers, toilets etc. in new and existing dwellings).

## DISCUSSION

There are several sources of difference between the end-use model (iSDP model) and the regression forecast.

- Base year – the unrestricted per capita demand for the regression model is based on the 2001–2006 period. For the end-use model, it is continually being updated based on changes to stock efficiency over time;
- Climate – the regression model allows for the influence of climate, the end-use model assumes a dry-average climate;
- Starting consumption – the end-use model projections start from ACTUAL observed consumption in the financial year beginning 2012. By contrast, the regression model takes an average of per capita demand over years under Stage 4 restrictions to use as the basis. As the final year of Stage 4 restrictions had the lowest demand, this means the average of per capita consumption under Stage 4 restrictions is higher than the ACTUAL figure used in the end use model projections. This is understood well with reference to Figure 3;
- Efficient stock – the end-use model incorporates improvements in stock efficiency whereas the regression model does not explicitly; a proxy can be incorporated by modifying the level of bounce-back specified;
- Changed behaviours – the end-use model introduces a proxy for relaxed behaviours over time in Table 1; the regression model incorporates this as part of the bounce-back variable specified.

*(Please see overleaf for Table 1, then turn the page again for Conclusion of paper)*

**Table 1. Medium end-use projection.**

| End-use [ML] | 30/6/2011 | 30/6/2012 | 30/6/2013 | 30/6/2014 | 30/6/2015 | 30/6/2016 | 30/6/2017 | 30/6/2018 | 30/6/2019 | 30/6/2020 | 30/6/2021 | Assumptions |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agricultural demand modelled | 1413 | 1433 | 1453 | 1474 | 1495 | 1516 | 1537 | 1558 | 1580 | 1601 | 1622 | Agricultural use assumed to be as per pre-restrictions (i.e. 100%) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened agricultural demand | 1413 | 1433 | 1453 | 1474 | 1495 | 1516 | 1537 | 1558 | 1580 | 1601 | 1622 | |
| Commercial demand modelled | 1292 | 1311 | 1329 | 1348 | 1367 | 1386 | 1406 | 1425 | 1445 | 1464 | 1484 | Efficiency savings in place in 2011 for commercial use (e.g. showers, toilets) assumed to endure over projection period |
| Percent of projection under bounce-back scenario | 85% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | |
| Dampened commercial demand | 1098 | 1049 | 1064 | 1079 | 1094 | 1109 | 1125 | 1140 | 1156 | 1171 | 1187 | |
| Industrial demand modelled | 4087 | 4146 | 4205 | 4265 | 4325 | 4386 | 4447 | 4509 | 4570 | 4632 | 4694 | Efficiency savings in place in 2011 for industrial use (e.g. efficient technologies) assumed to endure over projection period |
| Percent of projection under bounce-back scenario | 85% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | |
| Dampened industrial demand | 3474 | 3317 | 3364 | 3412 | 3460 | 3509 | 3558 | 3607 | 3656 | 3706 | 3755 | |
| Institutional demand modelled | 443 | 449 | 455 | 462 | 468 | 475 | 482 | 488 | 495 | 502 | 508 | Efficiency savings in place in 2011 for institutional use (e.g. showers, toilets) assumed to endure over projection period |
| Percent of projection under bounce-back scenario | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | |
| Dampened institutional demand | 354 | 359 | 364 | 369 | 375 | 380 | 385 | 391 | 396 | 402 | 407 | |
| Non-revenue water demand modelled | 2836 | 2864 | 2893 | 2921 | 2951 | 2980 | 3011 | 3042 | 3073 | 3104 | 3136 | Non-revenue water assumed to be as per pre-restrictions (i.e. 100%) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened non-revenue water demand | 2836 | 2864 | 2893 | 2921 | 2951 | 2980 | 3011 | 3042 | 3073 | 3104 | 3136 | |
| Other demand modelled | 790 | 802 | 813 | 825 | 836 | 848 | 860 | 872 | 884 | 895 | 907 | Other potable assumed to be as per pre-restrictions (i.e. 100%) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened other demand | 790 | 802 | 813 | 825 | 836 | 848 | 860 | 872 | 884 | 895 | 907 | |
| Other residential demand modelled | 565 | 573 | 581 | 589 | 598 | 606 | 615 | 623 | 632 | 640 | 649 | Other residential assumed to be as per pre-restrictions (i.e. 100%) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened other residential demand | 565 | 573 | 581 | 589 | 598 | 606 | 615 | 623 | 632 | 640 | 649 | |
| Recreational demand modelled | 1524 | 1541 | 1560 | 1578 | 1596 | 1615 | 1633 | 1652 | 1671 | 1690 | 1708 | Recreational assumed to be 30% of pre-restrictions level in 2011 rising to 80% of pre-restrictions level in 2016 |
| Percent of projection under bounce-back scenario | 30% | 40% | 50% | 60% | 70% | 80% | 80% | 80% | 80% | 80% | 80% | |
| Dampened recreational demand | 457 | 617 | 780 | 947 | 1117 | 1292 | 1307 | 1322 | 1337 | 1352 | 1367 | |
| Residential basins demand modelled | 858 | 870 | 883 | 895 | 908 | 921 | 933 | 946 | 959 | 972 | 985 | Basin use in 2011 85% of pre-restrictions (due to more efficient taps) assumed to rise to 100% in 2017 from relaxed behaviours, teeth cleaning etc. |
| Percent of projection under bounce-back scenario | 85% | 87% | 89% | 91% | 93% | 95% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential basins demand | 729 | 757 | 786 | 815 | 844 | 875 | 933 | 946 | 959 | 972 | 985 | |
| Residential baths demand modelled | 672 | 681 | 691 | 701 | 711 | 721 | 731 | 741 | 751 | 761 | 771 | Bath use in 2011 85% of pre-restrictions (due to behaviour change) assumed to rise to 100% in 2017 due to relaxed behaviours |
| Percent of projection under bounce-back scenario | 85% | 87% | 89% | 91% | 93% | 95% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential baths demand | 571 | 593 | 615 | 638 | 661 | 685 | 731 | 741 | 751 | 761 | 771 | |
| Residential clothes washers demand modelled | 2609 | 2595 | 2582 | 2571 | 2562 | 2554 | 2548 | 2544 | 2542 | 2541 | 2542 | Clothes washers in 2011 85% of pre-restrictions (via new technology and full load behaviour) assumed to rise to 100%: relaxed full load behaviour |
| Percent of projection under bounce-back scenario | 85% | 87% | 89% | 91% | 93% | 95% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential clothes washers demand | 2217 | 2258 | 2298 | 2340 | 2382 | 2426 | 2548 | 2544 | 2542 | 2541 | 2542 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residential coolers demand modelled | 271 | 275 | 279 | 283 | 288 | 292 | 296 | 301 | 305 | 310 | 314 | Coolers use as per pre-restrictions levels (100%) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential coolers demand | 271 | 275 | 279 | 283 | 288 | 292 | 296 | 301 | 305 | 310 | 314 | |
| Residential dishwashers demand modelled | 161 | 164 | 166 | 169 | 172 | 175 | 178 | 181 | 184 | 187 | 190 | Dishwashers as per pre-restrictions levels (100%) – these are a small end use overall so any efficiency savings from new technologies small |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential dishwashers demand | 161 | 164 | 166 | 169 | 172 | 175 | 178 | 181 | 184 | 187 | 190 | |
| Residential landscapes demand modelled | 6150 | 6233 | 6316 | 6400 | 6485 | 6570 | 6656 | 6741 | 6828 | 6914 | 7000 | Landscapes use in 2011 30% of pre-restrictions assumed to rise to 80% in 2021 as new gardens and lawns planted and watered |
| Percent of projection under bounce-back scenario | 30% | 35% | 40% | 45% | 50% | 55% | 60% | 65% | 70% | 75% | 80% | |
| Dampened landscapes baths demand | 1845 | 2181 | 2526 | 2880 | 3242 | 3613 | 3993 | 4382 | 4779 | 5185 | 5600 | |
| Residential pools demand modelled | 27 | 28 | 28 | 29 | 29 | 29 | 30 | 30 | 30 | 31 | 31 | Pools as per pre-restrictions levels (100%) – small use anyway |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential pools demand | 27 | 28 | 28 | 29 | 29 | 29 | 30 | 30 | 30 | 31 | 31 | |
| Residential outdoor misc. demand modelled | 904 | 917 | 931 | 945 | 959 | 973 | 987 | 1001 | 1015 | 1030 | 1044 | Outdoor misc. (car washing etc) assumed to rise from 30% in 2011 to 80% in 2017 as people swap bucket for hose |
| Percent of projection under bounce-back scenario | 30% | 35% | 40% | 45% | 50% | 55% | 60% | 60% | 60% | 60% | 60% | |
| Dampened outdoor misc. demand | 271 | 321 | 372 | 425 | 479 | 535 | 592 | 601 | 609 | 618 | 626 | |
| Residential tap leaks demand modelled | 635 | 644 | 654 | 663 | 673 | 683 | 693 | 702 | 712 | 722 | 732 | Tap leaks as per pre-restrictions (100%) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential tap leaks demand | 635 | 644 | 654 | 663 | 673 | 683 | 693 | 702 | 712 | 722 | 732 | |
| Residential unexplained trend demand modelled | 1675 | 1700 | 1726 | 1753 | 1779 | 1806 | 1833 | 1860 | 1887 | 1915 | 1942 | Trend is a correction term (100%) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened unexplained trend demand | 1675 | 1700 | 1726 | 1753 | 1779 | 1806 | 1833 | 1860 | 1887 | 1915 | 1942 | |
| Residential showers demand modelled | 5634 | 5679 | 5724 | 5771 | 5819 | 5868 | 5919 | 5971 | 6024 | 6078 | 6132 | Showers in 2011 at 80% of pre-restrictions due to new technology and shorter showers, assumed to rise to 100% in 2021 due to longer showers |
| Percent of projection under bounce-back scenario | 80% | 82% | 84% | 86% | 88% | 90% | 92% | 94% | 96% | 98% | 100% | |
| Dampened residential showers demand | 4507 | 4657 | 4808 | 4963 | 5121 | 5281 | 5446 | 5613 | 5783 | 5956 | 6132 | |
| Residential sinks demand modelled | 664 | 670 | 677 | 683 | 690 | 697 | 705 | 712 | 719 | 727 | 735 | Sinks as per pre-restrictions levels (100%) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential sinks demand | 664 | 670 | 677 | 683 | 690 | 697 | 705 | 712 | 719 | 727 | 735 | |
| Residential toilet demand modelled | 2249 | 2229 | 2210 | 2192 | 2175 | 2155 | 2137 | 2120 | 2104 | 2089 | 2075 | Toilets as per pre-restrictions levels (stock turnover towards efficient accounted for in demand component of model) |
| Percent of projection under bounce-back scenario | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | |
| Dampened residential toilet demand | 2249 | 2229 | 2210 | 2192 | 2175 | 2155 | 2137 | 2120 | 2104 | 2089 | 2075 | |
| **Total demand 100%** | **35,456** | **35,804** | **36,158** | **36158** | **36,884** | **37,255** | **37,635** | **38,019** | **38,410** | **38,804** | **39,201** | |
| | | | | | | | | | | | | |
| Dampened demand (to ~match actual 26,556 in 2011) | 26,809 | 27,489 | 28,459 | 29,449 | 30,461 | 31,429 | 32,511 | 33,286 | 34,079 | 34,885 | 35,705 | |
| Population | 264,279 | 268,084 | 271,918 | 275,779 | 279,667 | 283,583 | 287,553 | 291,521 | 295,515 | 299,504 | 303,488 | |
| Litres per capita per day | 278 | 281 | 287 | 293 | 298 | 304 | 310 | 313 | 316 | 319 | 322 | |

## CONCLUSION

This paper contrasts two approaches to modelling future bounce-back scenarios. The regression model allows future changes in climate or periods of restrictions to be modelled but does not show *where* water demand increases post-drought (e.g. longer showers, greater garden irrigation).

By contrast, the end-use model offers the ability to construct future scenarios, but rates of uptake are estimated in the absence of recent data on experiences in other jurisdictions around Australia. The combination of these models allows future predictions to be made, while detailing what such future consumption patterns would mean in practice.

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## REFERENCES

Anderson RL, Miller TA & Washburn MC (1980): Water Savings From Lawn Watering Restrictions During a Drought Year, Fort Collins, Colorado, *Journal of the American Water Resources Association*, 16, 4, pp 642–645.

Beatty K (2011): Unsung Water Savings – How People in Greater Sydney Saved Water During Drought Restrictions. AWA Water Efficiency Conference, 1–3 March 2011, Melbourne.

Hansen RD & Narayanan R (1981): A Monthly Time-Series Model of Municipal Water Demand, *Water Resources Bulletin*, 17, 4, pp 578–585.

Kenney DS, Klein RA & Clark MP (2004): Use and Effectiveness of Municipal Water Restrictions During Drought in Colorado, *Journal of the American Water Resources Association*, 40, 1, pp 77–87.

Kidson R, Spaninks F & Wang Y (2006): Evaluation of Water Saving Options: Examples From Sydney Water's Demand Management Programs, paper presented to the 2006 AWA Water Efficiency Conference, 13 October 2006, Ballarat, Victoria.

McKibbin J, Inman M & Turner A (2009): ISDP: A New National Tool For Integrated Water Resource Planning. Paper presented at Ozwater'09, 16–18 March 2009, Melbourne, Victoria.

Neal B, Meneses C, Hughes D & Wisener T (2010): The Impact of Water Restrictions on Regional Urban Demand in the 2006/07 Drought. Paper presented at Ozwater'10, 8–10 March 2010, Brisbane, Queensland.

Roberts P (2008): Estimating the Impact of Drought Restrictions on Indoor Use. Paper presented to the 2008 AWA Water Efficiency Conference, 30 March–2 April, Sunshine Coast, Queensland.

Spaninks F (2010): Estimating the Savings From Water Restrictions in Sydney. Paper presented at Ozwater'10, 8–10 March 2010, Brisbane, Queensland.