Designing Cost Effective Water Demand Management Programs in Australia

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Abstract

This paper describes recent experience with integrated resource planning (IRP) and the application of least cost planning (LCP) for the evaluation of demand management strategies in urban water. Two Australian case studies, Sydney and Northern New South Wales (NSW) are used in illustration. LCP can determine the most cost effective means of providing water services or alternatively the cheapest forms of water conservation. LCP contrasts to a traditional approach of evaluation which look only at means of increasing supply. Detailed investigation of water usage, known as end-use analysis is require for LCP. End-use analysis allows both rigorous demand forecasting, and the development and evaluation of conservation strategies. Strategies include education campaigns, increasing water use efficiency and promoting wastewater reuse or rainwater tanks. The optimal mix of conservation strategies and conventional capacity expansion is identified based on levelised unit cost. IRP uses LCP in the iterative process, evaluating and assessing options, investing in selected options, measuring the results, and then reevaluating options. Key to this process is the design of cost effective demand management programs. IRP however includes a range of parameters beyond least economic cost into the planning process and program designs, including uncertainty, benefit partitioning and implementation considerations.

Keywords

Least cost planning, demand side management, water conservation, water reuse

INTRODUCTION

Least Cost Planning and Integrated Resource Planning, were developed for the electricity industry in the United States in the 1980's (Mieir *et al.*, 1983) to compare energy conservation programs to increased generation as sources of supply. The principles of LCP and IRP have been transferred to planning of other large infrastructure systems including water (Beecher, 1996; Dziegielewski *et al.* 1993) wastewater (Howe and White, 1999) and gas (Greenberg and Harshbarger, 1993). Resource conservation or demand side management is central to LCP and IRP. Demand management is any program that modifies (decreases) the level and/or timing of demand for a particular resource. Demand management programs are designed to promote conservation either through changes in consumer behaviour or changes to the stock of resource using equipment (Greenberg and Harshbarger, 1993). Behaviour change in consumers can be promoted via education campaigns or through economic instruments such as pricing. In the urban water industry, conservation can also be provided through alternative supplies such as rainwater storage tanks or wastewater reuse. Wastewater is conserved only if reuse occurs on-site. Increasing resource use efficiency remains the key strategy for water conservation. Increasing efficiency can involve either replacing water using equipment with more efficient types or through finding and repairing leaks in the distribution system (Beecher 1996). Replacing or regulating water using equipment and appliances as a conservation strategy is based on the notion that demand for a resource such as water is not in fact a demand for that resource itself but rather for the services that the resource provides, often called end use. Consumers are therefore seen to generate a demand for services, end uses, such as clothes washing and hot showers rather than a demand for kilolitres. End use analysis enables the amount of conservation from a measure to be estimated. In the first instance, it is assumed that providing the same services with less resources makes no difference to the consumer.

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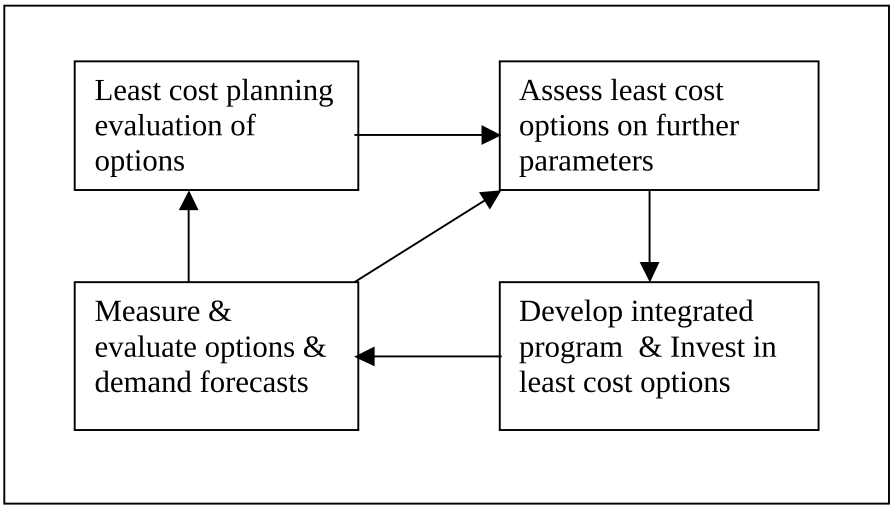
Least cost planning involves several steps, including: end-use analysis, demand forecasting, the design and modelling of demand management programs, estimating conservation from programs, evaluation of costs of conservation, estimating conventional supply costs, developing and costing alternative supply options if applicable, cost benefit analysis of all options, consideration of environmental externalities, sensitively analysis, and reporting. Detailed end-use modelling of how a supplied resource (energy or water) is actually used by customers, provides a much more rigorous basis for demand forecasting, and allows for both the development and evaluation of demand management programs, in particular end-use efficiency. More rigorous demand forecasts also provide better estimates of the future costs of conventional supply augmentation. Results are usually presented in present value terms, often in terms of cost per unit supplied (or conserved) to allow direct comparison of demand management measures relative to increased supply.

Integrated resource planning and LCP are often seen as synonymous, however although both involve consideration of demand management for meeting future service needs, IRP provides a broader framework into which LCP fits. Over time, an IRP process should see the iterative reapplication of LCP as part of a cycle of evaluating and assessing options, investing in selected options, assessing conservation results and demand forecasts and then re-evaluating options, (see Figure 1). Integrated resource planning also takes into account a range of parameters which go beyond the costs. Planning decisions about demand management need to include a range of other issues including equity; uncertainty of supply/conservation; timeframes for implementation and the potential for changes to rates structures.

Figure 1 Integrated resource planning involves the iterative re-evaluation of options



In Australia, some urban water utilities have invested significant funds in demand management programs. The reasons have included: the high costs of bulk water supply; the benefits of deferring capital works; the benefits of downsizing treatment plant and distribution upgrades; as well as licence conditions imposed by government. The paper describes recent experience with LCP and IRP in two regions: Sydney, Australia's largest city; and the Rous Water supply area in northern NSW. Sydney is unique in Australia because the water utility, Sydney Water Corporation (Australia's largest, serving nearly 4 million people) had a regulatory requirement to reduce demand per capita by 25% in 2001 and 35% by 2011 from 1991 levels of 503 litres per person per day (LCD). This has been modified as an intermediate target in 2005.

END-USE ANALYSIS

End-use analysis, is a methodology that can define the ways that customers use water, to as great a level of disaggregation as possible. This can be achieved by the use of customer surveys of water using appliances (toilets, showers, taps) and water using practices (frequency of bath and shower use, frequency of clothes washing), through analysis of market research data for large appliances (eg clothes washers) or through industry sales statistics provided by manufacturers. End-use models combine the appliance stock and technical data with behavioural/usage data. Demographic and land use data is also needed, including most obviously population data. Housing stock (dwelling type mix) and occupancy (number of persons per dwelling) also strongly influence demand. Modelled demand is correlated to historical demand data, for bulk water production, and metered customer data by sector. Non residential sectors, commercial, industrial and institutional sectors are included to varying degrees of disaggregation dependent on the sectors proportion of total demand.

The importance of end-use analysis in understanding demand is illustrated by the example of the decrease in water demand due to toilets in residential dwellings in Sydney, Australia. The average flush volume of cisterns in Australia has decreased significantly from about 11-13 litres in 1980 to less than 4 litres today, due to the development of the dual flush toilet. All toilets manufactured in Australia are now 6 litre/ 3 litre dual flush (White 1998, 1999). As older toilets are replaced and new houses are built, the stock of toilets in use changes, and less water is used in toilets per person. Between the mid-1980’s and today, these changes in toilet efficiency will have reduced the per capita demand by nearly 20 litres per person per day, a total of 24,000 ML/a saving for Sydney by 2001. By the year 2020 this will have halved the per capita demand for water in toilets.

The second stage of end-use modelling involves developing and assessing a range of demand management measures. The end-use model allows potential levels of conservation to be estimated.

Demand management measures

Demand management measures aim to minimise either the overall or peak demand for water (or energy or other resource). Measures can be categorised as shown below.

- *Increase system efficiency*: No change in resource usage by consumers but less system losses. Examples: leakage detection and repair; change in system operations such as pressure reduction and changes to mains flushing and reservoir cleaning; installing peak balancing capacity.
- *Increase end use efficiency*: Less resource used by the consumer to provide the same service. Examples: Regulating for AAA rated shower heads and dual flush toilets in new developments; enforce minimum performance standards on new appliances (dishwashing machines, clothes washing machines); offering financial incentives for water efficient purchase and installation; programs to retrofit efficient equipment into existing buildings.
- *Promoting distributed sources of supply*. Provide services via a locally sourced resource not currently being used. Examples: encouraging household rainwater tanks and greywater reuse systems; provide recycled effluent for non-potable uses via dual reticulation.
- *Substitute resource use*. Provide same service without use of the resource in question. Examples: Planting indigenous plants adapted to local rainfall; use of waterless sanitation.
- *Improve the market in resource usage.* Inform the consumer about the full costs of their resource use. Examples: full cost recovery charges for water use; volume-based pricing set at or above the long run marginal cost; providing better feedback on the level and cost of ongoing water usage by universal metering with at least quarterly billing or smart metering with instant feedback; remove perverse incentive for increased resource use such as declining block tariffs; provide comprehensive information on the environmental impacts of water use, run education campaigns; conduct detailed water use analysis (audits) for water customers in key sectors.

EVALUATING WATER AND WASTEWATER CONSERVATION

Least cost planning uses an economic evaluation of options, as the aim is to minimise the total social cost of meeting service needs As a true economic analysis is difficult, evaluation in LCP often uses what is termed a total resource cost (TRC) test to compare direct costs of conservation by demand management programs to the cost of supply. This test includes all costs and benefits to both the utility and its consumers in the analysis. Decreases in consumer bills spent on the conserved resource are not included in the TRC test as the utility sees these savings as a cost of foregone revenue. Equity issues between groups are not addressed by the TRC test, and equity between future and current generations is only addressed in relation to the discount rate applied to future costs. Urban water and wastewater conservation has the potential to reduce both the economic cost and the ecological impacts of providing urban water services. Economic cost savings result from eliminating or reducing the size of capacity augmentations as well as the operating and maintenance costs of treating and distributing potable water, and collecting and treating sewage. Some ecological impacts of urban water systems may be included in the evaluation of water and wastewater conservation as costed externalities if monetary values can be agreed on.

The comparison of supply to conservation is often constructed in terms of unit cost, with conserved water or wastewater being equated to an equivalent increase in supply. This recognises that supply for a new development can be obtained by increases in capacity or by increasing the efficiency of existing and future water users. The preferred cost measure is levelised unit cost which is the present value of all costs of a measure or option over the present value of all water supplied (or conserved). A number of authors, including Paul Herrington (1987) and Patrick Mann *et al*. (1980) have described calculating unit cost by using present value of a physical water flow. They calculated a water supply scheme marginal capacity cost using the term average incremental cost (AIC). This AIC used the present value of a physical water flow in the calculation of a unit cost, but only included future capital costs of supply and corresponding capacity increases. Levelised unit cost (L) as defined by White and Howe (1998), is similar but conceptually slightly broader as it can account for all capital and operating expenditure by water or wastewater service providers or their customers in providing for increased flows or for reduced demand, see equation 1.

$$L = \frac{PV(costs)}{PV(water\ saved\ or\ supplied)} \qquad (1)$$

Demand management measures may affect various parameters other than average volumes that in turn dictate costs in an urban water system (Maddaus, 1999). On the water supply side parameters include: peak day demand, peak hourly demand and amount of potable supply consumed per capita. On the wastewater side potential parameters other than average dry weather flow include: peak wet weather flow, BOD load and nutrient loads at sewage treatment. Conservation measures might also avoid energy use for hot water, quantities of detergents needed, and stormwater infrastructure.

Many externalities can not be effectively valued and included in present value calculations. For those that can, ‘market’ values are often inconsistent and/or inadequate. External costs that can be valued in surrogate markets include, the cost to other water uses of water taken from a particular catchment, CO_2 releases and the costs resulting from a water borne illness. Other impacts of urban water systems that do not have either an actual or surrogate dollar value include, impacts such as phosphate and micronutrient loss from agricultural land effluent volumes released to the ocean, and some pollution releases to the environment. These externalities need to be included in IRP as parameters beyond least cost. It is also important to remember that evaluation is not a snapshot activity but should be a dynamic learning process. Key factors being the need to question assumptions, and include knowledge gained from previous analyses in subsequent iterations.

CASE STUDIES

Two case study regions and the programs implemented are described in this section. The first case study has been described previously in White (1994, 1997, 1998). The second case study has been described by Howe and White (1999). The assessment of these programs and recalibration of end-use and demand forecasting models over time has not previously been described.

Rous Regional Demand Management Strategy

The Rous Regional Demand Management Strategy was commenced in 1996, with the aim of reducing the demand for water in a region of high population growth. Rous Water is the bulk water supply authority to four local councils in the north coast region of New South Wales, Australia, supplying a population of about 70,000 people.

This strategy, which resulted in a comprehensive water efficiency program outlined below, provides an example of the benefits of deferring capital works. In this case deferral of the adopted schedule of capital works (with a present value in 1996 of A$30m) by one year, results in a financial benefit of A$1.4m. This means that any measure which reliably reduces demand by 1 ML/a provides a financial benefit of more than A$3,500. During the Rous Regional Demand Management Strategy many options were identified and implemented that had a cost significantly lower than this.

The program developed included the following components:

- pricing and billing reform;
- leakage detection and repair;
- rebates and give-aways for water efficient shower heads;
- point of sale rebates for front loading washing machines;
- discounted residential retrofit;
- free water audits for non-residential customers;
- a water efficient demonstration house and garden;
- effluent reuse in a new village;
- a school education program. (White, 1998).

Support for components of the program that reduce hot water use was provided by the Sustainable Energy Development Authority of New South Wales, which has an objective of reducing greenhouse gas emissions in cost effective ways. The local electricity retailer, NorthPower also contributed to the washing machine program (White, 1997).

Sydney Water Demand Management Program

In 1997, Sydney Water Corporation, the largest water service provider in Australia, commissioned the Institute for Sustainable Futures to undertake a major end use analysis and least cost planning study. The study considered over forty different options to reduce demand, covering all water use sectors (residential, commercial, industrial, institutional, unaccounted and non-metered water) and all end uses (e.g. toilets, showers, taps, washing machines, garden and lawn watering). The options also covered the range of possible means of implementing water efficiency measures, including regulation, pricing, education and advisory services, loans, incentives and retrofitting. A number of reuse options were also modelled including industrial, potable, greywater, rainwater tanks and golf course irrigation. The options were modelled by estimating the potential demand reduction that would be achieved at different levels of investment in each option. Options were selected on a range of criteria including the cost to the community to implement the option and the ability to provide timely reduction in demand.

Results of subsequent case studies (Howe and White 1999) in specific sewer catchments indicated that demand management had the potential to reduce potable water consumption, effluent discharge, and nutrient loads to the environment while avoiding costs for system augmentation, on going operational costs, pollution licensing fees, energy and chemical usage by Sydney Water, energy and detergent use by customers. The expected effect of options on externalities in the form of carbon dioxide and nutrient releases to waterways were calculated. Table 1 summarises the selected program developed for the Sydney-wide least cost planning study.

Table 1.Demand management program designed to meet Sydney Water's Operating Licence

Measure	**Estimated demand reduction in 2011 (litres per capita per day)**	**Levelised cost (AUS$/kL)**
1. Shower head performance standard	8.6 LCD	0.0014
2. Price increase (A$0.10/kL over 2 years)	1.9 LCD	0.0018
3. Clothes washer performance standard	3.5 LCD	0.041
4. Outdoor water use restrictions	1.8 LCD	0.063
5. Shower head rebate (AUS$10)	0.7 LCD	0.14
6. Residential indoor audit & retrofitting	3.4 LCD	0.19
7. As for 6 (free for low-income)	1.5 LCD	0.25
8. Active leakage control	7.2 LCD	0.30
9. Industrial & commercial audits	2.9 LCD	0.42
10. Hotel audits	1.3 LCD	0.42
11. Outdoor water use promotion	0.2 LCD	0.49
12. Industrial reuse project 1	2.3 LCD	0.53
13. Industrial reuse project 2	1.8 LCD	0.65
14. Outdoor irrigation system audits	0.3 LCD	0.67
15. Washing machine rebate (A$150)	0.4 LCD	0.70
Total demand reduction in 2011	**38.0 LCD**	

Not all options have been able to be implemented. Options 1 and 3 are scheduled for implementation in 2003 for achievement of the 2011 – 35% water consumption reduction target. The program is ranked in order of levelised cost.

In 1999 Sydney Water began implementing the majority of the programs, costing over A$60m, and requiring the participation of more than 10% of the 1.4 million domestic residences supplied by Sydney Water. The response by customers to the residential program in particular has been dramatic. In Shellharbour, where the residential assessment and retrofitting program was piloted, a 25% uptake rate was experienced compared to a 10% estimate. It appears that other programs such as the industrial and hotel audits and the shower head rebate program are under performing. A first year analysis of the program is currently being conducted to evaluate the performance against assumptions and to assess the actual costs and benefits of each program component. This analysis includes statistical comparison of participants versus control groups to assess actual customer demand reduction (Howe and White, 1999).

ASSESSMENT OF DEMAND MANAGEMENT PROGRAMS

As part of the assessment of the Sydney Water Demand Management Program, statistical analysis of the residential retrofit program has been undertaken, initially (as a pilot) implemented in Shellharbour, south of Sydney. The methodology used is described in Dziegielewski *et al*. (1993). Comparison group analysis using winter period demand data shows that the program resulted in a demand reduction of 18 ± 7 kL/a at the 95% confidence level. Using demand data for spring, the average reduction in demand is 23 ± 5.5 kL/a for each participating household. The Sydney Water Least Cost Planning Study resulted in an estimate of the savings from a residential retrofit program of 27 kL/a for participating households (Sarac, Day and White, forthcoming). This equates to an average saving of 74 ML/a (39 - 88 ML/a, or 62 - 100 ML/a for the whole pilot program with 3,517 participating households, based on the winter and spring data respectively), which is consistent with the modelled reduction of 95 ML/a.

An analysis has also been carried out on the program undertaken by Rous Water and described in this paper, which involved the same retrofitting components as the Shellharbour Residential Retrofit Program. The results of this analysis were that the average reduction in water demand per participating household was approximately 35 ± 26 kL/a at the 95% confidence level, consistent with the estimated savings for participating households of 43 kL/a (Sarac, Day and White, forthcoming). In the Rous Water program, data for the flow rates of existing showerheads, knowledge of occupancy rates and other key household attributes made prediction of savings easier.

DISCUSSION AND CONCLUSIONS

Further case studies, described in more detail in Howe and White (1999) indicated that demand management programs were likely to have a greater benefit: cost ratio where augmentation of sewage treatment plant capacity was planned. Research by Lund (1987, 1990) in least cost planning applied to scheduling of both water and waste infrastructure (but not wastewater) illustrates how demand management measures become economic as augmentation approaches.

The other major conclusion of this work is the importance of an iterative approach to least cost planning, which involves a testing of the savings that are predicted from water conservation programs, followed by an incorporation of the results into the original model.

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