WATER SERVICES ASSOCIATION OF AUSTRALIA

Identifying Costs for Wastewater Services

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Overview of WSAA

The Water Services Association (WSAA) is the peak body of the Australian urban water industry. Its 30 members and 27 associate members provide water and sewerage services to approximately 15 million Australians and to many of our largest industrial and commercial enterprises.

WSAA was formed in 1995 to provide a forum for debate on issues important to the urban water industry and to be a focal point for communicating the industry's views. WSAA encourages the exchange of information and cooperation between its members so that the industry has a culture of continuous improvement and is always receptive to new ideas.

The functions of WSAA are:

- be the voice of the urban industry at the national and international level and represent the industry in the development of national water policy,
- facilitate the exchange of information and communication within the industry,
- undertake research of national importance to the Australian urban water industry and coordinate key national research for the industry,
- develop benchmarking and improvement activities to facilitate the development and improved productivity of the industry,
- develop national codes of practice for water and sewerage systems,
- assess new products relating to water, sewerage and trade waste systems on behalf of the water industry,
- jointly oversee the Smart Approved Watermark Scheme for products and services involved in conserving water use
- coordinate annual metric benchmarking of the industry and publish the National Performance Framework with the Federal and State Governments.

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Executive Summary

Wastewater service providers are currently facing a number of significant, industry wide challenges, including economic regulation, the increasing prevalence of wastewater re cycling and, to a lesser extent, third party access applications. These emerging issues firmly demonstrate the need to look beyond traditional "whole of business" cost analysis and to develop an understanding of the elements that drive wastewater service costs, including the drivers of future expenditure and the relative magnitude of costs by location and business segment.

WSAA has previously commissioned a systematic review of the cost of potable water services and the impact of a cost-based pricing regime. WSAA has commissioned Marsden Jacob Associates (MJA) to expand on the previous study through identification of the costs of providing wastewater services.

Cost Methodologies

There are multiple methods of cost analysis. The most appropriate method depends on the precise question asked. Relevant considerations include:

- whether costs are **forward-looking** or **backward-looking**. The economic focus on forward-looking costs contrasts with the traditional accounting focus on costs that have been previously incurred or sunk into a project;
- the **time period** of the analysis determines which assets or operating activities must be considered. In the short run very few costs are variable. Over the longer term, costs which are fixed in the short term, such as labour and capital expenditure, can also become variable;
- whether the costs are expressed as **total costs** (e.g. $million), **annual costs** (e.g. $million per year), **unit costs** (e.g. dollars per household or equivalent tenement), **marginal or incremental costs** (e.g. dollars per incremental household or incremental equivalent tenement)

Each methodological consideration relates to a different question or purpose. For example, backward-looking costs may be used to evaluate the past performance of a business while forward-looking costs might be used to evaluate potential new business opportunities. Methodological considerations are also important for different pricing applications. Economic theory suggests that the volumetric element of the tariff should reflect the long run marginal cost of supply. However, while marginal costs are useful in designing tariff structure, pricing for full cost recovery must also recognise the cost of past investments. Therefore, in accordance with COAG guidelines on pricing, most Australian water businesses employ a two-part tariff, where the volumetric charge is intended to reflect marginal costs and the fixed annual charge recovers the residual revenue required to ensure overall revenue adequacy. Charges based on marginal costs alone are typically insufficient to ensure overall revenue sufficiency for the service provider.

The WSAA Project Steering Committee identified that the current study should examine the three cost methods most commonly employed for regulated pricing

- incremental costs, measured using the Long Run Marginal Cost (LRMC) methodology – commonly used for calculation of the volumetric component of two part tariffs;
- costs relating to the long run costs "avoided" from a significant reduction in demand or transfer of demand to a third party;
- the cost associated with servicing existing demand, measured using the 'Building Block' methodology and commonly applied in price path and revenue target setting.

Long Run Marginal Cost can be approached two ways - the Average Incremental Cost approach or the Marginal Incremental/Decremental Cost approach. The Average Incremental Cost (AIC) approach measures the total cost of servicing all new demand (expressed as a unit cost), while the Marginal Incremental/Decremental Cost (MIC) approach measures the change in cost caused by a defined increase or decrease in demand (also expressed as a unit cost). Each approach is employed for a different purpose. The AIC method is appropriate for the net impact of new demand (e.g. for determination of new customer contributions), while the MIC approach is appropriate for sending economic price signals and use in option evaluation, as it reflects the actual change in cost if demand is altered. The Marginal Incremental/Decremental Cost requires more intensive planning and modelling than the Average Incremental Cost approach to achieve accurate results. Both methods require good knowledge of the options available to meet future wastewater treatment and disposal needs and the optimum timing and sequencing of these options.

Avoided costs are effectively a subset of Long Run Marginal Costs and represent the cost savings if demand is reduced by a defined amount. The costs avoided by a particular action or change in customer behaviour could impact any segment of the system (retail, collection, transmission, treatment or disposal) and is highly dependent on the characteristics of the particular case. To illustrate the concepts and issues involved in determining avoidable costs, this report includes the calculation of avoidable costs for each of the case studies examined. For the purposes of this exercise, the avoided cost calculation is based on a sewer mining "access" arrangement, in which a third party provides retail, treatment and disposal services, but requires access to the incumbent's transmission system. Transmission costs are therefore not considered avoidable. It is important to reiterate that avoided costs could relate to any, or none, of the segments of the wastewater system, depending on the particular circumstances and purpose of the calculation.

The calculation of long run costs requires careful specification and must take into account considerations such as:

- the forecasting, planning and sequencing required to develop a least cost supply schedule;
- the size of the increment or decrement – results demonstrate that a relatively small change in the size of the increment or decrement applied in the Marginal Incremental/Decremental Cost calculation can have a substantial impact on the LRMC result;
- physical constraints – timing and locational constraints such as local infrastructure needs, supply/demand "catch-up" and constructability;
- timeframe – the timeframe of the analysis will be dependent on the application of the calculation. In general, a longer time frame is preferred for most applications;
- whether the site is established or a greenfield site – greenfield sites have greater flexibility to alter both short and long run costs and would therefore typically have a higher unit long run marginal or avoided cost.

The **Building Block method** is applied differently than the two marginal cost approaches and is favoured by Australian water regulators for calculating revenue targets and price paths. Long run marginal cost approaches typically calculate a net present value or a unit cost for expenditure over the coming 20-50 years. In contrast, the Building Block method calculates a total annual cost of supply for existing and new demand within a defined regulatory period (typically 3-5 years).

The Building Block cost is calculated as:

Annual operating and maintenance expenditure

plus Depreciation

plus A Return on Assets (ROA).

The Building Block approach has a number of advantages for revenue target setting including:

- it is relatively easy to calculate from existing and forecast accounting reports;
- over time the Building Block approach generates a return for the service provider approximately equal to the initial asset value; and
- if calculated using "optimised" or "efficient" replacement cost, Building Block costs indicate the cost at which a competitor could efficiently duplicate the system, in theory placing an upper bound on prices (in practice, the actual bypass price is typically much higher than the Building Block cost).

Executive Summary
continued

Cost Drivers and Choice of Case Studies

To illustrate the levels and distribution of the costs of wastewater systems in Australia, this study examines six hypothetical case studies. The case studies were developed to illustrate different physical characteristics, such as location and the type of system. Information from a number of actual service providers was manipulated to create realistic case studies with sufficient variance to demonstrate the plausible impact of different characteristics. The case studies have been developed purely for illustration purposes and do not represent any actual wastewater system.

To inform the choice of case study that best illustrates the differences in cost between locations and business segments, it is necessary to identify and understand the drivers of cost for wastewater services. To develop a shortlist of the primary drivers of cost, the MJA team relied on a number of sources, including interviews with wastewater planners, investigations by the UK economic regulator (Ofwat), the WSAA Project Steering Committee and MJA's own experience in advising water businesses across Australia and New Zealand. The shortlist is shown in Table 1.

Collection (reticulation) capital costs are typically met by land developers in Australia and have therefore been excluded from the case study analysis. For the sake of simplicity, the ongoing cost of operation and maintenance of the collection system has been included within the transmission costs.

Five of the primary factors influencing cost – growth, disposal method, peak wet weather flow, transmission distance and the size and timing of capacity increments – were represented through the use of six schemes variations. Each scheme contains combinations of elements that reflect "typical" groupings of each of the drivers, as detailed in Table 2. The two remaining primary drivers which could be modelled through available case study information – volume and chemical/biological load – were captured "cross-sectionally". That is, the impact of volume and load was modelled for each of the six case studies, based on expert engineering assessment, and a unit cost for each chemical/biological load factor was derived separately.

After identifying the relevant case study elements, MJA met with actual wastewater service providers to identify costs and cashflows for catchments with relevant attributes. After consultation with the WSAA Project Steering Committee, several hypothetical case studies were developed based on a synthesis of data from actual schemes to reflect the required attributes. MJA then undertook intensive modelling of the case study data to determine the relevant costs by location and business segment.

Table 1: Key Cost Drivers and impact on business segments

Cost Driver	Primary business segments impacted
Number of connections	Retail, Collection, Transmission, Treatment and Disposal (All)
Disposal method	Treatment, Disposal
Peak wet weather flow	Transmission, Treatment and Disposal
Volume discharged	Collection, Transmission, Treatment and Disposal
Chemical and biological load factors, including:	
o Biological Oxygen Demand (BOD)	Transmission, Treatment and Disposal
o Suspended Solids (SS)	Treatment and Disposal
o Salt	Treatment and Disposal
Topography	Transmission
Density of development	Collection, Transmission
Collection/transmission/disposal distance	Collection, Transmission, Disposal
Other cost considerations	
Size and timing of capacity increments	Collection, Transmission, Treatment and Disposal
Critical sewers	Transmission

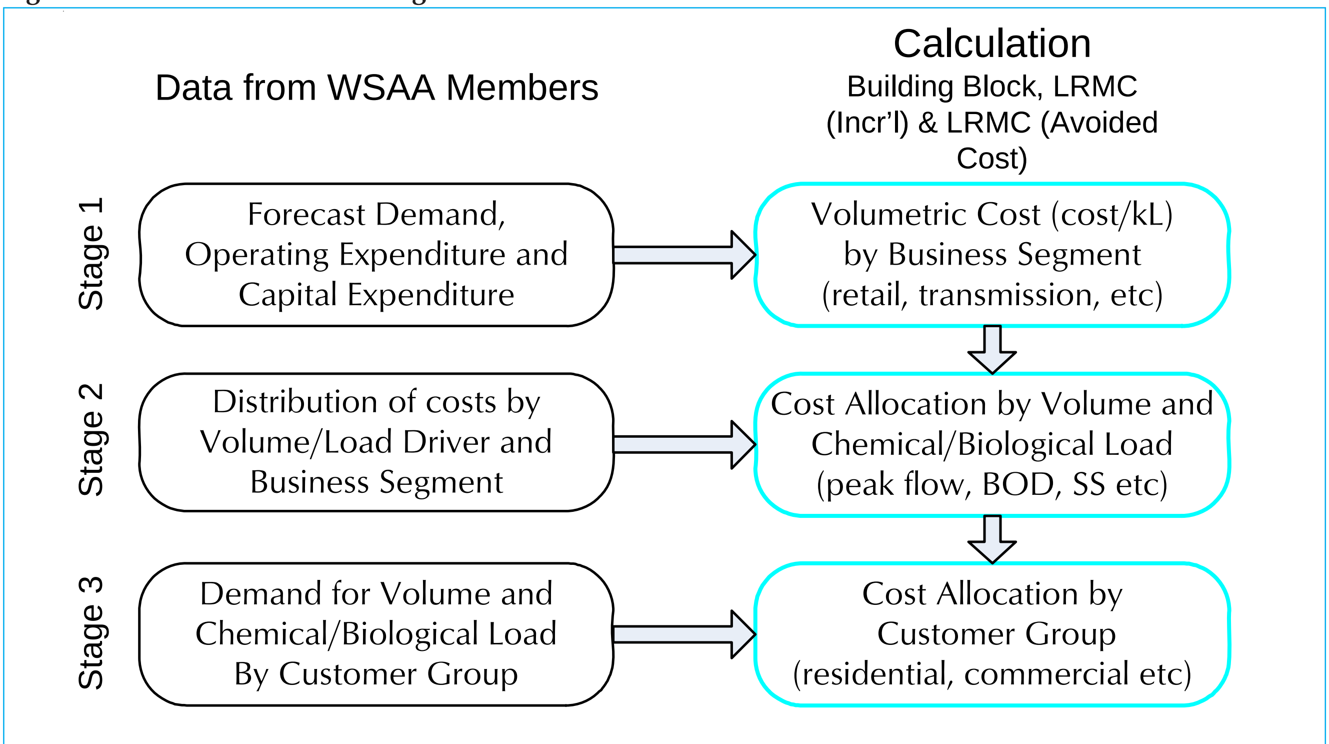
Table 2: Case Study characteristics

Scheme	Characteristics	Disposal method	Wet Weather: Dry Weather Flow
"ModOcean"	Moderate growth, ocean disposal	Ocean discharge	4x
"MOLoWWF"	Moderate growth, ocean disposal, reduced wet weather flow	Ocean discharge	1.5x
"MO10yrscap"	Moderate growth, ocean disposal, ten years' growth capacity	Ocean discharge	4x
"MOHiTrans"	Moderate growth, ocean disposal, long transmission distance	Ocean discharge	4x
"ModInland"	Moderate growth, inland disposal, some recycling planned, big growth allocation	River discharge	4x
"HiRcycl"	High growth, recycling, greenfield	Recycling/ Ocean discharge	4x

Case Study Results

The results were determined through a three-stage process, illustrated in Figure 1.

Figure 1: Process for determining Wastewater Costs



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In consultation with WSAA members, the information from actual wastewater schemes was synthesised to reflect the six case studies identified in Table 2. For Stage 1, the volumetric cost by business segment was determined by comparing total costs (Building Block, LRMC or Avoided Cost) for each segment against the total volume of wastewater treated. For Stage 2, the costs of each business segment were allocated by volume and chemical/biological load driver, based on a cost allocation matrix developed through expert engineering assessment. Finally, Stage 3 of the analysis combined the usage information for each customer group (by volume and chemical/biological load) with the unit costs derived in Stage 2 to derive costs for each scheme and each customer group.

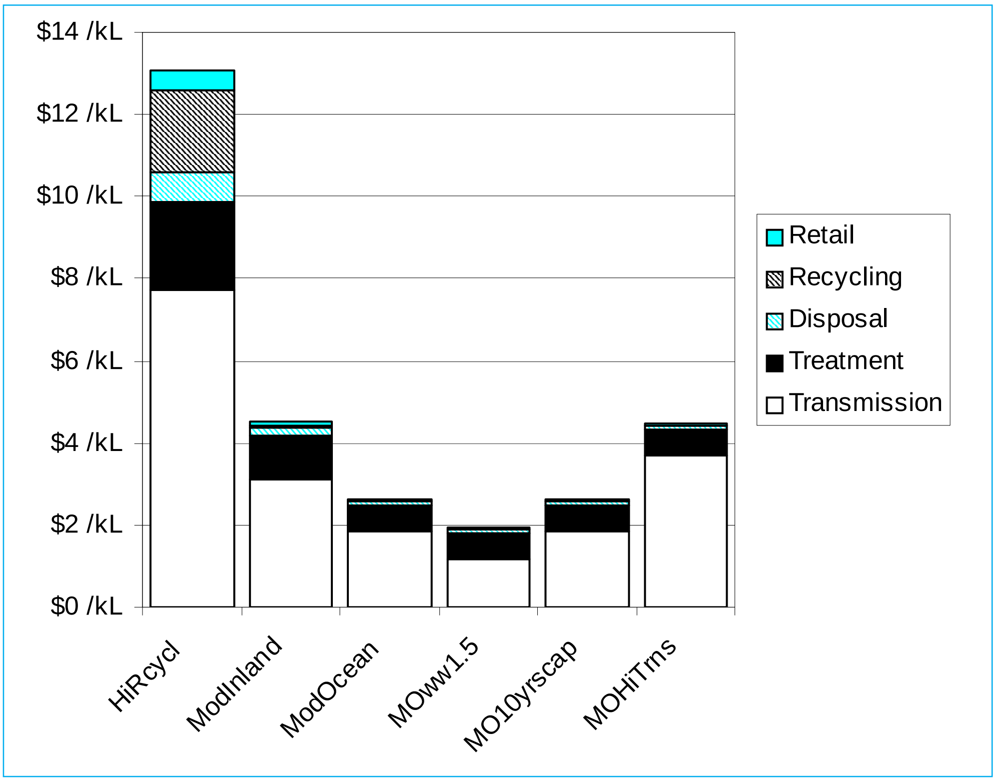
Each case study includes the full cost of water recycling. In practice, water recycling might be the least cost, or indeed the only, water supply solution and it could be more appropriate to allocate recycling costs to the water rather than the wastewater system. Alternatively, water recycling costs might be considered part of a holistic integrated water management system (including water, wastewater and stormwater management) and benefits might not be allocated to any one system element in isolation. For the purposes of this report, each case study analysis includes the full cost of recycled water transmission and treatment, however recycled water costs have been separately identified wherever possible.

The volumetric cost results for each methodology and for each of the six case studies are reviewed in turn below. To facilitate a coarse comparison of results, unit costs are presented on a purely volumetric basis (i.e. total cost divided by total wastewater volume treated). We then consider the impact of separate volume and chemical/biological load drivers across all schemes.

Building Block

The unit cost results of the Building Block approach for each of the six case studies are shown in Figure 2.

Figure 2: Building Block Costs by Location and Business Segment



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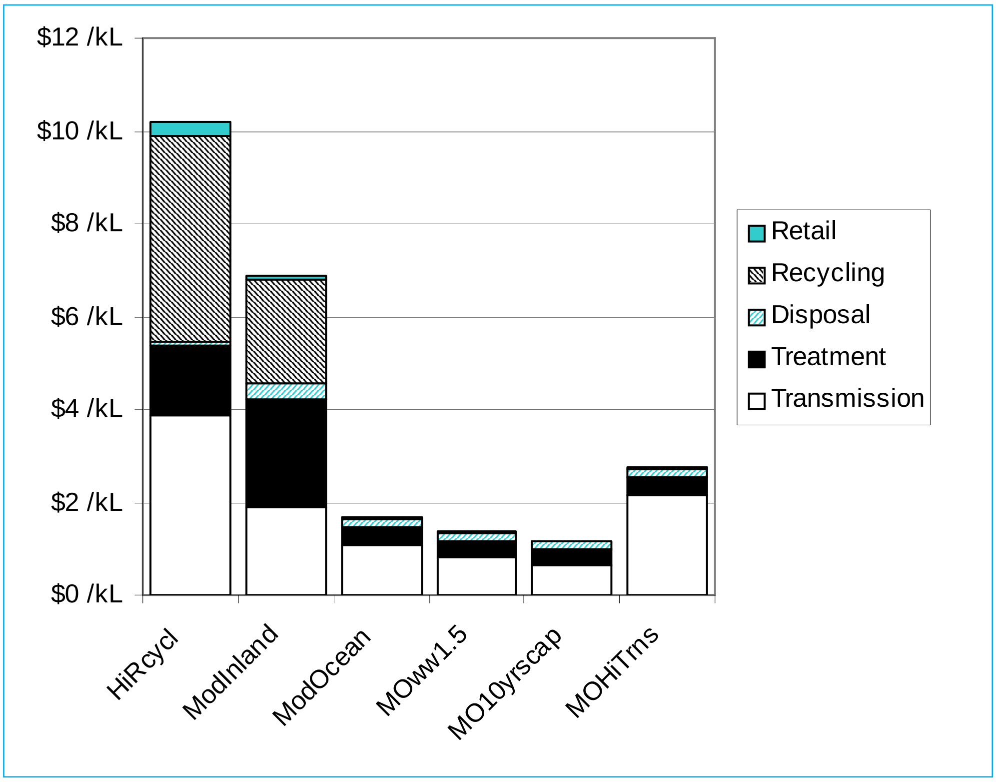
In all of the case studies, the cost of existing assets is dominated by the cost of transmission. This is a common trait of water and wastewater supply systems. By comparison, the cost of treatment and disposal in the modelled schemes represents between 22% and 37% of the total cost. Retail customer management represents a relatively small component of overall cost, as does recycling (other than Location 1).

The costs for the high growth recycling scheme are substantially higher than the cost of all other schemes, even when the cost of recycling is excluded (note that recycled water transmission assets are included under "Recycling" in the figure above). The high cost is in part due to the small size of the scheme – initially the scheme has only 10% of the flow of the ocean disposal case studies. Furthermore, interpreting results on a purely volumetric basis can be misleading. For example, the cost of the "HiRecycl" scheme does *not* account for savings in the water system or in the developer's reticulation infrastructure. In addition, the scheme operators are assumed to employ community education and technology to substantially reduce the volume of water use and 'smart sewers' to reduce sewer infiltration, both of which will lower the volume of wastewater requiring treatment (thereby reducing the denominator of the unit cost calculation).

Long Run Marginal Cost (Incremental)

As illustrated in Figure 3 *future* costs present a quite different story. Across Australia, increasing regulatory standards and public expectations are substantially increasing the cost of wastewater treatment and disposal. Of the six modelled schemes, the fastest growing scheme ("HiRcycl") relies primarily on recycling for treatment and disposal. The capital expenditure on recycling for this scheme represents almost a third of the entire capital budget for the six schemes combined.

Figure 3: LRMC (Increment) by Location and Business Segment



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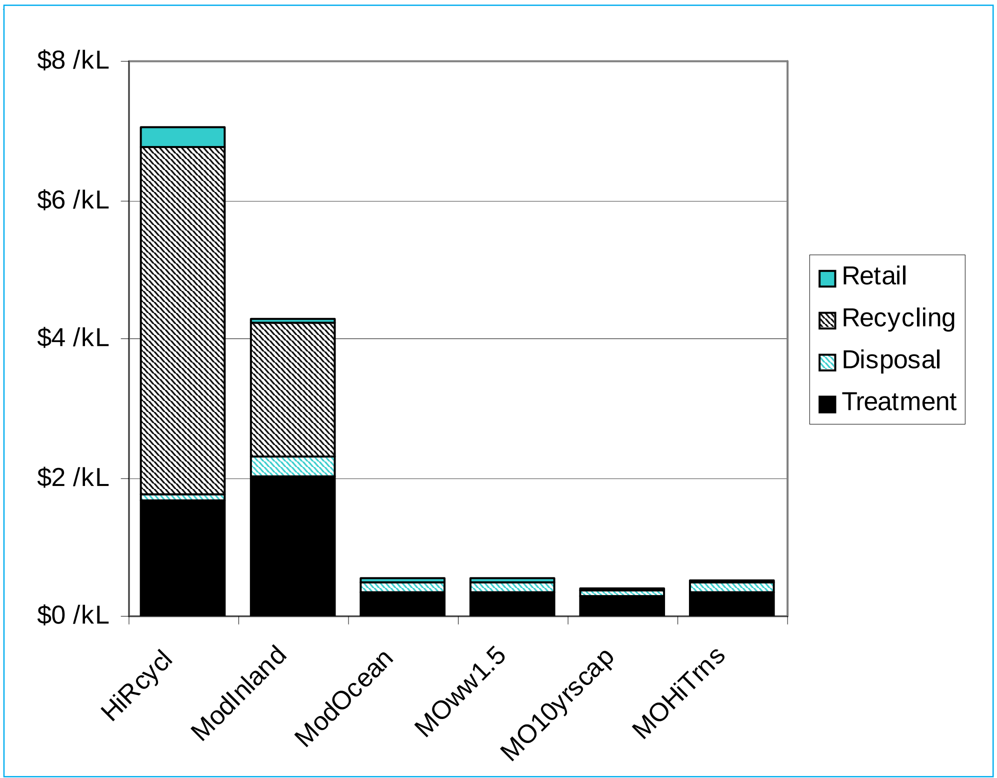
The long run costs for the high growth recycling scheme are substantially higher than the cost of all other schemes. Approximately half of the expenditure on water recycling is for dual reticulation and transmission, with the other half accounting for capital and operating costs to treat the water beyond the tertiary level. It should be noted that this result does *not* account for savings in the water system, which could represent savings in the order of $1/kL to $2/kL. In addition to the large expenditure on recycling, the figure above also demonstrates the continuing high proportion of wastewater transmission costs in non-recycling schemes.

The results demonstrate that the existing average costs are higher than future costs for all schemes other than the inland disposal case study ("ModInland"). This implies that under a cost reflective pricing system (noting the strict incompatibility of the different costing methods), it would be anticipated that costs would fall over time. The LRMC for the inland disposal case study is higher than the average cost due to substantial wastewater treatment plant upgrades planned to improve discharge quality over coming years. The transmission network will also be upgraded due to the increasing pressure on the existing, inadequate pipe network and the need for new infrastructure to cater for planned recycling measures. The high cost of treatment is typical for inland wastewater schemes, which tend to have more stringent environmental and health regulation governing discharge.

LRMC (Avoided Cost)

The case study analysis assumes that the avoided costs relate to an access arrangement in which a third party supplies retail, treatment and disposal services. The avoided costs are shown in Figure 4 (below) and demonstrate relativities similar to the incremental LRMC results, except that it has been assumed that wastewater transmission costs are not avoidable. Avoided costs are therefore significantly lower than incremental LRMC costs. As transmission costs have been excluded, wastewater treatment and recycling costs dominate the avoided cost calculation.

Figure 4: LRMC (Avoided Cost*) by Location and Business Segment



* Note: Avoided Cost case studies assume that wastewater transmission costs are unavoidable. Recycled water transmission costs are assumed to be avoidable and are included under "Recycling".

Breakdown by Cost Driver

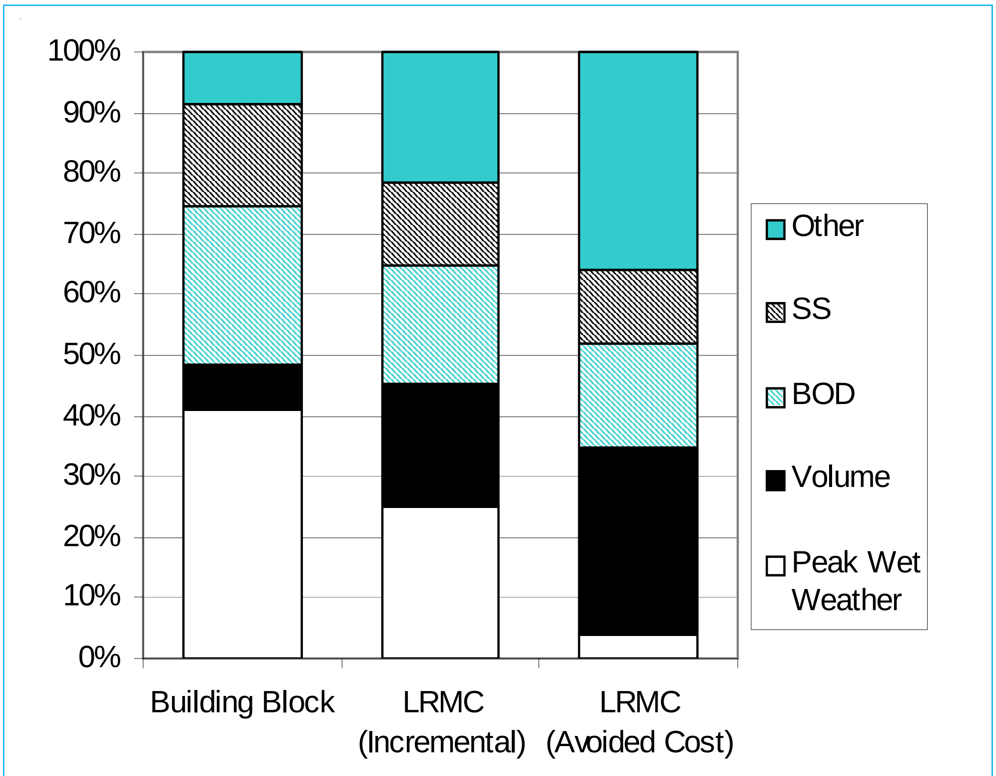
The three costing methodologies were also segregated by individual volume and chemical/biological load cost drivers. The net contribution of each cost driver to final cost allocations is summarised in Figure 5.

As illustrated, around 40% of Building Block costs across all case studies are driven by wet weather flows. This reflects the large proportion of transmission assets, which are predominantly driven by peak volumetric flows. By contrast, the annual volume discharged accounts for relatively little of the overall cost. BOD and SS combined account for more than 40% of existing costs due to their impact on wastewater treatment and transmission pipelines.

The costs are more evenly distributed when the incremental LRMC method is applied. The increased impact of volume and "other" reflects the high degree to which water recycling features in the future capital program. A significant element of the "other" category is pathogen removal for recycling. Annual volume also plays a more prominent role in the LRMC analysis as the water recycling network removes only a baseload of waste from the treatment plant and is therefore relatively unaffected by peak wet weather events.

The long run avoided cost results show a similar story, but wet weather flows play a further reduced role as transmission assets are assumed to be unavoidable or sunk costs.

Figure 5: Contribution to Total Cost by Cost Driver



Note: Avoided Cost case studies assume that transmission costs are unavoidable

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Key Conclusions

General Conclusions

The case study analysis emphasises that the cost of wastewater systems across Australia are highly relative to the location and the particular circumstances of the service provider and the receiving environment. The case studies examined in this report demonstrate substantial variations in both locational costs and costs distributed amongst business segments (i.e. retail, transmission, treatment, disposal and recycling).

The review of methodologies indicates substantial differences in results for each of the different methodologies, reiterating the importance of applying the appropriate methodological approach for each particular application or scenario. Contrary to common opinion, the review highlights that there may be a significant variation in results from applying different LRMC methodologies (i.e. long run Average Incremental Cost compared with long run Marginal Incremental Cost).

Furthermore, the analysis demonstrates that the long run Marginal Incremental Cost result is highly sensitive to the exact choice of increment or decrement. The results demonstrate the importance of choosing policy relevant increments or decrements when calculating LRMC. The high variance in results and inherent uncertainty of demand estimates also indicates that results should be considered across a range of volumes rather than relying on a single point estimate.

Case Study Results

The results support the traditionally held view that wastewater transmission costs form the most substantial part of a wastewater service provider's existing asset base. The long transmission distances modelled for one of the case studies ("MOHiTrans") had the highest impact on cost compared with all other drivers examined, with the exception of the method of disposal (both LRMC and Building Block costs increased by 60-70% compared with the "ModOcean" case study). Peak wet weather flows, were also shown to have a substantial impact on the cost of transmission and therefore the overall cost of service provision (costs were reduced by around 20-25% in the "MOLoWW" case study).

The case studies clearly illustrate the comparatively fast growth in wastewater treatment costs and in particular water recycling costs. The rapid increase in water recycling costs will put significant upward pressure on absolute wastewater treatment and disposal costs in the future, which may be at least partly offset by a reduction in the cost of, or need for, new potable water sources.

Retail customer service costs such as billing and meter reading were found to be a relatively small component of total costs (less than 3% of both existing and long run costs).

Future Issues

The high variability of results between locations demonstrates the potential susceptibility of wastewater schemes to inefficient "cherry picking" if third party access to infrastructure is granted and uniform pricing policies or regulations are maintained. The results also demonstrate the potential for significant under-recovery of past investments (represented by the Building Block cost) if access prices are based on LRMC alone. If incumbent service providers are required to charge new entrants at marginal cost, then the incumbent will not recover the full cost of their investments and the new entrant may gain a windfall benefit by acquiring access at a low cost and on-selling the service to customers at the full retail price. Various strategies can be employed to adjust prices to either the third party access applicant or the customer to compensate for these pricing issues.

Incumbent water utilities within jurisdictions that are developing access regimes would benefit from a firm understanding of the costs of each system element and the translation of these costs into a comprehensive pricing framework. The current study outlines cost results for six specific case studies, however each organisation will face a unique set of costs and cost drivers. To assist the industry, further research could be undertaken to improve the understanding of cost functions that relate to the major drivers of cost (e.g. the relationship between the capacity of a wastewater treatment plant and the cost).

With increasing economic regulation and the possibility of access challenges, utilities can expect mounting pressure to develop robust estimates of long run cost, in addition to the impact of incremental or decremental variations in demand. It is anticipated that regulators will require a far greater level of detail and disaggregation than has historically been required. As evidenced by preliminary requests from the ESC, it can be expected that regulators will require utilities to conduct long run incremental analysis of individual load variables (i.e. the change in cost resulting from a specific change in volume or load concentration) for the calculation of trade waste and other forms of wastewater pricing.

1. Introduction

Centralised treatment and disposal of wastewater underpins the health of modern urban settlements around the world. In Australia, residential and other customers pay more than $2 billion a year for these services, while the book value of wastewater infrastructure is over $26 billion.[1]

Identification and understanding of the cost of wastewater services by location and by business segment (i.e. retail, transmission, treatment and disposal) conveys important information for decision making regarding:

- the choice between different projects and options for wastewater services. Knowledge of costs is required by the relevant analytic tools such as benefit-cost analysis, cost effectiveness analysis or triple bottom line analysis;
- the relative profitability of each product or service;
- the relative cost and efficiency of servicing different locations and business segments;
- the identification of loss making areas and the inherent cross subsidies implied by uniform pricing arrangements;
- setting of regulated revenue/price levels for access to services or access to the infrastructure;
- developing tariff structures that send appropriate signals and incentives regarding marginal costs.

Accounting for costs by activity, business unit and locational node is common practice in Australian water and wastewater utilities. However, conventional accounting practices have major limitations, including:

- the primary focus on past or sunk costs. This focus is useful for performance reporting and the recovery of past costs, but does not relate to the forward-looking costs on which future investment and operating decisions need to be made;
- reporting is typically centred around internal business divisions and regulatory requirements rather than the drivers of cost or areas of threat or opportunity. This often necessitates special "off-line" costing analyses to understand the impact of emerging challenges such as new technologies, different regulatory pricing regimes, changes in customer behaviour and the potential impact of new market entrants.

WSAA has previously commissioned a systematic review of the cost of potable water services and the impact of a cost-based pricing regime. WSAA has commissioned Marsden Jacob Associates (MJA) to extend the previous study to identify the costs of wastewater services.

The process of analysis undertaken has been responsive and interactive: first, it was recognised that there were a number of interpretations of the term "cost". The Steering Committee suggested that the study should examine:

- incremental costs, measured using Long Run Marginal Cost methodology;
- marginal costs relating to the costs "avoided" from a significant reduction in demand or transfer of demand to a third party;
- the cost associated with servicing existing demand, measured using the 'building block' methodology.

Second, the Steering Committee also requested that the study provide an explicit set of guidelines so that WSAA members could readily understand and apply the relevant analyses themselves.

1.1 Purpose and Conduct of the Research

The purpose of this study is to investigate the costs associated with:

- the major business segments of urban wastewater systems (i.e. retail, collection, transmission, treatment and disposal);
- different locations for a system and its components; and
- costs due to degree of treatment.

To understand the level and distribution of costs between the major business segments and locations the study examines the costs of some six case studies. These case studies are specified with attributes reflecting the major drivers of the cost of wastewater schemes.

Cost information for each of these six case studies has been gathered and examined in terms of major business segments, namely:

[1] WSAA*facts* 2004

- **collection:** reticulation mains and associated fittings
- **transmission**: gravity mains, pressure mains, pump stations, wet wells, emergency overflow structures
- **treatment**: pre-treatment, primary treatment, secondary treatment, disinfection, biosolids removal
- **disposal**: ocean and river outfalls
- **retail**: call centre management, customer billing, meter reading

To inform the choice of case study that best illustrates the differences in cost between locations and business segments, it is necessary to identify and understand the drivers of cost for wastewater services. To develop a shortlist of the primary drivers of cost, the MJA team relied on a number of sources, including interviews with wastewater planners, investigations by the UK economic regulator (Ofwat), the WSAA Project Steering Committee and MJA's own experience in advising water businesses across Australia and New Zealand.

After identifying the relevant case study elements, MJA met with actual wastewater service providers to identify costs and cashflows for catchments with relevant attributes. After consultation with the WSAA Project Steering Committee, several hypothetical case studies were developed based on a synthesis of data from actual schemes to reflect the required attributes. Realistic case studies were developed to illustrate the plausible impact of different scheme characteristics. MJA then undertook intensive modelling of the case study data to determine the relevant costs by location and business segment.

A useful investigation of the reported costs of one wastewater system is provided by IPART (2005), in the investigation of the Sydney water and wastewater system. For this engagement the Marsden Jacob Associates' team included Mr Paul Webber, a principal of Wedgwood White, who assisted IPART to develop their case studies and cost modelling for that investigation. Mr Webber's role in this engagement was to conduct a methodological review and sample audit of the cost analysis.

1.2 Report Structure

In Chapter 2 we describe relevant measures of costs, how they are defined and calculated. We provide worked examples of the method for calculating incremental Long Run Marginal Cost, long run avoided costs and Building Block costs.

To ensure that the selection of available case studies illustrates the issues to the most useful extent possible, the study then examines the evidence on the drivers of costs (Chapter 3). Thus, we examine the primary drivers of cost and the impact they have on both existing costs and future expenditure.

Chapter 4 reviews the costing data provided for the study and outlines the results. The final chapter draws conclusions about relevant trends and issues.

1.3 Acknowledgement

MJA would like to acknowledge the assistance of WSAA members who provided cost data, insights and comment on the issues and the investigation.

2. Costing Methodologies

To understand the cost attributable to a location, a business segment or a particular customer, it is essential to understand that the appropriate concepts or measure depends upon the question asked. For the purposes of this study, the relevant concepts relate to the direct costs incurred or avoided by a water business or by government.

The costs of wastewater services – as with any service – can be defined in multiple ways. Relevant distinctions for this study include:

(i) whether costs are **forward-looking** or **backward-looking.** Economic concepts of costs are forward-looking in the sense that the focus is on the amounts that need to be outlaid in the future under specified assumptions. The economic focus on forward-looking costs contrasts with the traditional accounting focus on costs that have been previously incurred or sunk into a project.

Forward-looking costs refer to:

(a) the amount that will need to be spent now or in the future to purchase the input or service. Where there is a ready market for the inputs or services in question, this amount is determined simply by the quantities used and the market prices. However, where the availability of a good is limited, this cost can be set with reference to the opportunity cost in the next best use; and

(b) the amount that can be saved or avoided now or in the future as a result of a reduction in demand or a decision to invest or take some other action.

(ii) the **time period** of the analysis determines which assets or operating activities must be considered. In the short run very few costs are variable – items such as electricity and chemicals may rise or fall with a short term change in demand, but fixed labour costs and sunk asset costs will not vary. Over the longer term, costs which may be considered fixed in the short term can also become variable – for example, "sunk" assets will eventually require replacement and "fixed" labour costs can ultimately be varied by increasing or reducing staff numbers. Indeed, the point at which all costs become variable is the economist's definition of 'long run';

(iii) whether the costs are expressed as:

a. total costs (e.g. $million): economists will typically apply discounted cash flow analysis to calculate total costs;

b. annual costs (e.g. $million per year): methods for calculating the annual costs include:

i. annuities, where the capital expenditure (or asset value) and operating expenditure are converted to an annualised repayment schedule, using the WACC as the discount rate;

ii. building block costs, where the annual cost in any particular year is equal to the sum of annual operating cost, annual depreciation and the written down asset value multiplied by the WACC. Depending on the application, the asset value may be defined by engineering estimates (e.g. a written down replacement cost) or through regulatory determination (i.e. a regulatory asset value).

c. unit costs (e.g. dollars per household or equivalent tenement): typically calculated as the present value of total costs divided by the present value of demand; or

d. marginal or **incremental** costs (e.g. dollars per incremental household or incremental equivalent tenement): marginal costs are the amount that can be saved or avoided now or in the future as a result of certain actions such as a change in demand or an investment toward efficiency. Marginal costs are always measured as a change from a particular baseline scenario, which for some purposes may be a zero growth in demand or a zero expenditure scenario. Marginal costs can be expressed either as a total marginal cost (i.e. the absolute change from the baseline scenario) or as a unit marginal cost (i.e. the change in cost per unit of change in demand).

2.1 Application of Different Cost Concepts

Table 3 summarises some of the key applications of different cost concepts in the water and wastewater industry.

Table 3: Applications of different cost concepts

Cost concept	Expressed as	Relevant Application
Short Run Marginal Cost (SRMC)	Marginal cost	Short run pricing
Long Run Marginal Cost (LRMC)	Marginal unit cost	Volumetric price New customer contributions Option evaluation Evaluation of new business opportunities Evaluation of third party supply proposals
Annuity	Annual cost	Water pricing for major customers Telecoms price path regulation (TSLRIC)
Building Block costs based on Regulated Asset Value	Annual cost	Water price path regulation
Building Block costs based on Optimised Replacement Value	Annual cost	"Upper Bound" pricing
Cost per property (Building Block or annuity)	Unit cost	Review of business performance over time Benchmarking

There is no one 'true cost' of servicing a customer. Each form of cost analysis is relevant for a specific decision or purpose. For example, backward-looking costs may be used to evaluate the past performance of a business while forward-looking costs might be used to evaluate potential new business opportunities. Methodological considerations are also important for different pricing applications.

Two of the above cost concepts (and one variation) were agreed with the Steering Committee as the costing methods that would be applied throughout this study:

- the **Long Run Marginal Costs** (LRMC) to service **incremental** demand. Incremental LRMC can be defined as the long run, marginal cost to service either:
  - o all new demand growth; or
  - o a defined increase from the forecast level of demand.
- **Long Run Marginal Cost** of a **decrement** in demand – also referred to as long run **Avoided Costs**.[2] Long run Avoided Costs can be defined as the long run costs avoided if:
  - o no new demand growth is serviced (similar to the LRMC to service incremental demand, except that some costs may be unavoidable); or
  - o demand is reduced by a defined amount from expected levels.

[2] LRMC and Avoided Costs represent two aspects of the 'economic price approach' from the previous Cost Reflective Pricing Study for water.

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- the cost of supplying **existing services** using the regulatory **"Building Block"** approach.[3] This approach is commonly used by economic regulators to define price paths for water utilities. The Building Block approach is defined as annual operating expenditure, plus depreciation and a return on assets. Both depreciation and return on assets are typically calculated with respect to an efficient (or optimised) asset base.

2.2 Long Run Marginal Cost

Long Run Marginal Cost is a critical concept for both modern utility pricing and for project evaluation. The calculation of total long run marginal cost is a key input into "lower bound" pricing, as it determines the financial impact of growth, and is also widely used as the basis of the volumetric prices in a two part tariff. In addition, an understanding of the long run cost of planned water and wastewater infrastructure is important when determining the efficiency or otherwise of alternative solutions. For instance, the economic evaluation of new wastewater treatment technologies requires a firm understanding of the expected cost of conventional wastewater treatment methods.

Economic theory suggests that the volumetric element of the tariff should reflect the long run marginal cost of supply. However, while marginal costs are useful in designing tariff structure, pricing for full cost recovery must also recognise the cost of past investments. Therefore, in accordance with COAG guidelines on pricing, most Australian water businesses employ a two-part tariff, where the volumetric charge is intended to reflect marginal costs and the fixed annual charge recovers the residual revenue required to ensure overall revenue adequacy. Charges based on marginal costs alone are typically insufficient to ensure overall revenue sufficiency for the service provider.

The two primary approaches to calculating LRMC in the water industry are:

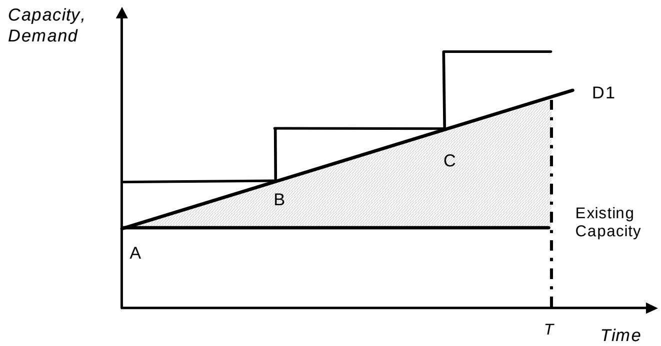
- the Average Incremental Cost approach; and
- the Marginal Incremental/Decremental Cost approach.

2.2.1 Average Incremental Cost

This method calculates the cost of increasing capacity above the current level of usage. The Average Incremental Cost (AIC) methodology measures all growth related expenditure against the growth in demand.

The AIC approach is represented in Figure 6.

Figure 6: Framework for estimating AIC



Suppose the optimal strategy for a water company is composed only of increases in supply capacity and the company's forecast in demand is given by D1. Given the existing capacity this implies a future supply deficit, equivalent at any point in time to the vertical distance between the vertical line representing existing capacity and forecast demand D1. Supposing the supply/demand balance is to be maintained through three successive infrastructure augmentations, with the stepped line representing changes in capacity, the AIC would be estimated as the present value of the costs of the three augmentations required to close the supply deficit divided by the present value of the contribution to supply/demand balance (represented by the shaded area).

As a formula the AIC method may be illustrated as follows:[4]

$$LRMC^{AIC} = \frac{PV\,(Incremental\_Cost)}{PV\,(Incremental\_Demand)}$$

---

[3] Referred to as 'proportional distribution' in the previous Cost Reflective Pricing Study for water.

[4] "PV" denotes the present value using a discounted cashflow analysis.

The information required to calculate the AIC is therefore:

- incremental capital cost, i.e. the capital expenditure schedule that relates to servicing growth in demand;
- incremental operating cost, i.e. the operating expenditure that relates to servicing growth in demand;
- the expected demand forecast.

2.2.2 Average Incremental Cost – Worked Example

Suppose a wastewater service provider currently treating 100GL per year had a growth in the volume of wastewater treated of 5 GL per year. The organisation has a capital expenditure of $50 million per year to maintain the condition of existing assets, and an additional $50 million per year on new transmission assets to service growth. An upgrade in 2006 will provide a total treatment capacity of 125 GL per year. For every additional 25 gigalitres treated, the organisation also requires a new wastewater treatment plant (WWTP) upgrade at a cost of $400 million.

The operating expenditure grows comparatively slowly each year, reflecting the growth in short run variable costs such as electricity and chemicals, increasing transmission maintenance costs and increasing administrative costs. With every wastewater treatment plant upgrade, the operating cost increases at a faster rate, reflecting the additional labour and materials required to operate a new wastewater treatment plant.

The demand, supply and cost schedule for this hypothetical service provider are tabulated in Table 4.

Table 4: Anticipated Demand and Cost Schedule – Worked Example

Year	Demand (GL treated)	WWTP capacity (GL)	Forecast Capital Expenditure	Forecast Operating Expenditure	Comment
2006	100	125	500	50.0	Current (baseline) year
2007	105	125	100	50.5	
2008	110	125	100	51.0	
2009	115	125	100	51.5	
2010	120	125	100	52.0	
2011	125	150	500	54.0	WWTP Upgrade
2012	130	150	100	54.5	
2013	135	150	100	55.0	
2014	140	150	100	55.5	
2015	145	150	100	56.0	
2016	150	150	500	58.0	WWTP Upgrade
2017	155	175	100	58.5	
2018	160	175	100	59.0	
2019	165	175	100	59.5	
2020	170	175	100	61.5	
2021	175	200	500	62.0	WWTP Upgrade
2022	180	200	100	62.5	
2023	185	200	100	63.0	
2024	190	200	100	63.5	
2025	195	200	100	64.0	

The long run Average Incremental Cost is the present value of the costs associated with new demand divided by the present value of the new demand (in megalitres). The extract of information required to calculate AIC is shown in Table 5.

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Table 5: Anticipated Demand and Cost Schedule – Worked Example

Year	Incremental Demand (GL treated)	Forecast Growth Capital Exp ($'000)	Incremental Operating Expenditure
2006	Current Year	Current Year	Current Year
2007	5	50	0.5
2008	10	50	1.0
2009	15	50	1.5
2010	20	50	2.0
2011	25	450	4.0
2012	30	50	4.5
2013	35	50	5.0
2014	40	50	5.5
2015	45	50	6.0
2016	50	450	8.0
2017	55	50	8.5
2018	60	50	9.0
2019	65	50	9.5
2020	70	50	11.5
2021	75	450	12.0
2022	80	50	12.5
2023	85	50	13.0
2024	90	50	13.5
2025	95	50	14.0
Present Value	462.3	1,247.10	67.8

Based on the information derived in Table 5 the long run Average Incremental Cost is:

$$LRMC^{AIC} = \frac{PV\,(Incremental\_Cost)}{PV\,(Incremental\_Demand)}$$

$$= \frac{PV(Capex\_for\_Growth) + PV(Incremental\_Opex)}{PV(Incremental\_Demand)}$$

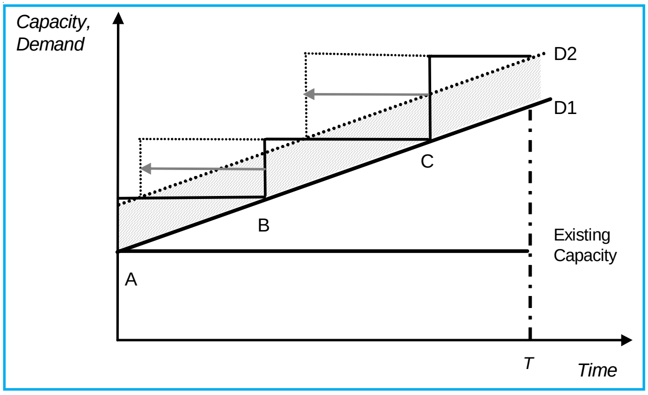
$$= \frac{1{,}247.1 + 67.8}{462.3}$$

$$= \$2.84/kL$$

2.2.3 Marginal Incremental/ Decremental Cost

Sometimes also referred to as the "Hanke Turvey" approach, this method measures possible changes in forecast demand against the corresponding change in forecast expenditure. The long run Marginal Incremental/ Decremental Cost (MIC) method is represented in Figure 7.

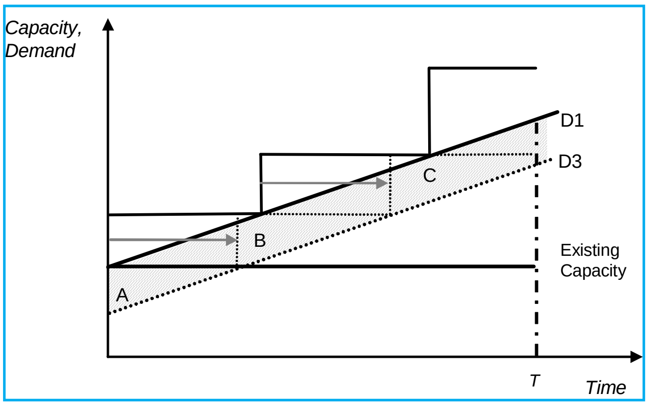
Figure 7: Framework for estimating LRMIC



D1 (solid line) represents a firm's original or "baseline" demand forecast. D2 (dotted line) is the alternative ("perturbated") forecast. The solid stepped line represents a series of increases in system capacity to meet the central forecast demand estimate, D1, at least cost, i.e. investment project A, B and C. The dotted stepped line is the investment schedule brought forward (represented by the arrows) to meet forecast demand plus the increment indicated by D2.

While this example uses an increment to demand, marginal cost can also be considered in the context of a decrement. With a decrement in demand, capital expenditure is deferred as the investment schedule may be posted to a later date. This is illustrated in Figure 8.

Figure 8: Framework for estimating Marginal Costs with a Decrement in demand



D3 (dotted line) is the alternative ("perturbated") forecast. The difference between the incremental cost and the decremental cost is not purely semantic since different estimates of the MIC are typically obtained.

The long run MIC is calculated as the difference between the present value of the expenditure implied by the two different demand forecasts divided by the present value of the marginal change in expected demand (represented by the shaded area in either Figure 7 or Figure 8).

The formula for calculating Marginal Incremental/ Decremental Costs (MIC) is shown below:

$$LRMC^{MIC} = \frac{PV(Change\_in\_cost)}{PV(Change\_in\_demand)}$$

where,

Change_in_cost is the forecast expenditure after the increment or decrement in demand *minus* the original or "baseline" forecast of expenditure; and

Change_in_demand is the forecast demand after the increment or decrement in demand *minus* the original or "baseline" forecast of demand.

The information required to calculate the long run MIC is therefore:

- the original or "baseline" capital expenditure – typically only growth expenditure is required as capital maintenance expenditure and expenditure to improve existing service levels will not be impacted by increments or decrements of demand;
- the capital expenditure after the increment or decrement of demand;
- the original or "baseline" operating expenditure;
- the operating expenditure after the increment or decrement of demand;
- the original or "baseline" demand forecast'
- the demand forecast after the increment or decrement of demand.

2.2.4 Marginal Incremental/ Decremental Cost – Worked Example

Assuming the same demand and expenditure profile as the previous example, Table 4 represents the original or "baseline" forecast of demand and expenditure.

The long run Marginal Incremental/Decremental Cost is the present value of the difference between the original or "baseline" forecast of expenditure and the forecast expenditure *after* the increment or decrement in demand, divided by the present value of the difference between the original forecast of demand and the forecast of demand after the increment or decrement.

In the simplest case, the impact of the increment or decrement of demand is to accelerate or decelerate capital and operating expenditure, as illustrated in Figure 7 and Figure 8. In practice, the timing may vary due to physical constraints on expenditure or location specific timing requirements. In addition, it may be possible to optimise the configuration of the infrastructure or to redesign the infrastructure requirements entirely. For the purposes of this example, we have applied the simplest assumption that capital and operating expenditure in any year is linked to the demand forecast for that year. The demand shown in Table 4 reflects the "trigger point" at which capital and operating expenditure is required. Perturbations of demand will therefore move the capital and operating expenditure to the new "trigger point" year.

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The original schedule of capital expenditure, operating expenditure and demand are shown in the table below, in addition to the costs and demand schedule associated with an increment of 10GL per year (note that the capital expenditure reflects growth expenditure only). This could reflect, for example, a proposal to create a new industrial park with a waste discharge of 10 GL per year (equivalent to more than 60,000 residential customers). The current WWTP has a capacity of only 125 GL per year (see Table 4), therefore if the scheme is growing at 5 GL per year (or approximately 30,000 residential customers per year), the treatment facilities planned for construction in 2011 time would require acceleration to 2009. In addition, expenditure related to transmission infrastructure would also be required – we have assumed for simplicity that the transmission infrastructure required for the increment in demand is exactly equal to the transmission infrastructure for the baseline growth in demand (i.e. $50 million capital expenditure plus associated operating expenditure for each 5 GL increase in demand).

As illustrated in Table 6, the increment of 10GL moves the original 2009 demand of 115 GL forward to 2007. This requires all expenditure originally planned for years 2007 to 2009 to be accelerated to 2007. From that point forward all capital and operating expenditure has been accelerated by two years.

Based on the information derived in Table 6 the long run Marginal Incremental Cost is:

Table 6: Anticipated Demand and Cost Schedule – Worked Example

Year	Original Demand ($demand_1$)	Adjusted Demand ($demand_2$)	Original Capital Expenditure ($capex_1$)	Adjusted Capital Expenditure ($capex_2$)	Original Operating Expenditure ($opex_1$)	Adjusted Operating Expenditure ($opex_2$)
2006	Base Year	Base Year	Base Year	Base Year	Base Year	Base Year
2007	105	115	50	150	50.5	51.5
2008	110	120	50	50	51.0	52.0
2009	115	125	50	450	51.5	54.0
2010	120	130	50	50	52.0	54.5
2011	125	135	450	50	54.0	55.0
2012	130	140	50	50	54.5	55.5
2013	135	145	50	50	55.0	56.0
2014	140	150	50	450	55.5	58.0
2015	145	155	50	50	56.0	58.5
2016	150	160	450	50	58.0	59.0
2017	155	165	50	50	58.5	59.5
2018	160	170	50	50	59.0	61.5
2019	165	175	50	450	59.5	62.0
2020	170	180	50	50	61.5	62.5
....						
2107	605	615	50	50	105	105
Present Value	3,106.8	3,273.0	2,010.2	2,250.3	1,021.6	1,043.9

Additional transmission required

WWTP upgrade accelerated

$$LRMC^{MIC} = \frac{PV(Change\_in\_cost)}{PV(Change\_in\_demand)}$$

$$= \frac{PV(Capex_2) - PV(Capex_1) + PV(Opex_2) - PV(Opex_1)}{PV(demand_2) - PV(demand_1)}$$

$$= \frac{2,250.3 - 2,010.2 + 1,043.9 - 1,021.6}{3,273.0 - 3,106.8}$$

$$= \frac{262.4}{166.2}$$

$$= \$1.58/kL$$

2.2.5 Marginal Incremental Cost vs Average Incremental Cost

The AIC and MIC methods are each appropriate for different applications. For example, the AIC method may be employed to calculate the net impact of new demand (e.g. for determination of new customer contributions). The MIC approach is appropriate for sending economic price signals and use in option evaluation as it reflects the actual change in cost that will occur with a change in behaviour rather than relying on an averaged approach. The MIC methodology requires more intensive data collection, planning and modelling. The MIC method can also produce volatile results depending on the increment chosen, particularly if future expenditure occurs in relatively large "chunks". In these cases, small changes in demand increments can have a significant impact on the result. Appendix A outlines international experience in the use and estimation of LRMC in the water industry and indicates that AIC is the more common methodological approach. By contrast, the Victorian ESC recently released an Information Paper outlining its preference for the MIC method (referred to as the "perturbation" method).[5] The ESC website also provides an Excel spreadsheet model to allow calculation of wastewater LRMC (available at http://www.esc.vic.gov.au/).

This study applies the long run MIC approach, but removes the high volatility from the results by considering a number of MIC results for different increments and decrements in demand. The issues surrounding LRMC calculation in practice are explored further in Section 2.4.

2.3 Avoided Cost

Avoided costs represent the costs that are not incurred if a particular driver is absent. For example:

- a proposed recycled water scheme may draw feed water *after* the wastewater treatment process. The water recycling proposal may therefore result in limited or no avoided cost for the wastewater scheme, but substantial savings for the potable water scheme. If the recycling process allows nutrients to be removed from the final discharge to waterways, there may be potential for the treatment plant to avoid future upgrades driven by nutrient load;
- a third party access applicant may seek access to an incumbent's transmission system to collect waste from existing customers within the incumbent's operating area. In the short run, the costs avoided by the incumbent might be limited to a reduction in electricity and chemical costs for treatment and pumping. In the longer term, the reduced volume may defer the incumbent's wastewater treatment plant and pump station upgrades;
- in a greenfield site, the long run avoided cost can represent the entire wastewater scheme. If the proposed greenfield development does not proceed, the cost of the entire system will be avoided.

The examples above demonstrate that avoided costs are highly situation dependent and rely on the precise specification of the scenario to be evaluated.

Avoided costs are, in a sense, a subset of Long Run Marginal Costs, representing the change in costs if demand is reduced from current levels. While long run marginal cost may be measured with respect to either an increase or decrease in demand from existing or future demand forecasts, the term "avoided cost" typically refers to the impact of a significant decrement from current demand from a particular location. For instance, this may represent the costs avoided costs by introducing water recycling or third party "sewer mining".

[5] ESC (September 2005), *Estimating Long Run Marginal Cost: Implications for Future Water Prices*, Information Paper

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To illustrate the concepts and issues involved in determining avoidable costs, this study includes the calculation of avoidable costs using a practical case study. For the purposes of this exercise, the avoided cost calculation is based on a sewer mining "access" arrangement. The scenario assumes:

- the operation will draw raw wastewater from the incumbent's system immediately prior to treatment;
- the third party would be required to treat and dispose of the wastewater at their own expense (it is irrelevant for the wastewater avoided cost calculation whether the third party on-sells the water or disposes of it in some other way – the distinction would be important if the avoided costs of water were also being calculated);
- this will be a true "access" arrangement, whereby full retail services are also provided to the retail customers.

Table 7 outlines the approach taken for this study.

Table 7: Avoided Costs applied in Case Studies

Avoided Costs	Capital	Operating
Transmission	No avoided costs	No avoided costs
Treatment Disposal Recycling Retail	Marginal cost for a significant demand decrement	Marginal cost for a significant demand decrement

It is important to reiterate that avoided costs could relate to any, or none, of the segments of the wastewater system, depending on the particular circumstances and purpose of the calculation. The scenario used for this report (i.e. that only transmission costs are considered unavoidable) has been developed for illustrative purposes only.

We work through an example of Avoided Costs using the Marginal Decremental Cost methodology below.

2.3.1 Avoided Cost: Marginal Decremental Cost – Worked Example

Assuming the same demand and expenditure profile as the previous example, Table 4 represents the original or "baseline" forecast of demand and expenditure. This example assumes that all expenditure other than transmission expenditure can be avoided. Transmission expenditure of $50 million capital per year and $10 million operating per year should therefore been removed from the information required to calculate Avoided Cost. The remaining capital costs represent expenditure on WWTP upgrades of $400 million as shown in Table 8.

Table 8: Anticipated Demand and Cost Schedule – Worked Example

Year	Demand (GL treated)	Forecast Capital Excl Transmission	Forecast Operating Excl Transmission	Comment
2006	100	0	40.0	Current (baseline) year
2007	105	0	40.5	
2008	110	0	41.0	
2009	115	0	41.5	
2010	120	400	42.0	WWTP Upgrade
2011	125	0	44.0	
2012	130	0	44.5	
2013	135	0	45.0	
2014	140	0	45.5	
2015	145	400	46.0	WWTP Upgrade
2016	150	0	48.0	
2017	155	0	48.5	
2018	160	0	49.0	
2019	165	0	49.5	
2020	170	400	51.5	WWTP Upgrade
2021	175	0	52.0	
2022	180	0	52.5	
2023	185	0	53.0	
2024	190	0	53.5	
2025	195	0	54.0	

The LRMC Marginal Decremental Cost is the present value of the original capital and operating expenditure forecast less the present value of the perturbed expenditure forecast, divided by the difference between the present value of the original demand forecast and the present value of the perturbed forecast.

The information required to calculate the LRMC Marginal Decremental Cost is therefore:

- the original or "baseline" capital expenditure – typically only growth expenditure is required as capital maintenance expenditure and expenditure to improve existing service levels will not be impacted by increments or decrements of demand. In some cases, upgrades for nutrient removal driven by environmental regulation could be avoided with a significant decrement in demand;
- the capital expenditure after the decrement of demand;
- the original or "baseline" operating expenditure;
- the operating expenditure after the decrement of demand;
- the original or "baseline" demand forecast;
- the demand forecast after the decrement of demand.

In the simplest case, the capital and operating expenditure after the decrement involves a deceleration of the timing of expenditure (as illustrated previously in Figure 8). In practice, the timing may vary due to physical constraints on expenditure or location specific timing requirements. In addition, it may be preferable for economic or other reasons to redesign the capital program entirely if demand is significantly reduced. For the purposes of this example, we have applied the simplest assumption that capital and operating expenditure in any year is linked to the demand forecast for that year. The demand shown in Table 4 reflects the "trigger point" at which capital and operating expenditure is required. Perturbations of demand will therefore move the capital and operating expenditure to the new "trigger point" year.

The original forecast and a decrement of 10 GL is shown in the following Table 9.

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Table 9: Anticipated Demand and Cost Schedule – Worked Example

Year	Original Demand ($demand_1$)	Adjusted Demand ($demand_2$)	Original Capital Expenditure ($capex_1$)	Adjusted Capital Expenditure ($capex_2$)	Original Operating Expenditure ($opex_1$)	Adjusted Operating Expenditure ($opex_2$)
2006	Base Year	Base Year	Base Year	Base Year	Base Year	Base Year
2007	105	95	0	0	40.5	39.5
2008	110	100	0	0	41.0	40.0
2009	115	105	0	0	41.5	40.5
2010	120	110	0	0	42.0	38.0
2011	125	115	400	0	44.0	43.0
2012	130	120	0	0	44.5	43.5
2013	135	125	0	400	45.0	44.0
2014	140	130	0	0	45.5	44.5
2015	145	135	0	0	46.0	42.0
2016	150	140	400	0	48.0	47.0
2017	155	145	0	0	48.5	47.5
2018	160	150	0	400	49.0	48.0
2019	165	155	0	0	49.5	45.5
2020	170	160	0	0	51.5	50.5
....						
2106	600	590	400	0	94.5	93.5
2107	605	595	0	0	95.0	93.4
Present Value	3,106.80	2,940.60	1,179.20	1,048.40	855.4	833.2

Table 9 shows that a decrement of 10 GL moves the 2007 demand of 105 GL back to 2009. The expenditure of $50 million on capital maintenance remains at the forecast timing, but expenditure on wastewater treatment plants has been deferred for two years. All operating expenditure estimates have also been moved back by two years because the difference in operating expenditure between years is assumed to be entirely driven by growth.

Based on the information derived in Table 9 the long run marginal (avoided) cost using the Marginal Incremental/Decremental Cost methodology is:

$$LRMC^{MIC} = \frac{PV(Change\_in\_cost)}{PV(Change\_in\_demand)}$$

$$= \frac{PV(Capex_2) - PV(Capex_1) + PV(Opex_2) - PV(Opex_1)}{PV(demand_2) - PV(demand_1)}$$

$$= \frac{1{,}048.4 - 1{,}179.2 + 833.2 - 855.4}{2{,}940.6 - 3{,}106.8}$$

$$= \frac{-152.8}{-166.2}$$

$$= \$0.92/kL$$

This example illustrates that the long run cost calculation for a decrement in demand (avoided cost) is similar in nature to the long run marginal cost calculation for an increment in demand. The avoided cost calculation results in a substantially lower unit cost because transmission has been excluded from the calculation. If transmission system costs were also avoided, the total avoided (MIC) cost would be $1.47/kL.[6]

[6] The difference between this result and the LRMC (incremental) result relates to the difference in the present value of an acceleration compared with a deceleration and the constrained timing of initial acceleration of demand (i.e. the first year's demand can not be accelerated by two years).

2.4 LRMC and Avoided Costs issues

LRMC and Avoided cost calculation raise a number of difficult methodological and practical issues of calculation. We address a number of these in turn below.

2.4.1 Developing a Least Cost Schedule

A common feature of long run cost approaches is that they assume that the investment (or series of investments) necessary to meet output has been optimised. This means that the resulting costs are such that a least cost schedule is created.

There are number of ways to achieve this "optimal" cost schedule, including mathematical modelling involving operations research and multi-period linear programming. Any mathematical model, however, is a simplified representation of the real world and as such may fail to accurately reflect practical issues and concerns such as environmental and social issues related to site selection. In any case, any estimation will be reliant on businesses having a thorough understanding of the relationship between demand and expenditure.

From a practical perspective, it may be more appropriate to rely on general business skills when developing a least cost schedule. This could entail using different investment analysis techniques such as ranking expansion alternatives on a whole-of-life or cost per unit basis (eg. annual yield for a dam, peak day capacity for WTP, peak hour capacity for balancing storages and peak flows per second for pipelines and rising mains).

Following is a typical approach for developing a least cost source development schedule:

- develop a list of alternative supply sources, their supply capacity and associated capital and operating cost;
- project the base case demand for 20-50 years into the future;
- calculate the unit cost of different demand and supply options and rank the alternatives;
- determine the sequence of supply and demand options based on a least cost schedule;
- adjust the demand schedule to reflect selected demand management options;
- determine the timing of supply options required to meet demand, allowing for appropriate security of supply buffers.

In the approach above we have excluded considerations related to externalities, such as social and environmental interactions. Costs to the environment or costs associated with impacts on social welfare are a critical part of water supply management and should be overlaid on these steps to determine the optimum sequencing and timing of water sources and demand strategies.

2.4.2 Size of Increments/ Decrements

When applying LRMC and Avoided Cost methods to examine incremental costs, we are interested in the way that changes in demand for existing or potential customers affect the investment profile of a utility. In the case of greater incremental demand, capital expenditure will be brought forward; conversely, where incremental demand falls, capital expenditure may be delayed.

The size of the increment or decrement in demand has a significant impact on the results. The size of the perturbation could be as little as the impact of adding or subtracting a single customer. The change in demand by a single customer will have relatively little impact on the system, but the combined impact of changes by many customers can have a profound impact. For most purposes, the choice of a large increment or decrement better reflects the potential impact of the aggregate of possible demand impacts.

Figure 9 demonstrates the impact of different increments and decrements on the Long Run Marginal Cost calculation under the LRMC (MIC) approach, based on an analysis of capital costs for the "ModInland" case study (see Section 3.5 for more details on the case study). The chart illustrates the significant difference in results between the AIC method and the MIC method. In this case, decremental volumes result in a LRMC around a half to two thirds of the AIC method. Incremental volumes also result in a LRMC around 20% lower than the AIC. The exact difference will vary according to the characteristics of the demand and expenditure profile.

The chart demonstrates that the LRMC result can be very sensitive to the choice of increment or decrement when considering small perturbations of demand. A decrement of 50 GL per annum results in a LRMC of \$4.02/kL, while a decrement of 100 GL results in cost of \$6.46/kL. The story is similar across each of the modelled schemes. It is unrealistic to expect the forecast of baseline demand, the size of capacity increments

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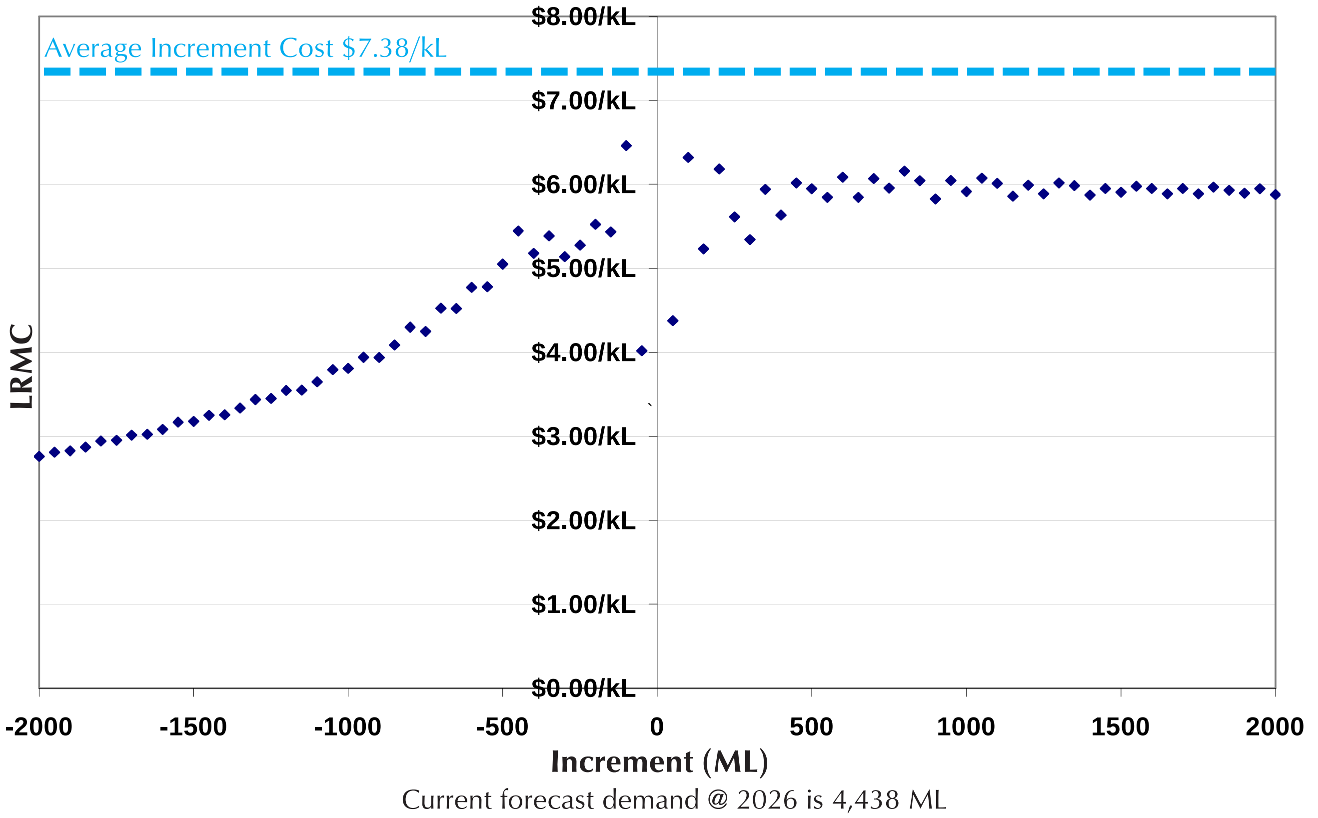
Figure 9: LRMC by Demand Increment



or the change in customer demand to be within this level of accuracy. As the increment or decrement becomes larger, the results begin to cluster but become less relevant to real world planning. The extreme ends of the figure represent an increase or decrease in demand by almost 50% of the forecast demand in 2026.

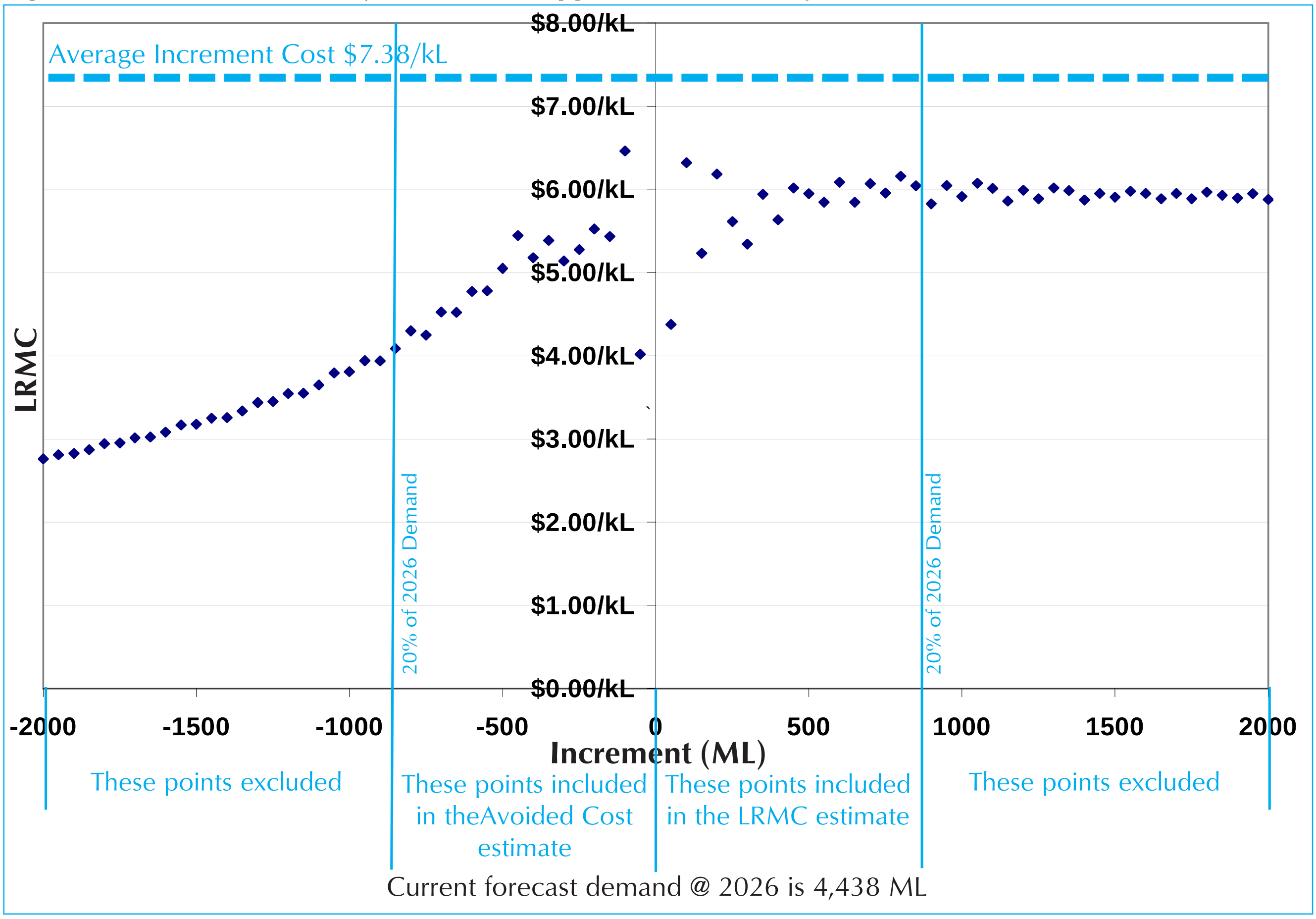
In practice, regulators and customers with an interest in LRMC may prefer to define a precise increment or decrement rather than use a range of estimates. However, the chart above demonstrates the inherent difficulty in relying on a single point estimate. The problem is exacerbated by the fact that typically neither the "base case" nor variations in demand can be predicted with accuracy. The "base case" demand can be influenced by a range of factors including weather conditions, water restrictions and conservation campaigns, population growth, income and industrial development. Similarly, the nature and the timing of the "base case" capital program is a forecast based on current information – in practice social, political and environmental concerns may change the program or the relative order in which water sources are brought on line. Finally, the increment or decrement itself is typically uncertain unless there is a well-defined customer seeking to access a contractually agreed volume of water.

At a minimum, a range of LRMC results should be modelled to test the sensitivity of varying the prescribed increment or decrement. If a single point increment or decrement is adopted, then the point estimate of LRMC should be compared against the modelled results to test its "fit" with other increments or decrements. Ideally, regression analysis can be applied to develop a single best-fit line.

If uncertainty precludes the use of a single point increment or decrement, an alternative approach may be to determine the average of all relevant increments or decrements. Preferably, the result would be weighted by the likelihood of the occurrence of each particular increment or decrement. The exact choice of mathematical technique will depend on the purpose of the calculation and the specific uncertainties involved.

For this exercise, we have assumed a maximum increment or decrement in demand of around 20% by 2026 (illustrated in Figure 10 below). For the remainder of this report "LRMC" refers to the average of all *incremental* LRMC results for perturbations between 0% and 20%, based on the assumption that current estimates of growth are conservative. The Avoided Cost result refers to the average of all *decremental* LRMC results for perturbations between 0% and 20%. These simplifying assumptions are intended for illustrative purposes only. The exact choice of increments and/or decrements will depend on the particular application.

Figure 10: LRMC Increments/Decrements Applied in Case Study Results



2.4.3 Physical constraints

The impact of perturbations in demand can be measured by identifying demand "triggers". The change results in a shift in timing of the capital expenditure from the forecast timing to a new point corresponding to the adjusted demand schedule. The exact timing of the new capital expenditure will also be tempered by real world constraints. For example, a change in demand may notionally bring forward capital expenditure by several years. However, as there are lead times in building infrastructure, acceleration of works may not be possible in some cases.

The location of land development may also be a determinant of capital expenditure timing. Capital expenditure on items such as treatment plant sites and major sewer mains are often required well ahead of the development front to minimise disturbance and construction costs.

Finally, capital sequencing may differ with optimisation for different increments or decrements in demand. Small perturbations may favour modular capital solutions that can be gradually upgraded over time (eg upgrading of an existing treatment plant). Major perturbations may favour the development of a major new standalone facility. An economic analysis of alternative solutions is required to develop the least cost whole of life solution.

Costing Methodologies
continued

2.4.4 Time frame

The choice of timeframe is both a methodological and practical issue. In cases where the evaluation of long run costs is related to a contract or a particular asset with a finite life, the appropriate timeframe is determined by the life of the project. Examples may include the increase in costs associated with supply to a major industrial customer, or the costs avoided during a fixed term recycled water trial. Importantly, the analysis should be extended such that flow-on impacts (after the contract expires) can be modelled. For example, at the expiry of a wastewater trial, new infrastructure may be immediately required to replace the lost capacity.

When calculating the long run marginal or avoided cost for an ongoing concern such as a water utility, there is no clear termination point for the analysis. Assets are continually being replaced or renewed and each property is effectively granted the opportunity to draw water from the system into perpetuity (subject to water supply availability and water restrictions).

For some applications, the timeframe for calculation of long run costs is determined by the purpose of the calculation. If the calculation is conducted to derive a volumetric charge for a two-part tariff, then the choice will depend on the nature of the intended price signal. In pure theory, economic efficiency is best served by setting prices closer to short run marginal cost. In practice, setting prices based on short run costs can cause serious market failures due to the large incremental cost of main sewers and wastewater treatment plants. In addition, considerations of equity and customer preference support a longer term approach.

For most applications, including option evaluations and the calculation of the long-term impact of adding new customers, the long run incremental or avoided cost should reflect the ongoing nature of water businesses and effectively be extended to perpetuity. Extension of the timeframe to perpetuity can be achieved either through the application of mathematical perpetual replacement formulae or by extending the timeframe such that changes in the cashflows become negligible in present value terms. At a 6% discount rate, a cashflow of:

- $100 in 20 years time would be worth $31 in present value terms;
- $100 in 50 years time would be worth $5 in present value terms;
- $100 in 100 years time would be worth less than 30c in present value terms;

Cashflows in 20 and even 50 years time can therefore still have a material impact on long run cost calculations. It is recommended that cashflows be identified or extrapolated for a minimum of 50 years, preferably 100 years where practical.

In practice, cashflow estimates are often not available for 50 years or more. A common method of approximating the cashflows after the final year of the analysis is through the use of "terminal values". Terminal values typically represent the remaining value of an asset at the end of an analysis period by adding a credit in the final year equal to the written down replacement cost of the asset. This credit is intended to approximate the remaining income generating potential of the asset. The terminal value is an imperfect estimate of either future income generating potential or future cashflows and is therefore typically less effective than extension of the cashflow model.

2.4.5 Established vs Greenfield Sites

The individual components of LRMC and Avoided Cost will vary depending on the status of the scheme:

- ***New scheme:*** In greenfield schemes, assets have not yet been constructed. All assets are therefore marginal and may be influenced by developer behaviour, such as the installation of water efficient appliances, or water recycling schemes. Prior to any expenditure on infrastructure, all costs are considered variable (i.e. potentially avoidable). Thus, these schemes will produce the highest estimate of LRMC or Avoided Cost. The greater flexibility of a greenfield site has been illustrated recently by the innovative Pimpama Coomera recycled water scheme. The wastewater and water schemes were able to be designed with maximum flexibility because the recycled water scheme was conceptualised and designed before the site was established. Brownfield sites offer far less flexibility in overall scheme design and therefore limit the ability to avoid costs.

- ***Existing scheme, new development:*** For new developments connecting to an existing scheme, existing sewers, major pump stations and treatment plants are sunk costs and excluded from the LRMC calculation. There may be scope to influence the cost of future upgrades. The cost of reticulation and other local assets will only be included in the calculation prior to the commencement of the development. If sized for ultimate capacity, the capital cost of these assets can not be affected after installation.
- ***Existing scheme, existing development:*** For existing developments, many mains are sized for ultimate capacity and will not be significantly influenced by changes in customer behaviour (particularly reductions in demand). Upgrades in pump stations and treatment capacity may still be affected by changes in demand, particularly those that have been staged. These established sites will typically have the lowest estimates of LRMC or Avoidable Cost.

2.5 Building Block Costs

In its simplest form, the Building Block approach calculates total annual cost as:

Annual operating and maintenance expenditure (including support costs)

plus Depreciation, i.e. return of capital

plus A Return on Assets (ROA) equal to the Weighted Average Cost of Capital

The Building Block approach is used by economic regulators for three primary reasons:

- it is relatively easy to calculate from existing and forecast accounting reports. In particular, the Building Block approach does not require estimates of long run infrastructure requirements beyond the regulatory period (typically 3-5 years);
- over time, setting revenue equal to the Building Block cost will generate a return approximately equal to the initial asset value. The depreciation and Return on Assets act in a similar way to a loan repayment schedule by returning the initial investment over time (depreciation) plus an allowance for interest on the reducing balance (ROA). If the asset value is not written down to reflect "optimisation" or changes in technology, the present value of the Building Block revenue will, over time, approximate the initial (regulatory) asset value; and
- if calculated using "optimised" or "efficient" assets and operating expenditure, Building Block costs indicate the cost at which a competitor could efficiently duplicate the system, in theory placing an upper bound on prices. In practice, large entry costs in the water industry mean that customers will only bypass the incumbent's system at a much smaller scale. The unit cost of bypassing the system for any particular customer or customer group will typically be much higher than the prices produced under an "optimised" asset value approach.

Costing Methodologies
continued

Building Block costs can be calculated a number of ways and can incorporate historic asset values, replacement costs, "optimised" replacement costs, regulatory asset values or renewals annuities.[7] A detailed list of Building Block methodologies and their key features is provided in Appendix B.

The use of "optimised" values for assets removes any over-design in the original asset. This reflects only the cost of those assets that would have been commissioned if the scheme were reconstructed today. When applied to pricing, this ensures that customers are not paying for over capacity that is no longer required.

A feature of the more sophisticated methods such as optimised replacement cost and renewals annuities is the need for extensive data and planning. These methods are often considered theoretically superior, but are relatively uncommon in practice due to limited information and the large investment required to obtain the necessary information.

More recently, economic regulators in the NSW, Victorian and WA water industry have set regulatory asset values for Building Block pricing. The initial Regulatory Asset Value (RAV) is commonly set to yield a revenue level between the economically efficient lower and upper bound ranges, with the precise level of the RAV set with reference to expected pricing outcomes. Regulators may, for example, set a RAV with the aim of maintaining current price levels or achieving a certain rate of return on past investments. This is sometimes described as setting a 'line-in-the-sand' valuation. Thus the initial asset value, and therefore the Building Block calculation, used in water industry price regulation is rarely related to independently verifiable costs.

The choice of initial Regulatory Asset Value involves a degree of judgement that cannot be deduced from costs alone and may take into account past commitments, impact on customers and government expectations. In the Australian water industry, the RAV will generally be less than the depreciated optimised replacement value of the assets. In the short term, regulators will typically set a RAV that minimises "price shocks", however in the longer term the price may increase (or decrease) depending on the relative quantum of future costs per customer compared with the existing Building Block cost per customer.

Box Insert A shows the several bases for determining the RAV that were examined and applied by the Victorian economic regulator, the Essential Service Commission.

The Building Block methodology can readily be calculated with known regulatory asset values and reported operating expenditure. Moreover, since it relates to the whole business it is often reasonably stable. In contrast, concepts such as LRMC, particularly marginal incremental cost, can be volatile and vary significantly according to the particulars of the case. The familiarity and stability of Building Block costs makes this a common approach for benchmarking across the industry.

Based on available water industry data, the current study has applied an "upper bound" approach to determining Building Block costs. That is, the total Building Block cost is equal to:

> Annual operating and maintenance expenditure (including support costs)
>
> *plus* Optimised Replacement Cost Depreciation
>
> *plus* A Return on the Depreciated Optimised Replacement Cost equal to the Weighted Average Cost of Capital.

[7] The long life of urban water industry assets has seen an almost complete move away from historic cost approaches with regard to both accounting and pricing. The original cost of assets that may have been constructed more than 100 years ago is considered to bear little relevance to current cost or pricing requirements. In practical terms, the historic cost recovery formula results in a very high cost recovery in early years and an extremely low recovery in later years as both depreciation and inflation erode the asset value. Replacement cost approaches have therefore been favoured by the industry for many years.

Box Insert A: ESC Determination of RAV

The Essential Services Commission (ESC) used a number of scenarios to derive initial RAVs that were consistent with one of the following outcomes:

Scenario 1 - Businesses' proposed prices and returns (unadjusted). This derives an initial RAV that delivers the prices and returns on past investments proposed by the water businesses as part of their respective Water Plans. This includes the businesses' assumptions about expenditure, demand, cost of capital and the level of capital contributions from new customers.

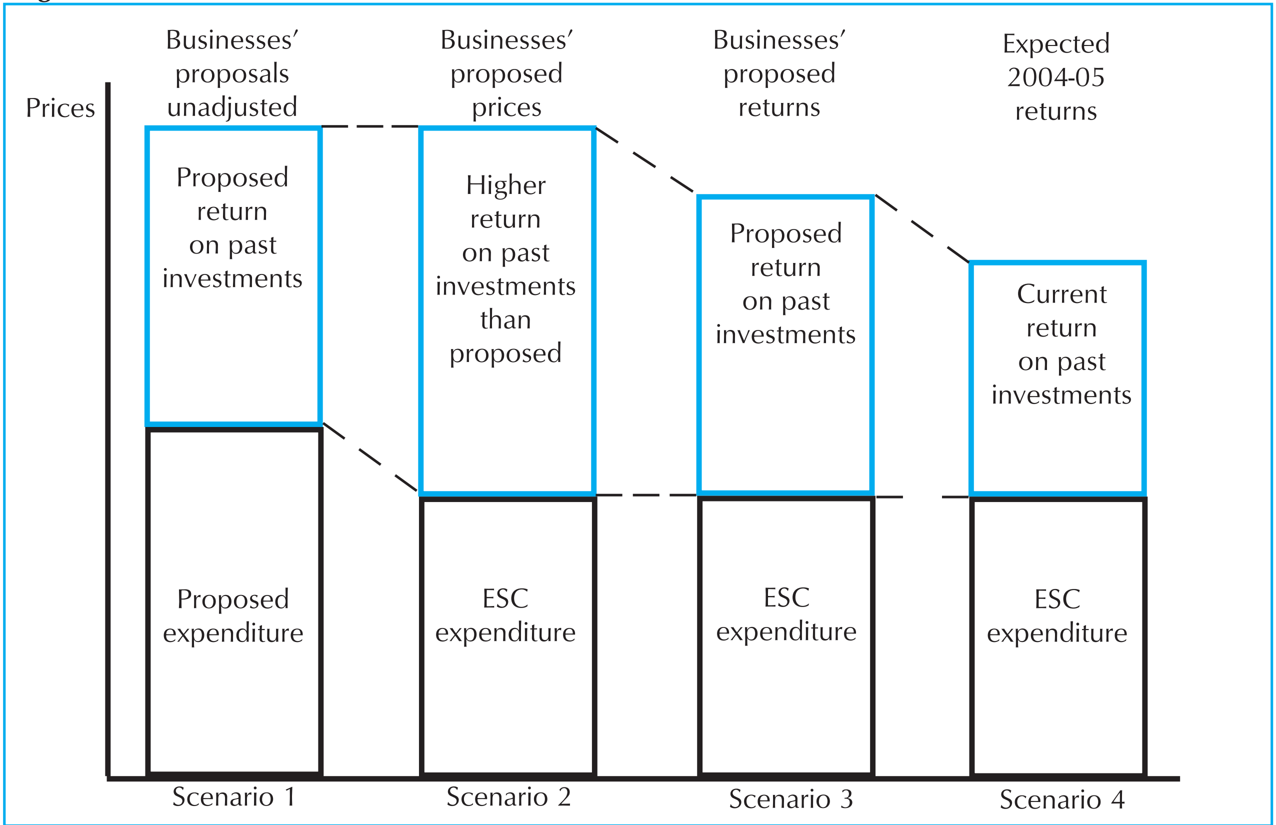
Scenario 2 - Businesses' proposed prices. This derives an initial RAV that delivers the proposed prices by the water businesses in their Water Plans. However, it reflects the ESC's view on assumptions about expenditure, demand, cost of capital and the level of capital contributions from new customers. As a result, any differences from the businesses' proposals in this regard will be reflected in a higher or lower return on past investments (and hence higher or lower initial RAV).

Scenario 3 - Businesses' proposed returns on past investments. This derives an initial RAV that delivers the dollar return on past investments assessed in the businesses' Water Plans. However, it reflects the ESC's view on assumptions about expenditure, demand, cost of capital and the level of capital contributions from new customers. As a result, any differences to the businesses' proposals in this regard will be reflected in higher or lower prices than proposed by the businesses.

Scenario 4 - Expected 2004-05 return on past investments This derives an initial RAV that delivers the return on past investments that the water businesses expected to make in the initial year as outlined in their Water Plans, and consistent with 2004-05 corporate plans. Under this scenario, any difference between the businesses' proposals and the ESC's view about expenditure, demand, cost of capital and the level of capital contributions from new customers would flow into higher or lower prices than those proposed by the businesses. Prices (and returns) would similarly be affected by any difference between the return on past investments proposed by the businesses as part of their Water Plans and that expected to be achieved in 2004-05 as set out in their corporate plans.

The four scenarios described above are depicted in Figure 11.

Figure 11: Scenarios for the Initial RAV



Adapted from: Essential Service Commission (March 2005), *Advice to the Minister for water, Regulatory asset values for the Victorian water businesses*

3. Cost Drivers and Choice of Case Studies

3.1 Introduction

The case studies in this study have been chosen to illustrate the levels and distribution of the costs of wastewater systems in Australia and how these may be affected by physical characteristics, such as location, and by the type of system. The case studies reflect the cost of supplying wastewater services from the standpoint of a major urban wastewater service provider, including the provision of retail services, transmission, treatment and disposal. Collection (reticulation) capital costs are typically met by land developers in Australia and have therefore been excluded from the case study analysis. For the sake of simplicity, the ongoing cost of operation and maintenance of the collection system has been included within the transmission costs.

A fully systematic and statistically rigorous study of the role of different drivers on the level and distribution wastewater costs would require the development of significantly more case studies. There are multiple relevant drivers and to examine these definitively would involve case studies from each member of WSAA. The current four-year benchmarking study commissioned by WSAA may provide such information but is beyond the scope and timeframe of this study.

To inform the choice of case study that best illustrates the differences in cost between locations and business segments (i.e. retail, collection, transmission, treatment and disposal), it is necessary to identify and understand the drivers of cost for wastewater services. To develop a shortlist of the primary drivers of cost, the MJA team relied on a number of sources, including interviews with wastewater planners, investigations by the UK economic regulator (Ofwat), the WSAA Project Steering Committee and MJA's own experience in advising water businesses across Australia and New Zealand.

3.2 Regulatory Analysis of Cost Drivers

An integral element of economic regulation of water in the UK is the use of econometric models to compare the economic efficiency of companies. The relative efficiency of individual companies determines the discount applied in calculating the regulator's approved price path. These econometric equations provide a basis for examining the key drivers of cost for wastewater service provision.

For the analysis of wastewater, there are five models for each of operating and capital expenditure. While the applicability of Ofwat's econometric analysis in the Australian context is debatable, the analysis behind the modelling provides useful insights into the drivers of wastewater systems generally. The models[8] include drivers for load, population, the relative spread of the network, and the number of sewer outflows and critical sewers[9]. Table 10 outlines the general composition of the models related to sewerage.

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8 The model definitions and elements derive from Ofwat (2003) *Water and sewerage service unit costs and relative efficiency 2002–2003 report*, Appendix 1, pp. 44-52.

9 *"Critical sewers are those, whose collapse repairs will be expensive or disruptive or those, which are considered to be strategically important. The principal structural criterion is that if a sewer should fail, the subsequent costs would be significantly higher than if rehabilitated before failure"* Ofwat (2006) *June return reporting requirements and definitions manual 2006*, March, Section2 Chapter 16, p. 6. Accessed at http://www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/AttachmentsByTitle/jr06_repreq_sec2_chap16_050106.doc/$FILE/jr06_repreq_sec2_chap16_050106.doc on 18 May 2006.

Table 10: Ofwat Econometric Model Drivers

Model	Model type	Explanatory factors
Operating expenditure		
Sewer network	Log linear	Sewer length*, area*, resident population*, holiday population
Large sewage treatment works	Log linear	Volume*, use of activated sludge treatment, suspended solids and BOD5*
Small sewage treatment works	Unit cost	Works size, works type, volume*
Sludge treatment & disposal	Unit cost	Weights of dry solids, disposal route*
Sewerage business activities	Unit cost	Billed properties*
Capital expenditure		
Sewerage infrastructure	Log linear	Length of sewer*; number of combined sewer overflows; proportion of critical sewers*
Sewerage non-infrastructure	Unit cost	Number of pumping stations (see Topography* below)
Sewage treatment	Log linear	Total load*; total number of works
Sludge treatment & disposal	Unit cost	Total weight of dry solids
Sewerage management & general	Unit cost	Billed properties*

Adapted from: Water Industry Commissioner for Scotland (2006) *Our work in regulating the Scottish water industry: The scope for operating cost efficiency*, Volume 4, p. 9 and Volume 5, p. 7.

Furthermore, special factors are applied to a number of companies (detailed in Appendix C), illustrating the depth, complexity and location specific nature of cost drivers in the wastewater industry.

The items denoted with an asterix (*) in Table 10 represent elements identified as critical drivers of cost for the development of illustrative case studies. Other items in the Oftwat analysis include:

- capacity related items such as number of works, size of works and weight of dry solids, which were assumed to be causally driven by volume and chemical/ nutrient load (identified as a separate driver);
- the holiday population is an important factor for small or medium sized settlements with a large holiday season tourist influx. The current study assumes that the costs associated with holiday population are closely reflected in the annual volume/load (for variable costs), the peak day volume (for transmission and treatment capacity) or the number of properties connected;
- combined sewers (i.e. combined wastewater and stormwater sewers) have been almost entirely abolished throughout Australia.

The drivers identified in the Ofwat analysis were compared with input from WSAA member engineers and planners, and WSAA Project Steering Committee to develop a final shortlist of cost drivers.

Cost Drivers and Choice of Case Studies
continued

3.3 Shortlist of Cost Drivers

In the Australian context, some of the best understood drivers of wastewater system costs include chemical/ biological load factors such as Biological Oxygen Demand (BOD), Nitrogen and Phosphorous. An understanding of the treatment requirements for nutrient and chemical loads is required to meet environmental discharge obligations. Chemical and biological load factors also appear in trade waste charges as they are readily influenced by customer behaviour.

Load factors predominantly impact the cost of the treatment process. Other drivers of cost, such as growth, are more general and apply (to varying extents) to all aspects of the transmission, treatment and disposal process.

Some of the key drivers of cost, such as the distance between the customer and the treatment point, are often overlooked as they are a function of local development and topographical conditions and are not easily influenced by customers after the settlement is established.

To develop a shortlist of the primary drivers of cost for wastewater services, the MJA team relied upon:

- discussion with, and information from, members of the WSAA Project Steering Committee;
- interviews with wastewater planners and engineers in WSAA member utilities;
- MJA's own experience in advising water businesses in Australia and New Zealand on costs and pricing; and
- the investigations into wastewater cost drivers commissioned by the UK economic regulator (Ofwat).

The key cost drivers of wastewater service costs identified through this analysis are identified in the table below.

The short-listed cost drivers and cost considerations are examined in turn in the following sections.

Table 11: Key Cost Drivers and impact on business segments

Cost Driver	Primary business segments impacted
Number of connections	Retail, Collection, Transmission, Treatment and Disposal (All)
Disposal method	Treatment, Disposal
Peak wet weather flow	Transmission, Treatment and Disposal
Volume discharged	Collection, Transmission, Treatment and Disposal
Chemical and biological load factors, including:	
o Biological Oxygen Demand (BOD)	Transmission, Treatment and Disposal
o Suspended Solids (SS)	Treatment and Disposal
o Salt	Treatment and Disposal
Topography	Transmission
Density of development	Collection, Transmission
Collection/transmission/disposal distance	Collection, Transmission, Disposal
Other cost considerations:	
Size and timing of capacity increments	Collection, Transmission, Treatment and Disposal
Critical sewers	Transmission

3.3.1 Number of connections / growth in connections

The number of connections impacts the absolute cost of all elements of the business, including retail, collection, transmission, treatment and disposal costs. The greater the number of connections, the more infrastructure and administrative support is required, except where spare capacity exists (see below). The unit cost (i.e. cost per megalitre treated or cost per residential equivalent) is also affected by the number of connections as larger scale transmission and treatment infrastructure typically benefit from increased economies of scale. Conversely, large-scale treatments and disposal costs can often suffer from diseconomies of scale as the magnitude of waste begins to have more serious impacts on the environment. For example, smaller, more remote schemes often employ low cost technologies such as wastewater treatment ponds. These require little operator attention but do not possess the ability to remove organic pollutants such as BOD, nitrogen and phosphorus to low levels. By contrast, the volume of waste treated means that larger urban centres must typically rely on ocean discharge as their primary means of wastewater disposal. Regulatory compliance standards often require this to be treated to a secondary or tertiary level (see degree of treatment).

The growth in the number of connections is typically the largest driver of capital expenditure. The growth rate drives treatment capacity, transmission requirements and reticulation costs. In the schemes reviewed for this study, growth accounted for more than 70% of total wastewater capital requirements (the remainder representing capital maintenance and service improvements).

3.3.2 Disposal method and degree of treatment

The method of wastewater disposal is determined by the size of the settlement, the availability of receiving bodies and the perceived health and environmental risks. Human health could be impacted if a certain disposal method has the potential to contaminate bathing water, groundwater or food supplies or could transmit pathogens through airborne insects or recreational contact. Lower levels of treatment will typically affect the environment, in particular local flora and fauna, to a greater extent. Greater levels of treatment can come at the cost of higher energy use (and therefore higher greenhouse gas emissions) and higher odour control requirements.

For non-coastal population centres and smaller coastal towns, inland disposal will often be the least expensive method of disposal. This can include discharge to inland water courses, infiltration or evaporation. However, for major urban centres increasingly strict regulations, diminishing public acceptance and the economics of multiple disposal points generally relegate inland disposal to a last resort option.

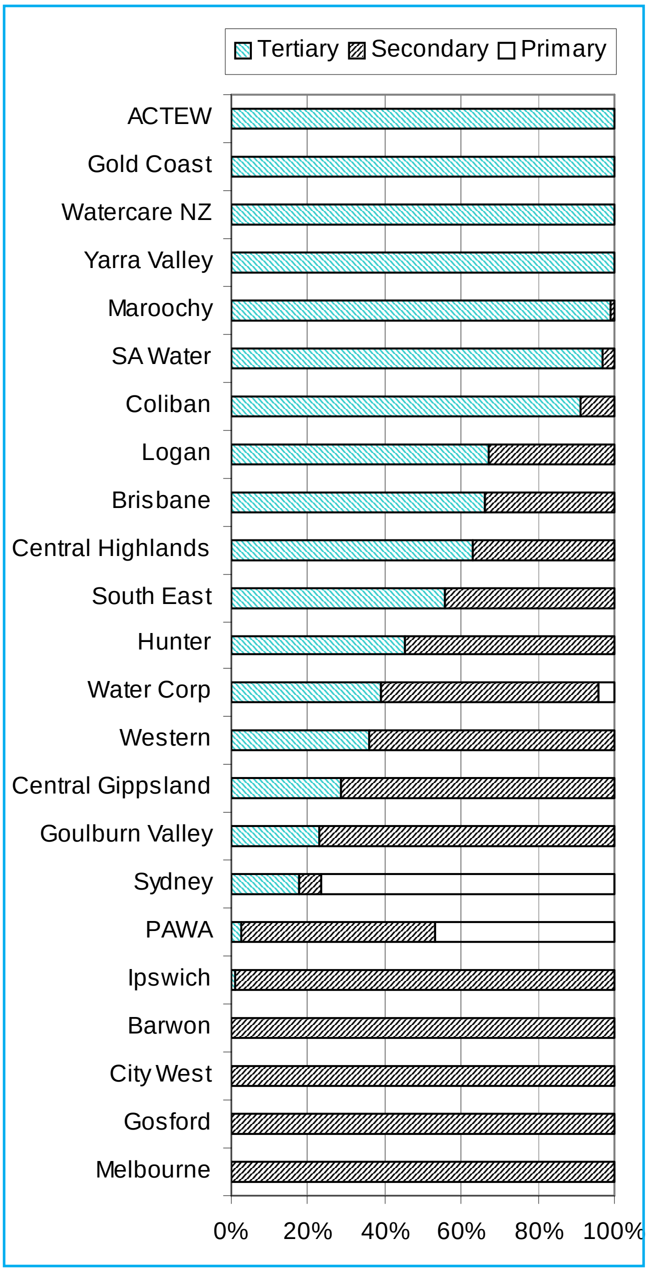
Discharge to oceans also has a poor reputation. Historical discharges of solids near popular beaches have affected national public perceptions of ocean disposal. Such perceptions and images are largely unfounded with modern treatment technology and disposal practices. While inland disposal would appear, *prima facie*, to require greater treatment costs to protect river ecologies, the cost of discharging to ocean can also be costly for a number of reasons, including:

- longer outfall pipelines
- greater odour management at coastal treatment plant sites
- higher coastal land values

The degree (and therefore cost) of treatment required is closely related to the ability of the receiving body to absorb or disperse contaminants. Higher levels of treatment are required for sensitive ecological areas or areas where ocean or river currents do not quickly disperse the outfall. The degree of wastewater treatment varies widely across Australia, as demonstrated in the following Figure 12.

Cost Drivers and Choice of Case Studies
continued

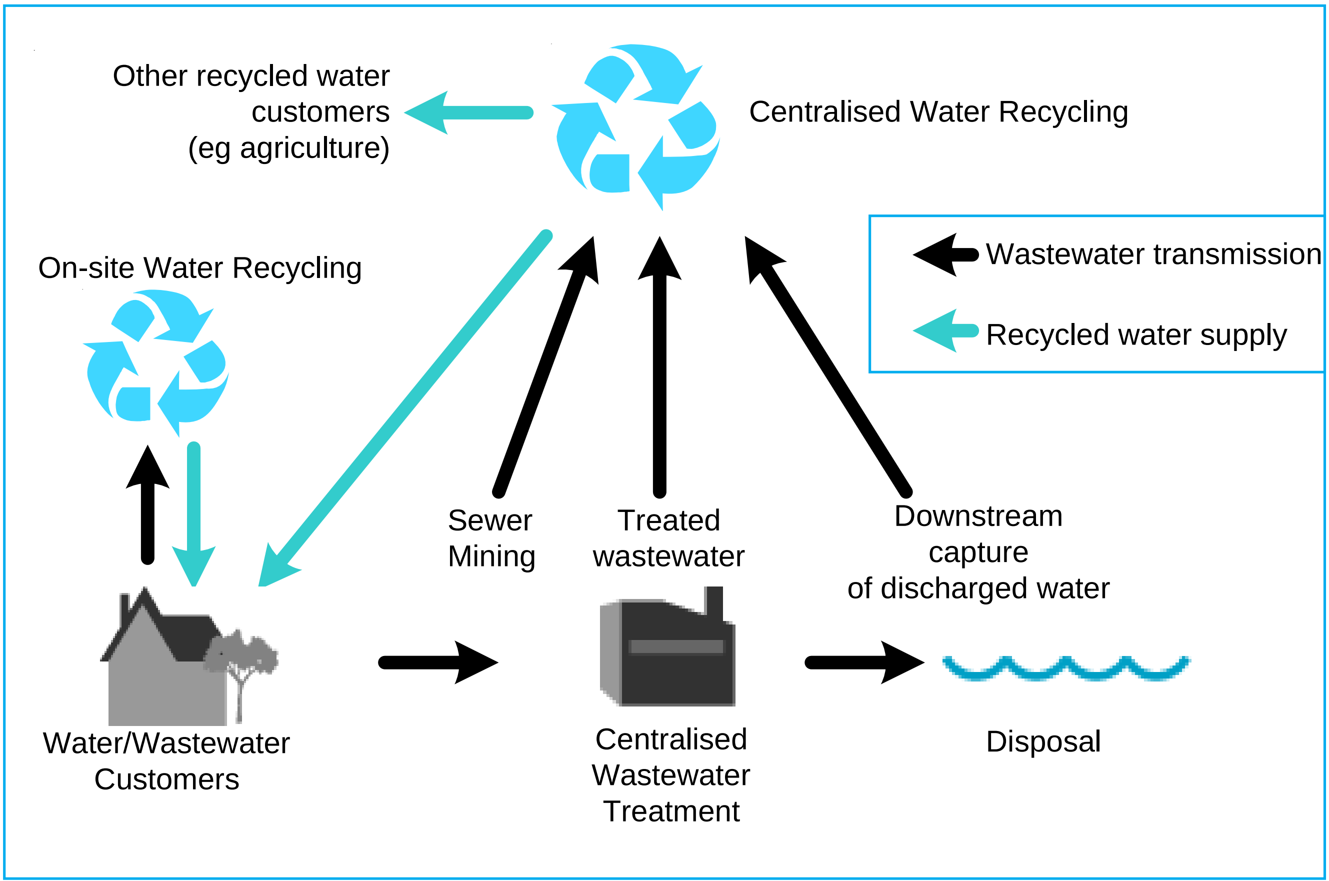
Figure 12: Wastewater Treatment levels by Utility



Source: WSAA*facts* 2005: figures relate to proportions of wastewater volumes treated to level for 2004/05

The third major method of disposal is via recycling, in one or more of its forms. Wastewater has gained greater recognition as an increasingly valuable resource and the adoption of wastewater recycling technology has expanded significantly in recent years. Application of recycled water to municipal parks and golf courses has been common over the past few decades, typically involving relatively low levels of treatment and small volumes of recycled water. The recent drought conditions have confirmed the role of recycled water as a valuable resource and current efforts are focused on large scale, often high technology, recycled water schemes. Applications for recycled water have included agriculture, industry, aquifer recharge and third pipe residential solutions. Wastewater recycling has the potential to impact every part of the wastewater transmission, treatment and disposal process as illustrated in Figure 13.

Figure 13: Potential Points of Wastewater Capture for Water Recycling



Water recycling may occur at the household level, at the local neighbourhood level, prior to centralised treatment, after treatment or even as extraction from a river downstream of the utility's discharge point. Although the role of water recycling is still being developed in Australia, the potential impact in the future may be substantial.

Recycling schemes vary widely in cost, reflecting the type of treatment (itself driven by the risks to human health and the class of water required), the scale of the plant and the distance that the recycled water needs to be transported.

Recycling to municipal parks, golf courses and agricultural areas may represent a relatively low cost treatment option. These options can become relatively expensive when transmission and reticulation costs are taken into account. Recycling for industrial or potable use is far more expensive and may require Reverse Osmosis or other high levels of treatment.

The primary advantage with recycling technologies is that they represent both a method of wastewater disposal and a source of water. Thus, even comparatively expensive recycling processes may represent an overall reduction in the cost of total water cycle management.

The lack of clear delineation between the water and wastewater processes means that the allocation of recycling costs between potable water, wastewater and recycled water customers is not straightforward. All three customer groups are beneficiaries of recycled water in one form or another. Determining the most efficient method for charging each customer group requires a series of judgements regarding the incremental cost of supplying each group, revenue adequacy for the utility, the by-pass price and each group's respective willingness or capacity to pay. See WSAA Occasional Paper 12 (2005) *Pricing for Recycled Water* for more information on issues related to recycled water pricing.

Cost Drivers and Choice of Case Studies
continued

3.3.3 Volume and Chemical/ Biological Load

Each wastewater system has a unique combination of organic and chemical loads that, together with the receiving environment, affect the nature and level of the treatment processes required. Volume and load drivers include:

- Peak day volume
- Annual volume
- Biological Oxygen Demand (BOD)
- Suspended Solids (SS)
- Salt

Chemical/biological load factors combine to influence a number of infrastructure and operating cost items, treatment costs in particular. Assets costs are typically affected by a combination of factors and therefore engineering assessment must be applied to derive a cost segmentation.

Load influences each stage in the wastewater treatment process to varying degrees. We therefore examine each stage of the wastewater process in turn.

Retail: Retail costs are relatively unaffected by chemical or biological load factors, except to the degree that they impact billing, frequency of meter reads and customer liaison requirements. The number of customer connections is typically considered a more relevant driver of retail costs.

Collection and Transmission: Collection and transmission infrastructure costs are predominantly driven by the pipeline capacity required to service peak volume. In the schemes reviewed for this study, transmission infrastructure represented more than 60% of existing capital costs and more than 80% of future expenditure. The vast majority of this infrastructure is pipeline cost. Wastewater pipelines are sized to cater for Peak Wet Weather Flows. This is determined in part by customer discharge, which is relatively stable between seasons, and wet weather events. The Peak Wet Weather Flow (PWWF) is typically between 3 and 5 times the Peak Dry Weather Flow (PDWF). This represents inflow into the transmission system caused by infiltration into joints, weaknesses and manholes, in addition to illegal stormwater connections to sewers.

This ratio can vary substantially between cities. For instance:

- in certain areas of Darwin, tropical cyclones can cause inflows of up to 30 times the dry weather flow; and
- at the other end of the spectrum in Perth, the relatively sandy soils do not hold water for the same period as many of the eastern state cities with more dense soils and therefore infiltration is lower. In addition, the majority of Perth sewers were constructed more recently than other cities and are predominantly PVC, PE or plastic lined. PWWF to PDWF ratios used for planning in Perth are therefore often a third of those used in other cities.

BOD was also noted to have a corrosive effect on transmission pipelines. The cost of combating the effects of BOD were found to range from minimal impact to almost 20% the capital cost and 25% of operating expenditure. A review of two WSAA members at either extreme of this range found:

- the organisation reporting the higher impact of BOD focused on preventing odours during the transmission process. Oxygen and chemicals were added into the sewer to limit hydrogen sulphide levels. A key part of the strategy was to reduce odour releases at pumping stations via submerged inlets, washing the walls of all major wet wells regularly and encouraging air flow through the wet well. This combination of control measures minimised the growth of wall slimes in the wet wells and hence reduced the potential for sulphide formation in wet wells; and
- the organisation reporting the lower impact of BOD had high sulphide levels and therefore corrosion was a key problem. Pipe installation was therefore predominantly PVC, PE or plastilined, minimising the corrosion of sewers. The sewers were sealed and there was no forced ventilation. This minimises the impact of BOD and wet weather infiltration, but results in high odours at the treatment plant site. In turn, this increased the need for expensive treatment plant covers, chemical scrubbing and other odour control solutions.

This comparison illustrates that the impact of each driver is highly location specific and that the best practice in each area may involve quite different technical solutions. The exact impact of each chemical/biological load driver on the collection and transmission system will depend on a combination of factors including (but not limited to) pipe material, maintenance practices, wastewater detention times, ground conditions and pipe lining.

Cost Drivers and Choice of Case Studies *continued*

Treatment and Disposal: The cost drivers for treatment vary according to the stage of the process. The majority of pretreatment infrastructure costs are driven by the raw volume of wastewater treated, while the secondary treatment costs are driven predominantly by the level of BOD, SS and other relevant load factors.

Salt load was raised as a significant emerging issue with the increasing use of recycling. For example, in Werribee Plains, high salt levels were identified as an impediment to growth in the use of recycled water.[10] Melbourne Water and City West Water are promoting the use of low salt detergents, cleaner industrial production processes and trade waste initiatives to reduce salt at source and investigating the construction of a desalination plant to further reduce salt levels at end-of-pipe. The Government is also providing funding to promote salt reduction and water savings by industry. In Queensland, the EPA's recycling guidelines suggested that trade waste agreements and consumer education be used to reduce salt inputs. The guidelines also suggested that users undertake measures (such as diluting recycled water) to meet their needs.[11]

The impact of salt levels on capital and operating expenditure is in early investigation stages at the current time and estimates of the impact of salt were not available for this study. Industry members interviewed by MJA also noted that salt reduction might potentially be pursued through demand side initiatives that may mitigate the need for infrastructure solutions.

The precise impact of each load driver on treatment costs will depend on the technology employed and standard of service required, including the level of treatment, method of disposal, odour control technology and practices, wastewater detention times and discharge requirements.

Several individual water authorities have invested substantial resources to understand the role of volume and chemical/biological load in driving the costs of their wastewater system. This investment has occurred in order to formulate their policies and charges for tradewaste. The variation in results from these investigations are illustrated by a comparison of the respective capital costs of treatment for two WSAA members operating quite different systems in the following tables.

WSAA Member A

	Treatment Capital Costs							Weighted Average
	Septicity Control	Screenings and Grit	Primary Treatment	Sec. Aeration	Sec. Clarification	Sludge Treatment	Effluent Pumping	
Flow - volume		30%	75%	45%	70%		100%	45%
Flow - peak								0%
BOD	90%		10%	35%	15%	15%		11%
SS		70%	10%		15%	85%		8%
Oils & Grease			5%					
Nitrogen				15%				36%
Phosphorous				5%				
Sulphur	10%							

WSAA Member B

	Treatment Capital Costs							Weighted Average
	Pre-treat	Primary	Secondary	BNR	Disinfect	Biosolids	Outfall	
Flow - volume	20%	20%	10%		90%		100%	13%
Flow - peak	60%	60%	0%		0%		0%	15%
BOD			70%		10%	30%		31%
SS	20%	20%	20%			70%		26%
Nitrogen				75%				15%
Phosphorous				25%				

[10] Reference/more detail.

[11] Environmental Protection Agency (2005) *Queensland Water Recycling Guidelines*, Waterwise Queensland, December, p. 66.

Cost Drivers and Choice of Case Studies
continued

The differences in the costs can be attributed to differences in treatment plant design, the different environmental discharge limits for each organisation, diverse customer loads, the comparative approach to odour control management and, it should be expected, differences in expert opinion when assessing the impact of each factor. These investigations underline the importance of volume and load as drivers of costs of wastewater systems but also illustrates the significant variation between locations.

The impact of various load factors used for the case study analysis in this project are shown in the tables below. In each case, these estimates have been based on the expert assessment of planners and engineers for an actual wastewater scheme. The results below are therefore intended for case study analysis only. Estimates for any particular location should be conducted by relevant experts with knowledge of the local wastewater infrastructure and the associated operating requirements.

The relative impact of each factor outlined in the tables above was applied to each scheme to determine the cost breakdown between business segments (ie transmission, treatment, disposal, recycling and retail) and between customer groups, based on assumptions about customer discharge volume and quality. The capital cost of the collection system was not included in this analysis, as it was assumed that all collection (i.e. wastewater reticulation) capital costs within the study time horizon would be funded by developers. The cost of operating the collection system has been included in the "transmission" category.

3.3.4 Topography

The natural topography of a city has a significant impact on wastewater transmission costs. A natural slope toward the ocean (or other disposal site) will allow extensive use of gravity systems and a relatively shallow depth of sewer. For cities with relatively flat topography, elevated coastal land or extensive hill or mountain terrain, pure gravity systems can be either technically unfeasible due the sewer grades required or economically unfeasible due to the depths involved. In these cases, cost-benefit trade off decisions must be made about the comparative use of gravity, pressurised transmission and alternating lift and gravity systems. Added pumping requirements increase the capital, the operating and the annual maintenance cost of a wastewater system.

3.3.5 Density of development

The density of development – or more precisely the size of lot frontages – primarily impacts the cost of the wastewater collection (reticulation) system. The density of development also has a flow on impact on the total length and breadth of the settlement and therefore on transmission distances (see 3.3.6 below).

As noted earlier, this study examines the cost of supplying wastewater services from the standpoint of a major urban wastewater service provider. Collection (reticulation) capital costs are typically met by land developers in Australia and have therefore been excluded from the case study analysis.

Table 12: Capital cost breakdown Adopted in Case Studies

	Drivers				
	Peak Day	Annual Volume	BOD	SS	Other
Transmission	60%	0%	20%	0%	5%
Treatment (Non-recycling)	15%	13%	31%	26%	15%
Disposal	15%	13%	31%	26%	15%
Recycling	0%	45%	5%	5%	45%
Retail	0%	0%	0%	0%	100%

Table 13: Operating cost breakdown Adopted in case Studies

	Drivers				
	Peak Day	Annual Volume	BOD	SS	Other
Transmission	40%	20%	25%	15%	0%
Treatment (Non-recycling)	3%	6%	58%	24%	10%
Disposal	3%	6%	58%	24%	10%
Recycling	0%	45%	5%	5%	45%
Retail	0%	0%	0%	0%	100%

3.3.6 Transmission/disposal distance

Pipeline costs typically represent two thirds or more of a wastewater service providers total asset base. Therefore the length of sewers required is a key driver of wastewater industry costs. The length of transmission sewers is driven by the distance between the customer and the treatment plant, while the cost of disposal pipelines is driven by the distance between the treatment plant and the outfall site. Typically, treatment plants are located on the coast or close to inland rivers to minimise the disposal distance and therefore the length and depth of major outfall pipelines.

WSAAfact 2005 indicates a significant diversity in the length of sewer mains per property between Australian wastewater service providers. The length of sewer mains per property ranges from 14 metres per property in Sydney and Melbourne, to more than 28 metres per property for the Central Gippsland Region and Coliban Region Water Authorities.

3.3.7 Size and timing of capacity increments

The scale of augmentation in the water and wastewater infrastructure is different from other utilities. At the simplest level, these differences in magnitude and timing arise from the greater depth of water and in particular sewerage infrastructure compared with the infrastructure for electricity and gas.

The minimum economic scale for increasing capacity in transmission, treatment and disposal infrastructure is substantial. For example, Sydney Water is currently upgrading the West Camden Sewage Treatment Plant as part of their long-term water and wastewater strategy. The upgrade will not only help to improve water quality in the Hawkesbury Nepean River system, but will also increase the capacity of the plant from 10.8 ML per day up to 23 ML per day. The increased capacity is sufficient to treat the waste from around 30,000 residential households.[12]

The large scale of wastewater treatment and transmission upgrades has a significant impact on both existing costs and forward-looking costs. The cost of the existing system may appear atypically expensive for the current number of customers if the system has significant capacity installed for future growth. Some costing systems value existing assets at their "optimised" value and deliberately remove the impact of spare capacity from their reported costs. Conversely, marginal costs (in particular future capital expenditure) may appear unusually low in systems that have recently conducted a significant capacity upgrade.

In the short run, capital expenditure in a system with capacity to cater for growth will be relatively unaffected by changes in the level of demand. In the longer term, an organisation with steadily increasing customer demand will require the construction of new capital works when excess capacity is fully utilised. Additional demand will contribute to the acceleration or deceleration in the timing of the construction of that infrastructure. The impact of new demand will depend, amongst other things, on the time at which spare capacity will be fully utilised. In present value terms, deferring expenditure that is proposed for construction in 10 years time would have around half the impact of deferring equivalent capital expenditure proposed for construction today. Deferring expenditure planned in 20 years time would have half the impact again.

Therefore, both backward and forward-looking costs will be a function of the minimum size of capacity augmentations and the point at which the business is placed in the infrastructure expansion cycle. If a recent upgrade has just been conducted, one would expect historic costs to appear high and future expenditure requirements to appear low. If the system is currently approaching maximum capacity and major upgrades are due in the short term, then capital expenditure could be expected to be approaching a peak.

The cost of wastewater transmission infrastructure is affected by timing more than any other asset, as the cost of increasing the capacity of transmission infrastructure at the time of laying is significantly less than the cost duplicating or upsizing the infrastructure after urban development is established. While treatment plant upgrades can be deferred for several years if a demand "trigger" has not been reached, assets such as sewer mains are typically uneconomic to install at sizes less than their long term capacity. Estimates of demand will therefore impact the size of the initial sewer main installation rather than the timing. Furthermore, cost and capacity do not typically increase at the same rate. For sewer mains in particular, upgrades at the time of installation are often relatively inexpensive as there are significant economies of scale in sewer trenching and laying.

[12] Assumes wastewater discharge is 400 litres/household per day.

Cost Drivers and Choice of Case Studies
continued

As an example, the cost of materials and installation of a 300mm sewer in an established area might be in the order of $430/m (values for this example have been provided anonymously from a contributing WSAA member - actual costs may vary significantly between cities). The cost of a 400mm sewer under the same conditions might be $670/m. The increase in cost between these is approximately 56%, while the increase in flow achieved is approximately proportional to the cross section area of the pipe or:

$$\frac{\Pi * \text{Radius}(1)^2}{\Pi * \text{Radius}(2)^2} - 1 = \frac{3.14 * 40{,}000}{3.14 * 22{,}500} - 1$$

$$= 1.78 - 1 = 78\%$$

Thus, a 78% increase in flow requires only a 56% increase in cost.

For all sewer mains greater then 300mm reviewed in this study, the analysis indicates that cost increases were proportional to approximately 45% of the increase in flow, e.g. a 10% increase in flow will result in a 4.5% increase in cost.

3.3.8 Critical sewers

Underground assets such as sewer mains have three distinguishing features compared with assets in other industries:

- the long asset lives, often up to 100 years or more;
- the difficulty in assessing asset condition due to the reduced opportunity for visible inspection and the limited opportunity to take the asset off-line for maintenance testing.

These features, and the potential for catastrophic consequences from asset failure, make an understanding of asset criticality a crucial issue for the wastewater industry. The criticality of replacement for each asset may be derived through risk analysis identifying factors such as the age of the asset, construction material, pumping pressure, environmental risk and potential disruption to customers. Combined, these factors will indicate the relative importance of asset replacement in each location, which in turn will suggest a certain capital prioritisation.

Risk analysis to identify the criticality of asset replacement is the subject of ongoing investigation in the water industry and will enable water utilities to better identify the timing and need for capital expenditure. Information on the criticality of asset replacement was not available for the case studies in this report.

3.4 Future Directions

The analysis undertaken has used existing design parameters and relationships to examine cost impacts. These analyses examine costs (particularly capital costs) over 50 years. It is possible that these relationships will vary over the course of the analysis with changes in demography, land planning and technology. Naturally, the impact of changes toward the end of the analysis period will have significantly lower impact, reflecting discounting.

UKWIR has noted[13] that climate change, environmental legislation, increasing urbanisation and resource stress are likely to have a significant impact on sewer design and costs over the next eighty years. The UKWIR analysis considered that likely responses could include:

- ‘closed loop’ systems (where treatment is as close to source as possible);
- disconnection of impervious areas;
- greater water recycling;
- improved transmission;
- new technology such as low flush toilets, black water separation and urine separation.[14]

Some of these technologies and practices are already being applied in parts of the world, including Australia.

By their nature, future “unknowns” cannot be factored into the present analysis but should be recognised in any forward strategic planning.

[13] UKWIR (2005) “Sewer Design in 2080” in *UKWIR News*, Issue 37, December

[14] UKWIR (2005) “Sewer Design in 2080” in *UKWIR News*, Issue 37, December, p.1

3.5 Case Studies

To facilitate an understanding of the impact of the major cost drivers on different locations and business segments, the project team, in consultation with the WSAA Project Steering Committee, developed six case studies to represent the major cost variations between schemes. The schemes used to represent each case study are a combination of actual schemes and modelled variations based on data supplied by other utilities. The resulting schemes are a synthesis of the representative elements of each system to create separate systems that mimic many of the standard wastewater industry attributes. For this study we have focussed on those issues unique to the wastewater industry and also draw out some of the additional methodological issues that were not considered in the *Cost Reflective Pricing Study* for water.[15]

Five of the primary drivers of cost – growth, disposal method, peak wet weather flow, transmission distance and spare capacity – were represented through the use of six schemes variations. Each scheme contains combinations of elements that reflect "typical" groupings of each of the drivers. All schemes developed assume that wastewater is treated to at least a tertiary level before disposal.

The six schemes developed for this report were:

Case "ModOcean" reflects a moderate growth (1-1.5% per annum) coastal settlement with tertiary treated ocean outfall. Ocean outfall disposal is expected to continue to be the primary method of disposal for customer growth in the foreseeable future. The scheme has significant transmission, treatment and disposal expenditure planned to service growth over the next ten years (and beyond). The scheme represents a single catchment area of a larger city, with a single pressurised main sewer "spine" running through the catchment. The scheme has typical eastern seaboard peak wet weather flows of around 4 times the peak dry weather flow.

Case "MOLoWWF" shares many characteristics with the "ModOcean" case, including moderate growth, tertiary treated ocean outfall and a single pressurised main sewer "spine" running through the catchment. The major point of difference is the peak wastewater flows, which are more representative of a low infiltration scheme, with peak wet weather flows of approximately 1.5 times peak dry weather flow.

Case "MO10yrscap" is also similar to Case "ModOcean" (moderate growth, tertiary treated ocean disposal, peak wet weather flows 4 times peak dry weather flows), but has recently completed a major treatment and transmission upgrade to cater for fore-

Scheme	Characteristics	Disposal method	PWWF : PDWF
"ModOcean"	Moderate growth, ocean disposal	Ocean discharge	4x
"MOLoWWF"	Moderate growth, ocean disposal, reduced wet weather flow	Ocean discharge	1.5x
"MO10yrscap"	Moderate growth, ocean disposal, ten years' growth capacity	Ocean discharge	4x
"MOHiTrans"	Moderate growth, ocean disposal, long transmission distance	Ocean discharge	4x
"ModInland"	Moderate growth, inland disposal, some recycling planned, big growth allocation	River discharge	4x
"HiRcycl"	High growth, recycling, greenfield	Recycling/ Ocean	4x

[15] Pickering, P, and Werner, L (2002) *Cost Reflective Pricing Study,* WSAA Occasional Paper 7

Cost Drivers and Choice of Case Studies
continued

cast growth over the next ten years. The scheme therefore has significant growth capacity over the next few years and will require little or no capital expenditure for growth unless the increase in demand is significantly faster than currently anticipated. Note that the Depreciated Optimised Replacement Cost (DORC – see Section 2.5) for "MO10yrscap" is similar to the "ModOcean" case study because the DORC methodology *excludes unutilised capacity*.

Case "MOHiTrans" is similar to the "ModOcean" case (moderate growth, tertiary treated ocean disposal, peak wet weather flows 4 times peak dry weather flows, limited capacity for growth), but has an average transmission distance twice that of the "ModOcean" case (total length of mains per property increases from just over 10 metres/property to more than 20 metres/property).

Case "ModInland" reflects a relatively small scheme (about one third the number of customers of the ocean disposal schemes) with larger block sizes (ie low density and therefore longer transmission distances) and moderate growth. The scheme has traditionally disposed of tertiary treated wastewater to an inland river and is unable to dispose to the ocean due to its non-coastal location. Tightening environmental regulations and community pressure mean that new wastewater discharge methods are also being examined for the future, including wastewater recycling.

Case "HiRcycl" represents a relatively new scheme, with a small number of customers, which is (hypothetically) located on the fringe of an existing major urban settlement. The scheme is expected to grow rapidly in coming years (quadrupling in size over 10 years) and developers have agreed to implement a third pipe wastewater recycling system throughout the development. The water will be supplied for non-potable outdoor use in addition, potentially, to some indoor applications (such as toilet use). The wastewater that is not recycled will be discharged to an ocean outfall. The greenfield nature of the development allows the wastewater recycling infrastructure, including third pipe reticulation, to be installed at a lower cost than would be the case if the settlement was already established. The developer may also gain benefits through lower reticulation and water efficiency compliance costs, however these have not been factored into cost estimates for the current exercise.

3.6 Relevance of Cost Drivers to Case Studies

Of the cost drivers identified in Section 3, the six hypothetical case studies will assist in understanding the impact of:

- Number of connections
  - o Small schemes ("HiRecycl" and "ModInland") compared with the other, larger schemes
  - o High growth ("HiRecycl") compared with moderate growth (all other schemes)
- Disposal method
  - o Recycling ("HiRecycl" and "ModInland"), inland disposal ("ModInland"), ocean disposal (all other schemes)
- Peak wet weather flow
  - o 1.5x PWWF:PDWF ("MOLoWWF") compared with 4x PWWF:PDWF (all other schemes)
- Transmission distance
  - o Long transmission distances ("MOHiTrans") compared with moderate transmission distances (all other schemes)
- Spare capacity
  - o Ten years' spare capacity ("MO10yrscap") compared with limited or no spare capacity (all other schemes)

3.6.1 Volume and Chemical/ Biological Load

The two primary remaining drivers – volume and chemical/biological load – are captured "cross-sectionally", i.e. the impact is considered for each scheme. The impact of each load driver has been modelled for each of the case studies based on the load / business segment analysis outlined in 3.3.3 and a unit cost for each load factor has been derived.

The relative impact of peak volume, annual volume, BOD and SS was synthesised from a combination of estimates from participating WSAA members. In addition the general category "other" was introduced to reflect cost drivers other than the volume and load factors identified, including:

- in the **transmission, treatment and disposal** process, "other" primarily represents other chemical/ biological load factors such as Nitrogen, Phosphorous, Oils and Grease;
- in the **recycling** process, "other" refers primarily to pathogen levels. Other factors such as BOD and SS are assumed to be removed before being introduced into the recycling process; and
- in the **retail** process, "other" refers to a complex interrelationship of administrative drivers including number of customers, type of customers, reporting requirements, frequency of meter reads and number of customer contacts.

4 Case Study Results

The case study results apply the methodology reviewed in Chapter 2 to actual data provided by selected WSAA members. The case study modelling determines the Building Block Cost, incremental LRMC and decremental LRMC (Avoided Cost) for each of each of the six hypothetical schemes. The results are strictly applicable only for the systems that were reviewed, however the case studies provide valuable lessons and insights regarding the application of the methodology and the order of magnitude of each of the major cost drivers.

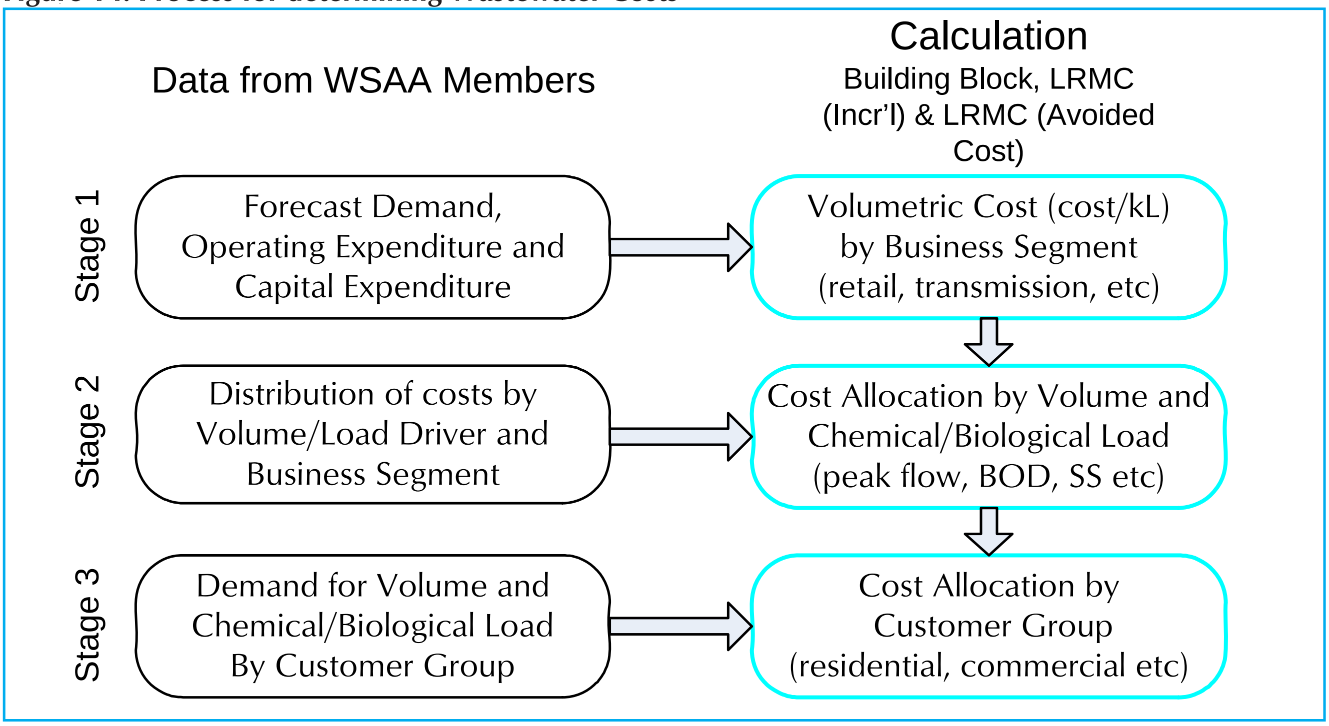
The results were determined through a three stage process, illustrated in Figure 14.

In consultation with WSAA members, the information from actual wastewater schemes was synthesised to reflect the six case studies identified in Section 3.5. Demand, operating and capital cost information was provided for periods ranging from 10 - 50 years and extrapolated for a total of 100 years. Operating and capital cost estimates were separately identified by business segment (i.e. retail, transmission, treatment, disposal and recycling).

For **Stage 1**, the volumetric cost by business segment was determined by comparing total costs (Building Block, LRMC or Avoided Cost) for each segment by against the total volume of wastewater treated (see Appendix D for calculation details). The volumetric cost calculation is intended to provide a coarse guide to the relative cost of each scheme. We discuss the methodology behind the volumetric cost calculation in Section 4.1 below and consider some of the limitations of relying solely on volumetric cost for comparison purposes in Section 4.3.

For **Stage 2**, the costs of each business segment were allocated by volume and chemical/biological load driver. The matrix required to allocate business segment costs by driver was discussed in detail in Section 3.3.3. The matrix applied in this exercise was developed through expert engineering assessment and assumes that the existing chemical and biological composition of wastewater will remain approximately the same over time. Based on the limitations of data availability, we have assumed that the matrix represents not only an appropriate method of allocating existing costs, but also an appropriate means of allocating future expenditure.

Figure 14: Process for determining Wastewater Costs



For calculating LRMC, a more accurate method of determining the impact of various cost drivers would be to analyse the marginal capital and operating cost associated with an increment and decrement for each load driver. For example, it may be possible to determine the additional cost associated only with a 10% increase in BOD. When determining the LRMC of individual chemical/biological load drivers, it will also be important to recognise the interactions between the various drivers and their combined impact on cost.

The result of the second stage of the analysis is a cost per unit derived for each cost driver, i.e.:

- a cost per kilolitre for volume-related costs and “other” costs;
- a cost per kilolitre per day for costs related to peak volume; and
- a cost per kilogram for costs related to BOD and SS.

These results are aggregated for each scheme to derive a total breakdown of costs by driver.

Finally, **Stage 3** of the analysis combines the usage information for each customer group (by volume and chemical/biological load) with the unit costs derived in Stage 2 to derive costs for each scheme and each customer group. The results are aggregated to provide a total breakdown of costs by customer group.

A methodological review and sample audit was conducted by Mr Paul Webber, a principal of Wedgwood White, Auckland. Mr Webber recently assisted IPART to develop their case studies and cost modelling for the *Investigation into Water and Wastewater Service Provision in the Greater Sydney Region*.

We first consider the Stage 1 methodology in more detail, and then discuss the results of each Stage in turn.

4.1 Stage 1: Volumetric Cost Calculation

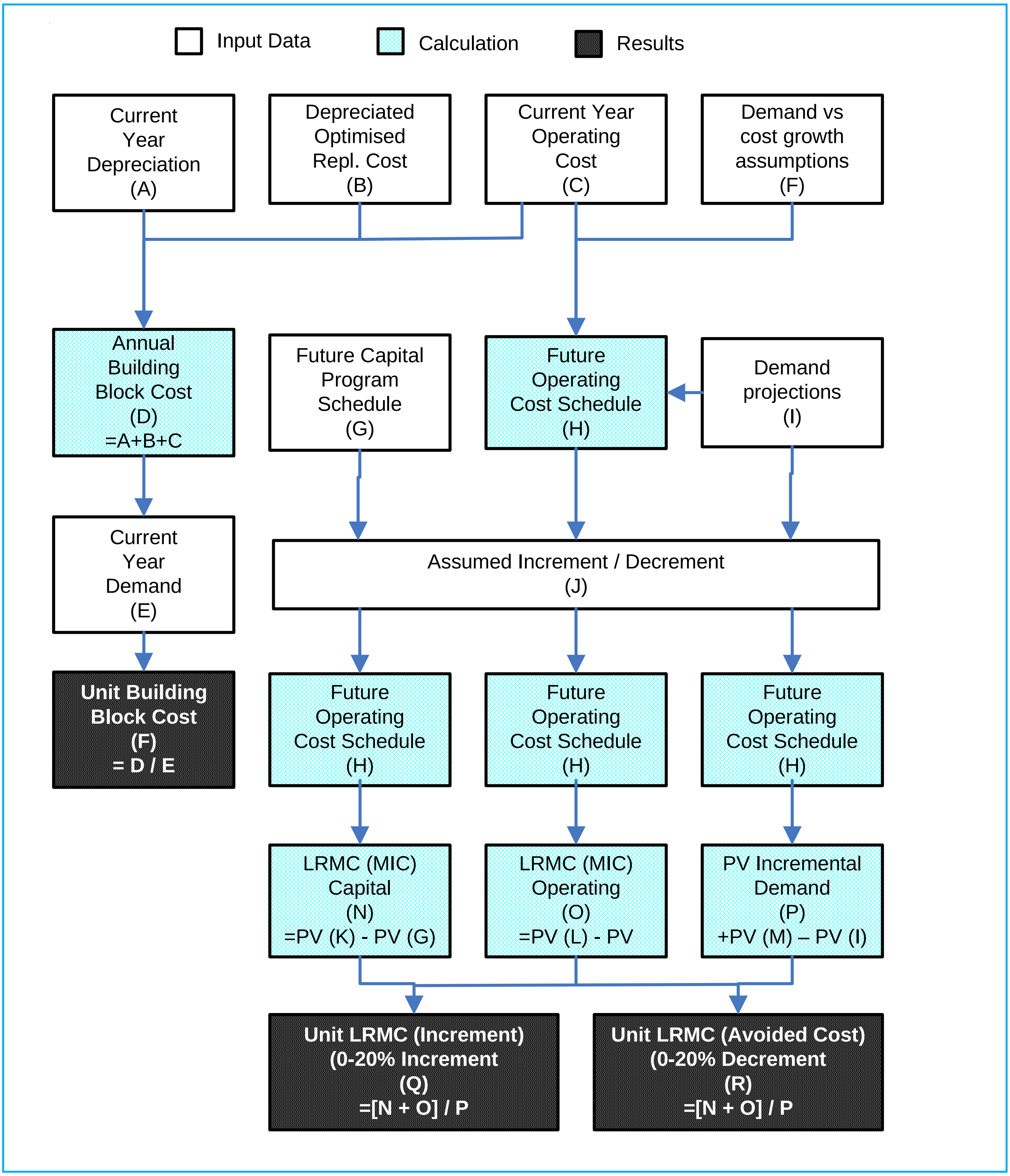
The volumetric cost calculation represents the *total cost* (including costs related to chemical or nutrient concentration) divided by the *total volume of wastewater treated*. The process for developing the volumetric cost estimates (i.e. cost per kilolitre) for each of the three costing methodologies is illustrated in Figure 15 overleaf.

As illustrated in Figure 15, the base information for the case study analysis included:

- LRMC (Incremental) and LRMC (Avoided Cost) calculation:
  - current year operating expenditure;
  - forecast demand schedule;
  - assumptions regarding the relative increase in operating cost compared with increases in demand. For this study, the following assumptions were adopted:
    - electricity and chemicals costs increase in direct proportion to volume;
    - maintenance cost growth relates to capital expenditure;
    - support costs increase at 33% of the rate of growth of demand (e.g. if demand increases by 3%, support costs increase by 1%)
  - future capital program.
- Building Block calculation:
  - current year Optimised Replacement Cost Depreciation;
  - Depreciated Optimised Replacement Cost;
  - current year operating expenditure;
  - current year demand.

Case Study Results
continued

Figure 15: Process to Develop Case Study Cost Estimates



The data was collected through a series of meetings and correspondence with WSAA member utilities. Additional information was also gained from other WSAA members to assist in "synthesising" the necessary case studies and to verify order of magnitude costs.

The information required to calculate Building Block costs (current year operating, depreciation and depreciated optimised replacement cost) was found to be readily accessible and clearly categorised by location and business segment (i.e. transmission, treatment and disposal). The primary shortfall of information related to long run costs (i.e. cost projections for 20 years or longer). MJA understands that this is not uncommon in the Australian water industry. Forward planning typically identifies costs with relative reliability over five years, with less reliable planning stretching to 10 years. For periods longer than 10 years, projections of the cost of long term water source solutions (and in many cases the water source planning itself) is limited. Accordingly, the MJA team relied on extrapolations of capital expenditure data beyond the tenth year, based on the assumption that the unit rate of capital spending (i.e. capital expenditure per megalitre) in the first ten years would be approximately equivalent to the unit rate in later years. It is likely that this assumption underestimates the magnitude of long term costs, as the least expensive wastewater treatment and disposal methods (the "low hanging fruit") will have been pursued in the earlier years.

The results have been modelled for each of the six case studies in accordance with the Building Block methodology and Marginal Increment/Decremental Cost approach to LRMC outlined in Chapter 2. The incremental LRMC was calculated as the average MIC for all increments from 0% to 20% of the 2026 forecast demand. The range of 0% to 20% was chosen to reflect a plausible range of demand increments for a wastewater service provider with no precise knowledge about potential increments in customer demand.

The long run "avoided costs" were calculated as the average MIC for all decrements from 0% to 20% of the 2026 forecast demand, for all business segments other than transmission. For illustrative purposes, the avoided cost scenario reflects an access regime in which one or more third parties seek access to an incumbent's transmission system in order to supply retail, treatment and disposal services to existing customers. The range of 0% to 20% was chosen to reflect a plausible range of demand decrements, assuming that the incumbent has no precise knowledge about the total number of customers that would be serviced by third parties in the future.

In practice, the use of a simple averaging process on a range as large as 0-20% may prove to be of little value. If the expected demand increment or decrement is well understood, or if multiple discrete results are meaningful, then a narrower range may be more appropriate. In this case, regression or other mathematical forms of analysis may be appropriate to "smooth" the relatively uneven series of results.

Each of the calculation methods is worked through in detail for the "ModOcean" case study in Appendix E. Results for each case study are provided in Appendix D, with a summary of results below.

4.2 Stage 1 Results: Cost Breakdown by Business Segment

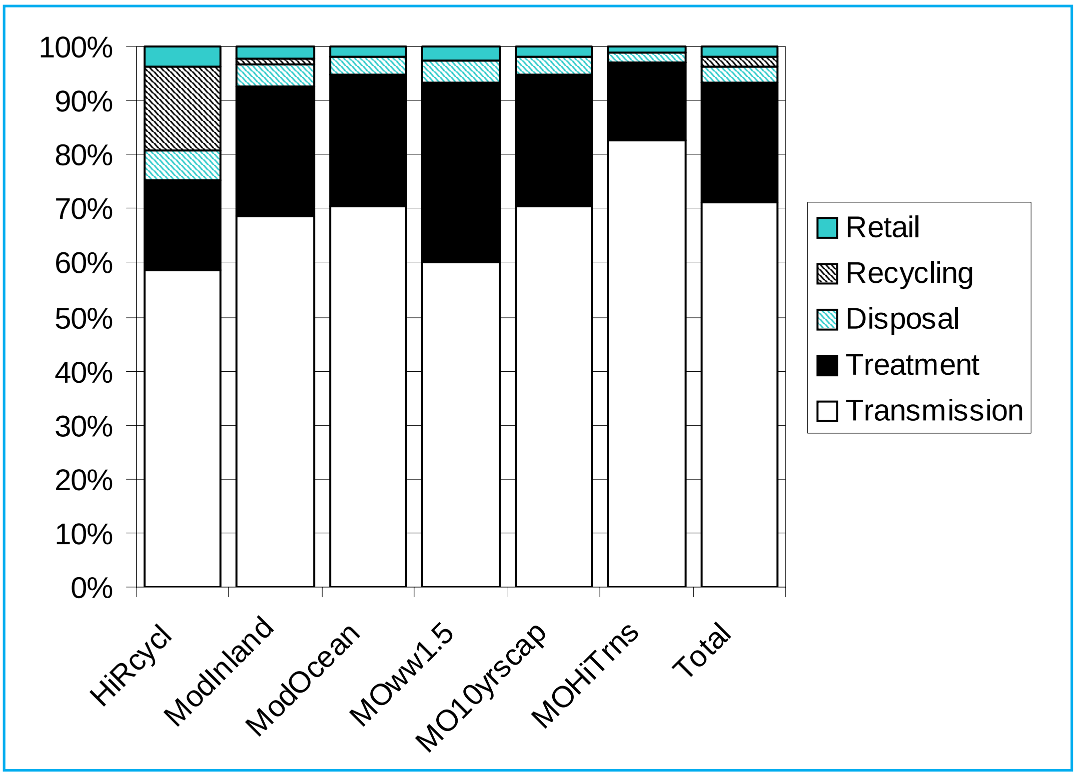
The cost of existing assets in all of the case studies was dominated by the cost of transmission. This is a common trait of water and wastewater supply systems. By contrast, treatment and disposal costs represent between 22% and 37% of the total cost. Retail customer management represents a relatively small component of overall cost, as does recycling (other than Location 1).

As noted earlier, the Building Block Cost is based on the Depreciated Optimised Replacement Cost (DORC – see Section 2.5) value of assets. Therefore, the Building Block cost for the scheme with 10 years worth of growth capacity ("MO10yrscap") is similar to schemes with limited capacity (in particular the "ModOcean" case study) because the DORC methodology excludes unutilised capacity.

The costs breakdown for each scheme is shown in Figure 16.

Case Study Results
continued

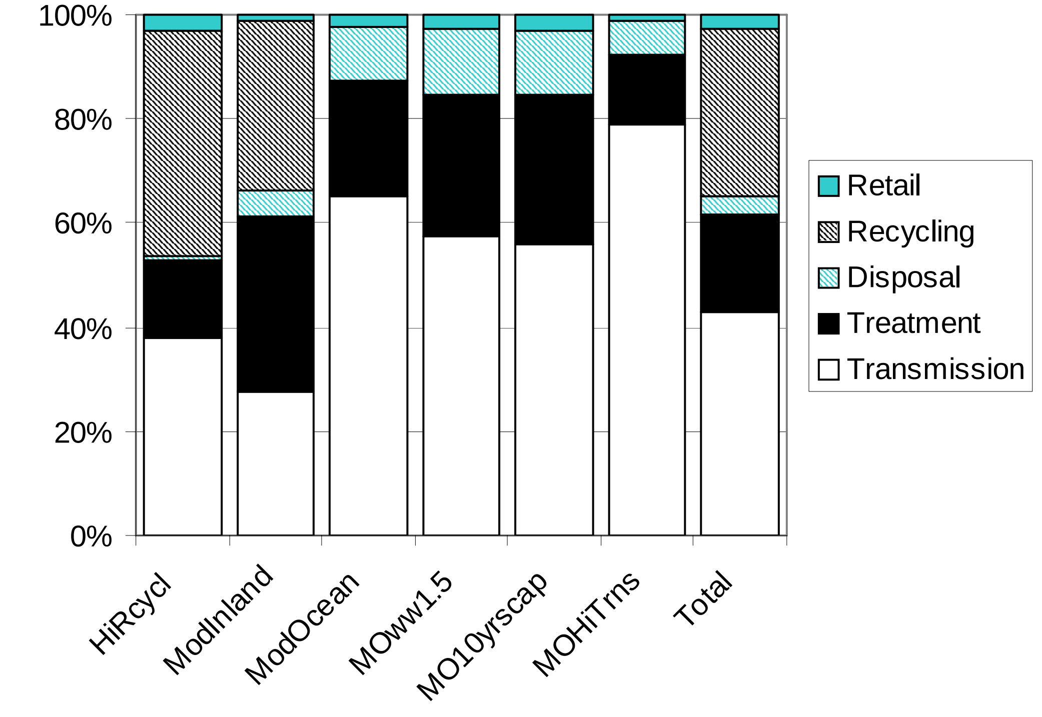
Figure 16: Building Block Cost by Business Segment



As is shown in the LRMC chart (Figure 17), *future* costs show a quite different story. Across Australia, increasing regulatory standards and public expectations are substantially increasing the cost of wastewater treatment and disposal. Of the six modelled schemes, the fastest growing scheme ("HiRcycl") relies primarily on recycling for treatment and disposal. The capital expenditure on recycling for this scheme represents almost a third of the entire capital budget for the six schemes combined, of which approximately half is accounted for by dual pipes and recycled water transmission assets and the other half represents additional treatment requirements.[16] In addition to the large expenditure on recycling, the figure below also demonstrates the continuing high proportion of wastewater transmission costs in non-recycling schemes.

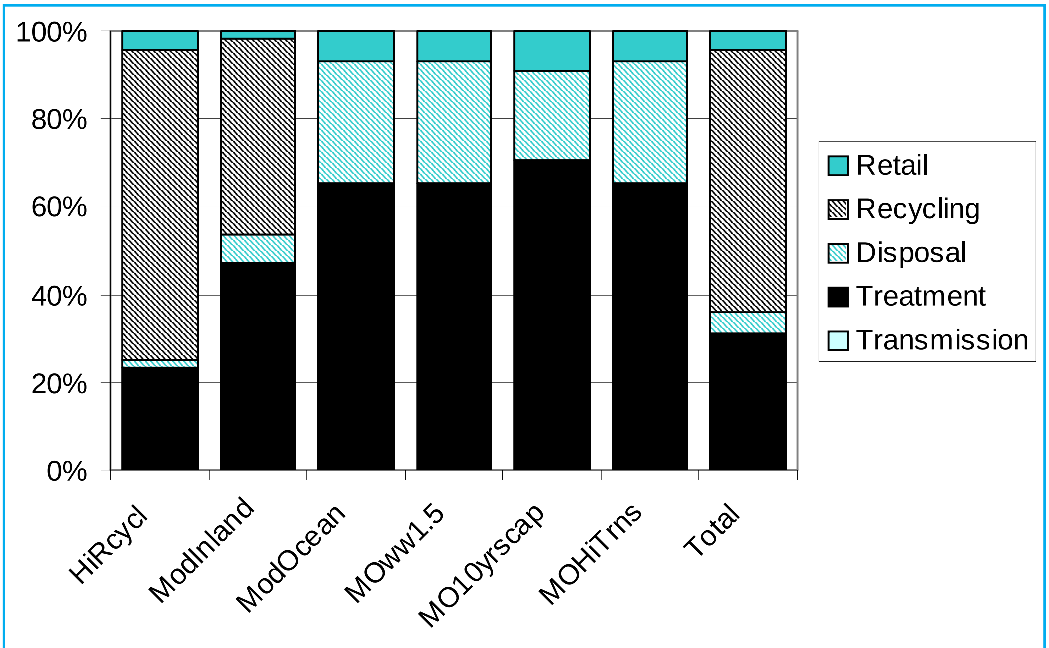
[16] Note that recycled water transmission assets are included under "Recycling" in each of the figures in this and subsequent sections.

Figure 17: LRMC by Business Segment



The Avoided Cost chart (Figure 18) shows a similar story, except that it has been assumed that transmission costs are not avoidable and therefore do not appear in the cost breakdown. Wastewater treatment and recycling costs therefore dominate the avoided cost calculation.

Figure 18: Avoided Cost* by Business Segment



* Note: Avoided Cost case studies assume that transmission costs are unavoidable. Recycled water transmission costs are assumed to be avoidable and are included under "Recycling".

Case Study Results
continued

4.3 Stage 1 Results: Total Volumetric Costs

On a purely volumetric basis, the locational results vary from $0.40/kL to $13.10/kL as shown below:

Table 14: Volumetric Cost by Scheme and Cost Methodology

Scheme	Description	LRMC (Increment) $/kL	LRMC (Avoided*) $/kL	Building Block $/kL
ModOcean	Mod Growth, ocean disposal	1.67	0.53	2.62
MOLoWW	Mod Growth, low PWWF	1.38	0.54	1.95
MO10yrscap	Mod Growth, growth capacity	1.18	0.40	2.62
MOHiTrans	Mod Growth, long transmission distances	2.75	0.53	4.46
MOInland	Mod growth, inland disposal, some recycling	6.86	4.30	4.53
HiRcycl	High growth, recycling	10.18	7.06	13.1
All		**4.81**	**2.87**	**4.24**

* Note: Avoided Cost case studies assume that transmission costs are unavoidable

The results reflect the incremental, avoided or existing cost (respectively) for each case study divided by the existing, incremental or decremental volume treated. This gives a coarse understanding of the relative cost of each scheme. The variation between schemes is substantial. The unit costs for the last two schemes are higher than the remainder, in part, as they are the smallest of the schemes and do not benefit from the same economies of scale.

The costs for the high growth recycling scheme are substantially higher than the cost of all other schemes, even when the cost of recycling is excluded. The high cost is in part due to the small size of the scheme – initially the scheme has only 10% of the flow of the ocean disposal case studies. Furthermore, interpreting results on a purely volumetric basis can be misleading. Key issues with regard to the "HiRecycl" scheme include:

- the unit cost results do *not* account for savings in the water system. As an indicative estimate, IPART have estimated LRMC of potable water as between $1.20/kL and $1.50/kL.[17] The Economic Regulation Authority in WA initially estimated the LRMC of water in Perth as between 72c/kL and $1.11/kL[18]. In addition, transmission system costs could also potentially be reduced due to the lower volumes of potable water required;
- the "HiRecycl" scheme will employ community education and technology to substantially reduce the volume of water use and 'smart sewers' to reduce sewer infiltration, both of which will lower the volume of wastewater requiring treatment (thereby reducing the denominator of the unit cost calculation); and
- residential recycling requires significant investment in early years, particularly to lay the third pipe network. By comparison, conventional wastewater treatment and disposal can be upgraded in a more modular fashion.

The results demonstrate that the existing average costs are higher than future marginal costs for all schemes other than "ModInland". This implies that under a cost reflective pricing system (noting the strict incompatibility of the different costing methods), it would be anticipated that costs would reduce over time. The LRMC for "ModInland" is higher than the average cost due to

[17] IPART, '*Prices of Water Supply, Wastewater and Stormwater Services: Final Determination and Report*', June 2005, p. 21

[18] Economic Regulatory Authority (2005) *Final Report on the Inquiry into the Cost of Supplying Bulk Potable Water to Kalgoorlie-Boulder*, p. 57.

substantial transmission system upgrades planned over coming years. This network upgrade is required due to the increasing pressure on the existing, inadequate pipe network and the need for new infrastructure to cater for planned recycling measures. The high cost of treatment is typical for inland wastewater schemes, which tend to have more stringent environmental and health regulation governing discharge.

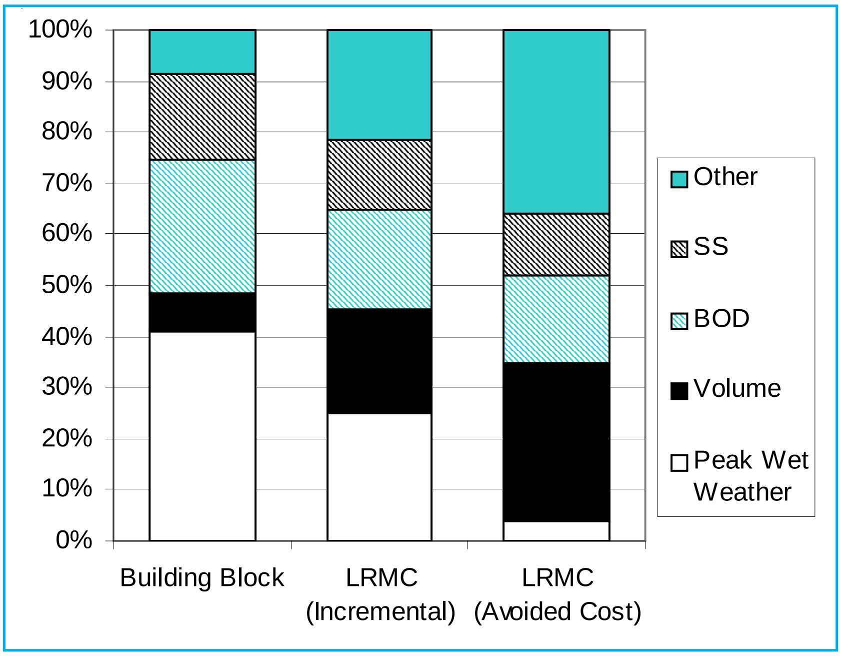
The "HiRecycl" scheme has a lesser impact on the average Building Block cost than it has on the LRMC and Avoided cost. This results from the substantial growth expected in that scheme. While initially a relatively small scheme, the "HiRecycl" scheme represents a significant proportion of wastewater customers over the longer term. This explains the apparent anomaly in the results, where the combined system cost is *higher* for LRMC than for Building Block costs, despite the fact that the Building Block costs are *lower* than LRMC for five out of the six case studies (including "HiRecycl" itself). Put in another way, the high cost of the recycled water scheme has a greater impact on LRMC than on Building Block costs because of the significant growth in the number of customers and therefore the higher weighting in the LRMC combined scheme calculation.

The avoided cost result is substantially lower than LRMC in all cases because transmission costs have been excluded. The avoided costs of the recycling scheme and inland disposal scheme remain significant, even with transmission costs excluded. The avoided cost of "Mod10yrscap" has an avoided cost of around 40c/kL treated, even with significant spare capacity in the existing system. An analysis of the underlying costs shows that 40% of avoided costs relate to capital expenditure on treatment plant and disposal upgrades. In the "Mod10yrscap" case study, the capital expenditure is not required for more than ten years, but the present value cost of capital deferral remains a significant factor. Around 30% of the avoided cost is the result of both short and long-term savings in day-to-day treatment plant costs such as energy, chemicals and materials.

4.4 Stage 2 Results: Breakdown by Cost Driver

The three costing methodologies were also segregated by individual cost driver to give a more precisely defined cost breakdown. The net contribution of each cost driver to final cost allocations is shown in Appendix F and summarised in Figure 19.

Figure 19: Contribution to Total Cost by Cost Driver



Note: Avoided Cost case studies assume that transmission costs are unavoidable

Case Study Results
continued

Almost 40% of existing costs in the Building Block method are driven by wet weather flows. The large impact of wet weather flows reflects the large proportion of transmission assets and the fact that the Building Block methodology calculates cost on the basis of the proportion of use rather than the marginal cost of augmentation (see footnote[19] for more detail). Note that the proportion of Building Block costs attributed to peak wet weather flows does not represent the costs that could be avoided if infiltration were reduced to zero - reducing wet weather infiltration to zero would avoid less than 5% of total cost (see Avoided Cost).

The annual volume discharged accounts for relatively little of the overall Building Block cost. BOD and SS combined account for more than 40% of existing costs due to their impact on wastewater treatment and transmission pipelines.

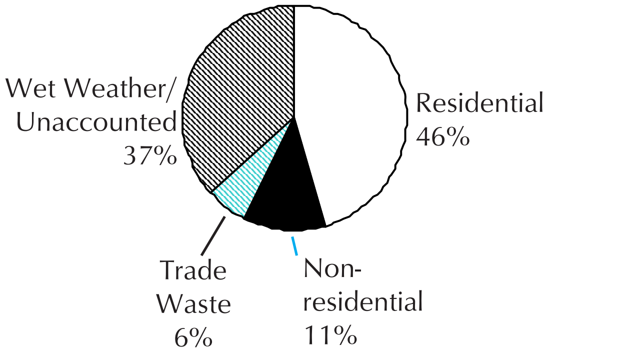
The costs are more evenly distributed when the incremental LRMC method is applied. The increased impact of volume and "other" reflects the high degree to which water recycling features in the future capital program. The "other" category partly consists of pathogen removal for recycling. Annual volume plays a more prominent role in the LRMC analysis as the water recycling network has been assumed to remove only a baseload of waste from the treatment plant. This assumes that some capacity is available to overflow from the secondary treatment plant into the ocean discharges of the remaining schemes during peak wet weather events.

The long run avoided cost results show a similar story, but wet weather flows play a further reduced role as transmission assets are assumed to be unavoidable or sunk costs.

4.5 Stage 3 Results: Breakdown by Customer Group

The contribution to existing costs based on the Building Block method is shown in Figure 20.

Figure 20: Contribution to Building Block Cost by Customer Group



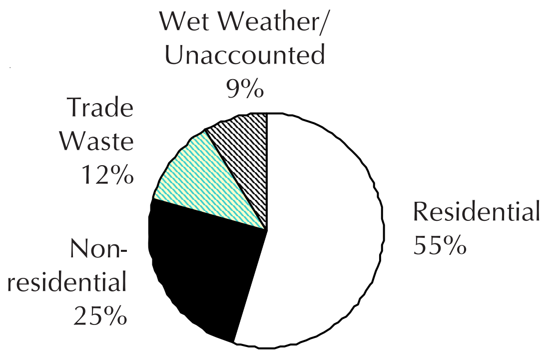
Almost half of existing costs are attributable to residential customers under the Building Block method. Interestingly, the next largest contributor (around 34%) is wet weather flows and unaccounted for water. Unaccounted for water represents the difference between actual discharge and chemical/biological load factors as measured at the treatment plant and estimates of demand using estimated load parameters for each customer. Unlike water, residential and commercial wastewater discharge is not measured directly and therefore the margin for error is significant. The unaccounted for wastewater also takes into account infiltration during wet weather events. The two are not separable without baseline data for dry weather unaccounted for water, which was not available for this study. Wet weather inflow events are likely to account for most of the wet weather/unaccounted result as almost 70% of the capacity of sewer mains in all schemes (other than "ModLoWWF") is designed to cater for wet weather inflows.

[19] The Building Block model distributes the cost of the pipe network in direct proportion to peak flow. The costs attributed to the peak wet weather flow reflect the increase in flow caused by wet weather divided by total flow, i.e. [wet weather flow minus dry weather flow] / [wet weather flow]. By contract, the marginal cost methodologies calculate the *marginal* cost of augmenting the network to accommodate wet weather flows. The marginal cost of augmenting pipe networks is relatively low because of the high fixed costs of pipe trenching and laying.

Estimates of the contribution of customer groups to LRMC (see Figure 21 below) demonstrates that wet weather events will account for a significantly lower proportion of future costs due to the increasing cost of treatment compared with transmission assets. This also results in a growing impact of Commercial and Trade Waste customers as the removal of BOD, SS, nitrogen, pathogens and other chemical/biological load factors become an increasing emphasis of future capital programs.

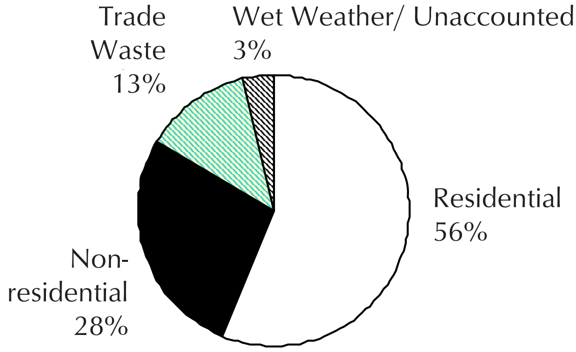
The contribution of wet weather flows is also significantly reduced because of the LRMC methodology. LRMC measures the change in costs caused by a change in demand (in this case wastewater flows). As outlined in Section 2.4, the marginal cost of increasing transmission capacity does not increase proportionately with the increase in peak flow. The cost of mains with a diameter greater than 300mm are estimated to increase at only 45% of the rate of the increase in flow. The non-linear nature of pipeline cost increases and the increasing emphasis on treatment rather than transmission combine to explain the relatively low value of 9% for the impact of wet weather flows and unaccounted water on LRMC.

Figure 21: Contribution to Long Run Marginal Cost by Customer Group



As the primary impact of wet weather flows is the transmission system, any reduction in flow events would have relatively little impact on avoidable costs, as the transmission system has been assumed to be a "sunk" cost. The contribution of each customer group to avoidable cost reflects this, as shown in Figure 22.

Figure 22: Contribution to Avoidable Cost* by Customer Group



* Note: Avoided Cost case studies assume that transmission costs are unavoidable

Case Study Results
continued

4.6 Stage 3 Results: Cost for Selected Customer Groups

Table 15 shows the annual cost of supplying selected customers. These are representative customer groups with "typical" characteristics. They are not an exhaustive list of customers, but are included to demonstrate the impact of each costing methodology and the variation between locations.

The Building Block cost to each customer reflects the theoretical "upper bound" of prices to customers. If prices to a particular customer group are higher than the Building Block cost, regulators may perceive the service provider to be overcharging because an efficient competitor could duplicate the system for a lower cost. In practice, the price at which customers would seek to by-pass the system is typically much higher than the Building Block cost.

If the regulator has determined a Regulated Asset Value below the "upper bound", prices will accordingly be lower than the costs shown in Table 15.

Table 15: Cost of Servicing selected customer groups

Wastewater characteristics

Cost Driver	Typical household	Restaurant	Beverage manufacturer	Hospital
Peak Day	0.56 kL/day	1.60 kL/day	240 kL/day	36 kL/day
Volume	205.86 kL	480 kL	87,600 kL	13,140 kL
BOD	51.47 kg	624 kg	183,960 kg	6,570 kg
SS	51.47 kg	317 kg	14,016 kg	1,314 kg

Case Study Results
continued

Table 15 (continued): Cost of Servicing Selected Customer Groups

Cost to a typical household ($ pa)

Scheme	Description	LRMC	Avoided Cost*	Building Block
ModOcean	Mod Growth, ocean disposal	221	93	327
MOLoWW	Mod Growth, low PWWF	236	98	329
MO10yrscap	Mod Growth, spare capacity	159	71	327
MOHiTrans	Mod Growth, long transmission distances	751	548	551
MOInland	Mod growth, inland disposal, some recycling	1,113	787	581
HiRcycl	High growth, recycling	1,644	1,374	1,886

Cost to a typical restaurant ($ pa)

Scheme	Description	LRMC	Avoided Cost*	Building Block
ModOcean	Mod Growth, ocean disposal	1,591	687	2,375
MOLoWW	Mod Growth, low PWWF	1,507	703	2,091
MO10yrscap	Mod Growth, spare capacity	1,164	536	2,375
MOHiTrans	Mod Growth, long transmission distances	1,591	687	2,375
MOInland	Mod growth, inland disposal, some recycling	5,958	3,936	4,109
HiRcycl	High growth, recycling	7,845	5,434	11,440

Cost to a typical beverage manufacturer ($ pa)

Scheme	Description	LRMC	Avoided Cost*	Building Block
ModOcean	Mod Growth, ocean disposal	372,569	164,521	554,225
MOLoWW	Mod Growth, low PWWF	344,185	166,966	475,354
MO10yrscap	Mod Growth, spare capacity	273,918	130,538	554,225
MOHiTrans	Mod Growth, long transmission distances	372,569	164,521	554,225
MOInland	Mod growth, inland disposal, some recycling	1,319,622	863,791	955,928
HiRcycl	High growth, recycling	1,722,539	1,154,739	2,625,297

Cost to a typical hospital ($ pa)

Scheme	Description	LRMC	Avoided Cost*	Building Block
ModOcean	Mod Growth, ocean disposal	18,167	7,778	26,858
MOLoWW	Mod Growth, low PWWF	18,608	8,100	25,864
MO10yrscap	Mod Growth, spare capacity	13,178	6,059	26,858
MOHiTrans	Mod Growth, long transmission distances	18,167	7,778	26,858
MOInland	Mod growth, inland disposal, some recycling	82,409	57,262	47,269
HiRcycl	High growth, recycling	119,250	95,543	146,782

* Note: Avoided Cost case studies assume that transmission costs are unavoidable

5. Conclusions

Identification and understanding of the cost of wastewater services by location and by business segment conveys important information for decision making regarding business performance, project evaluation and pricing. Cost analysis can take many forms and the most appropriate method of analysis will be determined by the intended application of the results and the precise question asked. For example, backward-looking costs may be used to evaluate the past performance of a business while forward-looking costs might be used to evaluate potential new business opportunities.

The Long Run Marginal Cost methodology is widely applied for volumetric pricing by economic regulators across Australia and internationally. LRMC recognises the fact that sunk costs cannot be varied by customer behaviour and calculates the cost associated with an increase or decrease in demand for a particular product or service. Long run costs may be determined with regard to the cost of servicing all new demand, or only the cost associated with a particular increment or decrement of demand (the long run marginal costs avoided by a decrement in demand are commonly referred to simply as 'avoided costs'). The appropriate method will depend on the purpose of the analysis. Under the Marginal Incremental/Decremental Cost approach, the LRMC can be extremely volatile depending on the exact choice of increment or decrement. The high variance in results demonstrates the importance of choosing policy relevant increments or decrements when calculating LRMC and, where demand estimates are uncertain, indicates that results should be considered across a range of volumes rather than relying on a single point estimate.

A second important cost concept for the water industry is described by the Building Block approach, which typically reflects the cost of replacing the existing system with the most recent technology and design techniques. The Building Block approach is commonly applied in revenue determinations by economic regulators, because price based on long run marginal cost would be insufficient to achieve full cost recovery over time. Economic theory suggests that the volumetric element of the tariff should reflect the marginal cost of supply, while the fixed annual charge should recover the residual revenue required to ensure overall revenue adequacy. In order to achieve full cost recovery and encourage further investment in the industry, the total revenue for the organization must recoup all efficient costs over time, including the cost of both past and future investments.

The most apparent lesson from the case study analysis is that the cost of wastewater systems across Australia are highly relative to the location and the particular circumstances of the service provider and the receiving environment. The case studies examined in this report demonstrate substantial variations in both locational costs and costs distributed amongst business segments (i.e. retail, transmission, treatment, disposal and recycling). The high variability of results between locations demonstrates the potential susceptibility of wastewater schemes to inefficient "cherry picking" if third party access to infrastructure is granted and uniform pricing policies or regulations are maintained. Regulators of access regimes must therefore be cognisant of the difference in costs between locations to avoid granting a windfall benefit to new entrants that may purchase access at a low price and on-sell the service at a higher uniform price.

The results also demonstrate the potential for significant under-recovery of past investments (represented by the Building Block cost) if access prices are based on LRMC alone. Various strategies can be employed to adjust prices to either the third party access applicant or the customer to compensate for these pricing issues. Incumbent water utilities within jurisdictions that are developing access regimes would benefit from a firm understanding of the costs of each system element and the translation of these costs into a comprehensive pricing framework. The current study outlines cost results for six specific case studies, however each organisation will face a unique set of costs and cost drivers. To assist the industry, further research could be undertaken to improve the understanding of cost functions that relate to the major drivers of cost (e.g. the relationship between the capacity of a wastewater treatment plant and the cost).

Conclusions
continued

The case study results confirm the traditionally held view that wastewater transmission costs form the most substantial part of a wastewater service provider's existing asset base. The long transmission distances modelled for one of the case studies had the highest impact on cost compared with all other drivers examined, with the exception of the method of disposal (both LRMC and Building Block costs increased by around 70% when transmission lengths were doubled).

Peak wet weather flows were also shown to substantially impact the cost of service provision (reducing costs by around 20-25%). An issue not addressed by the cost allocation procedure was the responsibility of third party service providers to treat wet weather flows. The potentially large wet weather volumes are not generated by customers and therefore disputes about allocation of wet weather flows may arise in "typical" access arrangement situations (i.e. where a third party provides both retail and treatment services but not transmission). Incumbents may claim that the third party should accept the infiltration associated with their infrastructure, while third parties may argue that the system is not optimally designed and therefore that the responsibility of infiltration should remain with the incumbent. The resolution of these issues will be a significant point of negotiation.

The case studies clearly illustrate the comparatively high growth in wastewater treatment costs and in particular water recycling costs. The rapid increase in water recycling costs will put significant upward pressure on absolute wastewater treatment and disposal costs in the future, which may be at least partly offset by a reduction in the cost of, or need for, new potable water sources.

Retail customer service costs (such as billing and meter reading) were found to be a very small component of total costs. This result appears contradictory to the view that competition for retail customer services will play an important role in promoting competition in the water and wastewater industry. The relatively small proportion of costs represented by retail customer services may, however, understate the importance of market entry by third party retailers. In the longer term, retail service providers may bolster their trust and credibility with customers through this apparently small "foot in the door" in order to eventually compete for infrastructure services. Furthermore, it is possible that retail functions such as call centres and meter reading could be aggregated across a number of utilities to increase the overall scale and scope of services.

Finally, with increasing economic regulation and the possibility of access challenges, utilities can expect increasing pressure to develop robust estimates of long run cost, in addition to the impact of incremental or decremental variations in demand. As evidenced by preliminary requests from the ESC, it can be expected that regulators will require utilities to conduct long run incremental analysis of load variables (i.e. the change in cost resulting from a specific change in volume or load concentration) for the calculation of trade waste and other forms of wastewater pricing. The development of long run costs and a reliable source development schedule is not only pertinent to pricing, but also to the analysis of water source options and prudent long term planning.

Appendix A: International Experience

LRMC cost concepts are used within the water, aviation and energy sectors. In the aviation sector, for example, LRMC may be used to set the price of access. As in the water industry the cost structures in aviation suffer from lumpiness and natural monopoly characteristics. As in water, there comes a point when increases in capacity can only be addressed by a major project i.e. some facilities simply cannot be expanded incrementally by their very nature (another whole runway or tunnel or road is required).

In the following we review practical experiences in the water sector. Our survey of the literature of the use of LRMC pricing in the water sector yielded few practical and complete examples of the use of LRMC. The most recent and transparent experience is Ofwat in the UK, however, LRMC costing has also been promoted by the Canadian Water Waste Water Authority and the World Bank through projects in developing countries.

Ofwat

In 2001 Ofwat published a series of reports under the heading “The role of Long Run Marginal Costs in the Provision and Regulation of Water Services”. The aim of these reports were to explain views on the relevance of LRMC in water service provision and in regulatory policy, publish and comment on existing estimates of LRMC, explain how greater consistency in the estimation of LRMC could be promoted, and consult on proposals for the future scope and format of LRMC submissions.

Table 16 shows the LRMC estimates provided by different water companies in the UK.

Separate estimates of LRMC are made by increment: ‘resources’, ‘treatment’, ‘bulk transport’ and ‘local distribution’. The sum of these increment costs yield the total LRMC.

Key observations that can be drawn from the Ofwat assessment include:

- variations in the LRMC occur as a result of varying prices per m^3 of water for water abstraction, treatment, and transport and distribution, depending upon local circumstances;
- LRMC include costs of provision of additional resources that might involve a variety of different schemes ranging from new boreholes, increased abstractions, or winter storage mechanisms; and
- distribution costs are included since additional distribution costs might be involved for new sources of supply.

Ofwat does not view the LRMC estimation as a standardised calculation. However, water companies are required to make explicit their assumptions, and present a thorough analysis that is demonstrably consistent with the company’s Water Resource Plan. Thus, Ofwat seeks to foster consistency in the approach to estimating LRMC and in the level of analysis.

Ofwat does not strongly recommend a specific approach to calculating LRMC. In particular it notes:[20]

> *“Companies should clearly specify the methodology used for calculating LRMC (average incremental cost or perturbation approach). It is preferable for companies to include analysis based on both approaches, which is likely to be based on similar underlying investments.”*

[20] Ofwat (2001) *The Role of Long Run Marginal Costs in the Provision of Water Services*, p. 60

Appendix A: International Experience
continued

Table 16: LRMC by company and area (increment)[21]

Water company	Resources	treatment	bulk transport	local distribution	Total LRMC
	p/m^3	p/m^3	p/m^3	p/m^3	p/m^3
Water and sewerage companies					
Anglian					
Anglian	16	12	15	1	45
Hartlepool	n/a	n/a	n/a	n/a	13-27
Dwr Cymru	n/a	n/a	n/a	n/a	47
Northumbrian*					
Northumbrian	11	5	28	13	58
Essex	n/a	n/a	n/a	12	56
Suffolk	65	0	0	20	86
Severn Trent	13	15	15	15	58
South West	22	21	n/a	7	49
Southern	n/a	n/a	n/a	n/a	37
Thames	42	3	2	1	49
United Utilities	20	5	11	12	49
Wessex	12	12	25	75	125
Yorkshire					
Yorkshire	25	0	0	2	27
York	0	10	13	4	27
Water only companies					
Bournemouth & West Hampshire	17	9	0	26	53
Bristol	14	2	0	0	16
Cambridge	40	4	0	9	54
Dee Valley	10	19	0	25	54
Folkstone & Dover	36	3	19	0	58
Mid Kent	0	95	25	0	120
Portsmouth	3	0	1	5	9
South East					
Northern	16	9	11	23	60
Southern	24	45	30	23	123
S. Staffordshire	9	6	16	11	41
Sutton & E. Surrey	39	0	n/a	25	64
Tendering Hundred	33	7	0	9	48
Three Valleys					
Three Valleys	8	14	13	0	35
North Surrey	34	28	24	4	n/a

Source: Ofwat "Tariff structure and charges 2002 – 2003 report", Table 26, p. 65.

Available at: http://www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/AttachmentsByTitle/of_trf99.pdf/$File/of_trf99.pdf

[21] Total LRMC figures may not add up due to rounding.

Appendix A: International Experience
continued

However, most, although not all, companies in the UK have adopted the AIC approach. The AIC approach requires consideration of the relationship between future costs and volume growth. However, it is necessary to separate out changes in future costs that are independent of volume growth. Water company studies of LRMC submitted to Ofwat suggest variation in terms of cost inclusions and exclusions in the AIC approach, in particular on issues dealing with metering, leakage, security of supply, and demand management.

Ofwat's view on these issues are summarised as follows:

***Metering*:** A number of LRMC submissions did not clarify whether metering costs have been included. The Ofwat view is that metering influences demand, the demand reduction associated with metering may be treated as a substitute for development of new resources and treatment facilities. For this reason, the costs associated with metering should be included in LRMC;

***Leakage*:** Leakage reduction forms a significant part of many companies' least cost investment schedules, by making more treated water available to customers and therefore constitutes a direct substitute for development of new resources and treatment works. On this basis, Ofwat believes that costs associated with reducing leakages, in present and future periods, should be reflected in companies' LRMC estimates.

***Security of supply*:** The majority of the LRMC submissions did not clarify the purpose of an intended individual scheme (i.e. whether it is for security of supply or growth). According to Ofwat, the cost of restoring security of supply and the output of such schemes should generally be excluded from estimates of LRMC based on the AIC approach. This is because these are future costs that must be borne regardless of growth in demand. Ofwat note, however, that it may be appropriate in some circumstances be appropriate to consider the costs of restoring security of supply as avoidable, for example if demand were to fall and in this case present an alternative calculation based on the costs of security of supply schemes.

***Demand management*:** Where water companies choose demand management measures as part of their least cost supply-demand balance program, these costs should be included in the calculation of LRMC. This is particularly appropriate where demand management defers the need for major resource investments.

Ofwat has provided guidance on which costs should be included and which costs should be excluded, to ensure standardisation of LRMC estimates. Indeed as noted by Ofwat:[22]

> *"Most companies have provided estimates of LRMC, with a breakdown of the components of their estimate. However, company submissions have contained varying levels of supporting analysis and explanation. In many cases it has been difficult to reconcile company submissions with water resource plans, underlying scheme details or companies' analyses of leakage economics. Many submissions do not clarify the methodology for deriving the least cost investment plan, or the nature of the alternative basis for the LRMC calculation. Sensitivity analyses have also not been presented by many companies."*

A key conclusion that can be drawn from the Ofwat experience is the importance *ex ante* to provide guidelines on the key inputs and assumptions when requiring water companies to engage in a LRMC exercise.

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[22] Ofwat (2001), p. 55.

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Canadian Water and Wastewater Authority

The Canadian Water and Wastewater Authority (CWWA) published a Rate Manual in 1993, the *Municipal Water and Wastewater Rate Manual.* This Manual sets out the Canadian approach to rate setting. It discusses the methods and theory underlying the logic and process of charge setting and comes with a fully documented charge software model (a spreadsheet to develop retail charges on a simple two-part tariff, featuring a volumetric charge and a fixed charge that varies by meter size).

The CWWA approach to charge setting is based on three principal goals: full cost recovery, the equitable distribution of costs among customers and the efficient use of both water resources and financial resources. In this respect the CWWA promotes a two part rate structure featuring a constant volumetric charge plus a meter charges that vary by size of service. The volumetric charge is based on LRMC and calculated using a AIC methodology. The cost model includes an option for peak load pricing where marginal capacity cost is allocated to the summer charges.

The World Bank

In 1977, the World Bank investigated alternative concepts of marginal costs for application in the water supply sector.[23] To our knowledge, this is the first attempt to consistently discuss different approaches to LRMC in the water sector.

The conclusions reached by the World Bank staff are:

It is not possible to establish a set of precise marginal cost estimation rules that can be followed in all circumstances; and

compromises are required that will depend on:

the degree of capital indivisibility;

the elasticities of demand; and

prices which currently prevail.

While the authors do not recommend one particular approach, they do conclude that:[24]

> *"It is when capital indivisibility enters the picture that [LR]AIC can become more appropriate, for then compromises must be reached between the need to avoid price fluctuations, the need to signal justification of investment, and the need to make best use of existing capacity."*

Indeed, the long run AIC is now a well recognised concept within the World Bank and frequently used in water supply projects.

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[23] Saunders, R. J., Warford, J.J., Mann, P.C., *Alternative Concepts of Marginal Cost for Public Utility Pricing: Problems of Application in the Water Supply Sector*, World Bank Staff Working Paper No 259, 1977.

[24] Ofwat (2001), p. 54.

Appendix B: Building Block Methodologies

Various methodologies for representing the total cost of an existing scheme, often referred to as "Building Block" methodologies, have been employed for different purposes in the water industry. The method for calculating Building Block costs may include:

1. Historic Cost Depreciation + ROA[25] on Written Down Historic Cost + Operating Costs
2. Replacement Cost Depreciation + ROA on Written Down Replacement Cost + Operating Cost
3. Optimised RC Depreciation + ROA on DORC[26] + Operating Cost.
4. Depreciation (Historic, Replacement, or Optimised) + Smoothed ROA + Operating Cost
5. Renewals annuity + ROA on initial investment + Operating Cost
6. Depreciation based on RAV[27] + ROA on RAV + Operating Cost

We briefly discuss their key features and uses:

Historic Cost Depreciation, ROA on Written Down Historic Cost, Operating Cost

Key features include:

- Rarely used in the industry today
- Considered to have poor intergenerational equity as it does not recognise the impact of inflation
- Retrospectively returns purchase cost of the asset, relatively risk free
- Diminishes over time as asset value reduces

Replacement Cost Depreciation, ROA on Written Down Replacement Cost, Operating Cost

Key features include:

- Commonly used in the industry
- Includes obsolete assets or over-designed capacity
- Retrospectively returns purchase cost of the asset, relatively risk free
- Diminishes over time as asset value reduces

Optimised RC Depreciation, ROA on DORC, Operating Cost

Key features include:

- Commonly used in the industry
- Excludes obsolete assets and over-designed capacity
- May return less than the original purchase cost of the asset. Higher risk may require a higher return or inclusion of obsolescence estimate.
- Diminishes over time as asset value reduces

Depreciation (Historic, Replacement, or Optimised), Smoothed ROA, Operating Cost

Key features include:

- Rarely used in the industry
- Advantages and disadvantages as under Historic, Replacement or Optimised methods above
- Smooths cost over time

Renewals annuity, ROA on initial investment, Operating Cost

Key features include:

- Still relatively uncommon in Australia
- Difficult to determine accurately
- May over or under-recover unless
- "Smooths" costing over time

Depreciation based on RAV + ROA on RAV + Operating Cost

Key features include:

- Commonly used by Australian economic regulators
- Adjusts the asset value for 'line in the sand' regulatory or government decisions, including the avoidance of price shocks
- Will return less than the original purchase cost of the asset on a present value basis
- Diminishes over time as asset value reduces

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25 Return on Assets (ROA). Historic cost formulae require the use of a nominal ROA, while replacement cost methods require an inflation adjusted or real ROA.

26 Depreciated Optimised Replacement Cost

27 Regulated Asset Value

Appendix C: Ofwat Special Factors

The table below shows the Special Factors allowed for price variations by the UK economic regulator (Ofwat). The table illustrates the diversity of factors that can influence wastewater costs.

Table 17: Ofwat Special Factors

Operating expenditure	Number of companies
Water resources (including bulk supplies)	9
Water quality	2
Water treatment	6
Leakage	4
High level of meter penetration	5
Sewage treatment and sludge	3
Location	0
Regional salaries and construction costs	8
Regional power costs	4
Debt	5
Coastal sewage treatment works	2
Traffic congestion	2
Burst rate	2
Location (other)	2
Welsh language obligations	1
Size and number of assets (including rurality)	3
Company size (small companies)	2
Accounting for depreciation	1
Impact of large industrial customers on the econometric models	2
Total operating expenditure	**63**

Capital maintenance expenditure	Number of companies
Shared water resources	1
Water treatment	1
Tight ammonia discharge consent	1
Number of meter replacements	1
High seasonal tourist population	1
Regional price adjustment	9
Impact of reservoir safety	1
Impact of coal mining	1
Company size (small companies)	2
M6 toll road	1
Total capital maintenance expenditure	**19**

Source : Ofwat (2005) *Water and sewerage service unit costs and relative efficiency 2003-04 report,* January, p. 59.

Appendix D: Detailed Results

Building Block ($'000 pa)

Case Study	(A1) WDRC	(B1) Op	(C1) Dep	(D1) ROA = (A1) * 6%	(E1) Total Cost = (B1) + (C1) +(D1)	(F1) Vol ML (existing)	(G1) Cost/kL = (E1) / (F1)
HiRecycl	41,640	6,252	1,617	2,498	10,367	792	13.10
ModInland	96,786	5,409	3,412	5,807	14,628	3,231	4.53
ModOcean	141,495	6,037	5,089	8,490	19,615	7,487	2.62
MOLoWW	96,502	6,037	2,785	5,790	14,612	7,487	1.95
MO10yrscap	141,495	6,037	5,089	8,490	19,615	7,487	2.62
MOHiTrans	234,696	9,465	9,861	14,082	33,408	7,487	4.46
	517,919	29,771	17,991	31,075	78,837	26,484	2.98

LRMC ($'000 PV) - notional 20% increment

Case Study	(A2) LRMC Capital ($'000 NPV)	(B2) LRMC Opex ($'000 NPV) = (E4) x 20%	(C2) LRMC Total ($'000 NPV) = (A2) +(B2)	(D2) Incr Vol MLs (PV 50 yrs) = (I4) x 20%	(E2) Capex/kL = (A2) / (D2)	(F2) Opex/kL = (B2) / (D2)	(G2) Total Cost/kL = (C2) / (D2)
HiRecycl	69,309	30,218	99,527	9,775	7.09	3.09	10.18
ModInland	16,912	3,101	20,013	2,916	5.80	1.06	6.86
ModOcean	4,539	3,435	7,974	4,764	0.95	0.72	1.67
MOLoWW	3,152	3,435	6,586	4,764	0.66	0.72	1.38
MO10yrscap	3,637	1,979	5,616	4,764	0.76	0.42	1.18
MOHiTrans	7,414	5,702	13,116	4,764	1.56	1.20	2.75
	97,549	42,168	139,717	26,984	2.31	0.30	5.18

Avoided Cost ($'000 PV) - notional 20% decrement

Case Study	(A3) Avoided Capital ($'000 NPV)	(B3) Avoided Opex ($'000 NPV)	(C3) Avoided Total ($'000 NPV) = (A3) +(B3)	(D3) Decr Vol MLs (PV 50 yrs) = (I4) x 20%	(E3) Capex/kL = (A3) / (D3)	(F3) Opex/kL = (B3) / (D3)	(G3) Total Cost/kL = (C3) / (D3)
HiRecycl	51,590	17,446	69,036	9,775	5.28	1.78	7.06
ModInland	11,341	1,203	12,543	2,916	3.89	0.41	4.30
ModOcean	1,374	1,168	2,542	4,764	0.29	0.25	0.53
MOLoWW	1,382	1,168	2,550	4,764	0.29	0.25	0.54
MO10yrscap	731	1,168	1,899	4,764	0.15	0.25	0.40
MOHiTrans	1,367	1,168	2,534	4,764	0.29	0.25	0.53
	66,418	22,152	88,570	26,984	3.00	0.25	3.28

Appendix E: Case Study "ModOcean" Worked Example

The following calculation illustrates the stages required to calculate the LRMC (Increment), the LRMC (Avoided Cost) and the Building Block costs for the "ModOcean" case study. A similar approach was applied for each of the six case studies identified in this report.

Long Run Marginal Cost - Increment

Table 18 shows a worked example of the LRMC (MIC) calculation for a 200GL increment above expected ("baseline") usage. The calculation is for illustrative purposes only. The final calculation of LRMC (MIC) averages every LRMC (MIC) result in from 50 GL to 1,900 GL (in 50 GL increments). This range represents increments of between 0.5% and 19.8% of the year 20 demand of 9,578 GL. For the purposes of this study, this is the range within which demand increments are expected to occur.

Table 18: LRMC for 200 GL Increment

Year	Original Demand ($demand_1$)	"Trigger" Demand (note 1)	Demand +200GL ($demand_2$)	Original Capital Expenditure ($capex_1$)	Adjusted Capital Expenditure ($capex_2$)	Original Opex ($opex_1$)	Adjusted Opex ($opex_2$)
2006	Base Year	Base Year	Base Year	Base Year	Base Year	Base Year	Base Year
2007	7,641	7,564	7,841	1,074	4,668	6,156	6,300
2008	7,796	7,718	7,996	3,594	6,913	6,273	6,417
2009	7,950	7,873	8,150	6,913	2,774	6,389	6,533
2010	8,104	8,027	8,304	2,774	1,273	6,504	6,648
2011	8,259	8,181	8,459	340	1,642	6,617	6,761
2012	8,335	8,297	8,535	933	1,427	6,674	6,818
2013	8,412	8,374	8,612	821	1,282	6,730	6,874
2014	8,489	8,451	8,689	821	1,282	6,786	6,930
2015	8,566	8,527	8,766	1,427	1,282	6,842	6,986
2016	8,642	8,604	8,842	1,282	1,282	6,898	7,042
2017	8,719	8,681	8,919	1,282	1,282	6,953	7,097
2018	8,796	8,758	8,996	1,282	1,844	7,008	7,152
2019	8,873	8,834	9,073	1,282	-	7,062	7,207
2020	8,949	8,911	9,149	1,282	1,844	7,117	7,261
….	….	….	….	….	….	….	….
Present Value (100 yrs)	156,143		159,278	32,541	35,787	124,411	126,671

Note 1: Case studies use a "Trigger" demand rather than the "Original" demand to determine the timing of capital and operating costs. Ideally the "trigger" point would be determined by the engineering capacity of relevant infrastructure. For this study, the "trigger" point for new infrastructure costs is assumed to be the mid-point of the current year and previous year demand.

The long run marginal cost of an increment of 200 GL is therefore:

$$LRMC^{MIC} = \frac{PV(Change\_in\_cost)}{PV(Change\_in\_demand)}$$

$$= \frac{PV(Capex_2) - PV(Capex_1) + PV(Opex_2) - PV(Opex_1)}{PV(demand_2) - PV(demand_1)}$$

Appendix E: Case Study “ModOcean” Worked Example

continued

$$= \frac{35{,}787 - 32{,}541 + 126{,}671 - 124{,}411}{159{,}278 - 156{,}143}$$

$$= \frac{5{,}506}{3{,}135} = \$1.76/kL$$

As noted, this is an illustrative result only. The case study analysis applied this calculation to every increment between 0 and 20% to determine an average incremental LRMC over the whole range. The results for each increment are shown in Table 19.

Table 19: LRMC Results for “ModOcean” case by increment

Increment (GL)	Increment (%)	Capital Cost/kL	Operating Cost/kL	Total Cost/kL	Comment
50	0.5%	0.47	0.72	1.19	
100	1.0%	1.07	0.72	1.79	
150	1.6%	0.94	0.72	1.66	
200	2.1%	1.04	0.72	1.76	+200 GL increment used for worked example (above
250	2.6%	0.99	0.72	1.71	
300	3.1%	1.05	0.72	1.77	
350	3.7%	0.99	0.72	1.71	
400	4.2%	1.02	0.72	1.74	
450	4.7%	0.97	0.72	1.69	
500	5.2%	1.00	0.72	1.72	
550	5.7%	0.96	0.72	1.68	
600	6.3%	0.93	0.72	1.66	
650	6.8%	0.94	0.72	1.66	
700	7.3%	0.93	0.72	1.65	
750	7.8%	0.97	0.72	1.69	
800	8.4%	0.93	0.72	1.65	
850	8.9%	0.96	0.72	1.68	
900	9.4%	0.95	0.72	1.67	
950	9.9%	0.96	0.72	1.68	
1000	10.4%	0.95	0.72	1.67	
1050	11.0%	0.97	0.72	1.69	
1100	11.5%	0.95	0.72	1.67	
1150	12.0%	0.94	0.72	1.66	
1200	12.5%	0.96	0.72	1.68	
1250	13.1%	0.94	0.72	1.67	
1300	13.6%	0.96	0.72	1.68	
1350	14.1%	0.95	0.72	1.67	
1400	14.6%	0.96	0.72	1.68	
1450	15.1%	0.95	0.72	1.67	
1500	15.7%	0.96	0.72	1.68	
1550	16.2%	0.95	0.72	1.67	
1600	16.7%	0.96	0.72	1.69	
1650	17.2%	0.95	0.72	1.68	
1700	17.7%	0.95	0.72	1.67	
1750	18.3%	0.96	0.72	1.68	
1800	18.8%	0.95	0.72	1.67	
1850	19.3%	0.96	0.72	1.68	
1900	19.8%	0.95	0.72	1.67	
Simple average, all increments 0-20%		0.95	0.72	1.67	Average incremental cost for all increments 0-20%

Appendix E: Case Study "ModOcean" Worked Example *continued*

As illustrated in Table 19, the long run capital cost is highly variable for small increments, but relatively stable for large increments. This is a function of the assumptions used to forecast growth expenditure. For large increments of demand that were beyond the current planning horizon, increases in capacity were assumed to occur at a cost equal to the average cost of capacity for the first 10 years (i.e. within the current planning horizon). Similarly, unit incremental operating costs were assumed to be the same for all increments or decrements of demand. In practice, infrastructure capital and operating costs beyond the current planning horizon are likely to more expensive than current planned infrastructure as utilities take advantage of "low hanging fruit" and undertake the least expensive infrastructure upgrades first.

The LRMC cost using the Marginal Incremental/ Decremental Cost approach for increments between 0% and 20% is an average of $1.67/kL.

Long Run Marginal Cost – Decrement (Avoided Cost)

Table 20 shows a worked example of the long run avoided cost (MIC) calculation for a 200GL decrement below expected ("baseline") usage, where transmission costs are assumed to be unavoidable. The calculation is for illustrative purposes only. The final calculation of LRMC (MIC) averages every LRMC (MIC) result in from -50 GL to -1,900 GL (in 50 GL increments). This range represents decrements of between 0.5% and 19.8% of the year 20 demand of 9,578 GL.

Table 20: LRMC for 200 GL Decrement

Year	Original Demand ($demand_1$)	"Trigger" Demand (note 1)	Demand -200GL ($demand_2$)	Original Capital Expenditure excl transm'n ($capex_1$)	Adjusted Capital Expenditure excl transm'n ($capex_2$)	Original Opex excl transm'n ($opex_1$)	Adjusted Opex excl transm'n ($opex_2$)
2006	Base Year	Base Year	Base Year	Base Year	Base Year	Base Year	Base Year
2007	7,641	7,564	7,441	382	-	2,645	2,596
2008	7,796	7,718	7,596	1,277	382	2,682	2,633
2009	7,950	7,873	7,750	2,456	1,277	2,719	2,670
2010	8,104	8,027	7,904	986	2,456	2,756	2,707
2011	8,259	8,181	8,059	121	986	2,793	2,744
2012	8,335	8,297	8,135	331	-	2,812	2,763
2013	8,412	8,374	8,212	292	121	2,831	2,782
2014	8,489	8,451	8,289	292	-	2,851	2,802
2015	8,566	8,527	8,366	507	331	2,870	2,821
2016	8,642	8,604	8,442	456	292	2,889	2,840
2017	8,719	8,681	8,519	456	292	2,909	2,860
2018	8,796	8,758	8,596	456	507	2,928	2,879
2019	8,873	8,834	8,673	456	456	2,947	2,898
2020	8,949	8,911	8,749	456	456	2,966	2,917
….	….	….	….	….	….	….	….
Present Value (100	156,143		153,007	11,562	10,517	51,764	50,996

Note 1: Case studies use a "Trigger" demand rather than the "Original" demand to determine the timing of capital and operating costs. Ideally the "trigger" point would be determined by the engineering capacity of relevant infrastructure. For this study, the "trigger" point for new infrastructure costs is assumed to be the mid-point of the current year and previous year demand.

The long run avoided cost associated with a demand decrement of 200 GL (for all business segments other than transmission) is therefore:

$$LRMC^{MIC} = \frac{PV(Change\_in\_cost)}{PV(Change\_in\_demand)}$$

Appendix E: Case Study "ModOcean" Worked Example
continued

$$= \frac{PV(Capex_2) - PV(Capex_1) + PV(Opex_2) - PV(Opex_1)}{PV(demand_2) - PV(demand_1)}$$

$$= \frac{10{,}517 - 11{,}562 + 50{,}996 - 51{,}764}{153{,}007 - 156{,}143}$$

$$= \frac{-1{,}813}{-3{,}135}$$

= \$0.58/kL

As noted, this is an illustrative result only. The case study analysis applied this calculation to every decrement between 0 and 20% to determine an average long run avoided cost over the whole range. The results for each increment are shown in Table 21.

Table 21: LRMC Results for "ModOcean" case by Decrement

Decrement (GL)	Decrement (%)	Capital Cost/kL	Operating Cost/kL	Total Cost/kL	Comment
-50	-0.5%	0.16	0.25	0.40	
-100	-1.0%	0.37	0.25	0.62	
-150	-1.6%	0.32	0.25	0.56	
-200	-2.1%	0.33	0.25	0.58	-200 GL decrement used for worked example (above)
-250	-2.6%	0.33	0.25	0.57	
-300	-3.1%	0.33	0.25	0.58	
-350	-3.7%	0.31	0.25	0.56	
-400	-4.2%	0.34	0.25	0.58	
-450	-4.7%	0.31	0.25	0.56	
-500	-5.2%	0.33	0.25	0.57	
-550	-5.7%	0.32	0.25	0.57	
-600	-6.3%	0.30	0.25	0.55	
-650	-6.8%	0.32	0.25	0.56	
-700	-7.3%	0.31	0.25	0.56	
-750	-7.8%	0.31	0.25	0.55	
-800	-8.4%	0.31	0.25	0.55	
-850	-8.9%	0.31	0.25	0.56	
-900	-9.4%	0.30	0.25	0.54	
-950	-9.9%	0.30	0.25	0.55	
-1000	-10.4%	0.30	0.25	0.54	
-1050	-11.0%	0.30	0.25	0.54	
-1100	-11.5%	0.29	0.25	0.54	
-1150	-12.0%	0.28	0.25	0.53	
-1200	-12.5%	0.28	0.25	0.53	
-1250	-13.1%	0.28	0.25	0.52	
-1300	-13.6%	0.28	0.25	0.52	
-1350	-14.1%	0.27	0.25	0.52	
-1400	-14.6%	0.27	0.25	0.51	
-1450	-15.1%	0.26	0.25	0.51	
-1500	-15.7%	0.26	0.25	0.51	
-1550	-16.2%	0.26	0.25	0.50	
-1600	-16.7%	0.26	0.25	0.50	
-1650	-17.2%	0.25	0.25	0.50	
-1700	-17.7%	0.25	0.25	0.49	
-1750	-18.3%	0.24	0.25	0.49	
-1800	-18.8%	0.24	0.25	0.49	
-1850	-19.3%	0.24	0.25	0.48	
-1900	-19.8%	0.23	0.25	0.48	
Simple average, all decrements 0-20%		0.288	0.245	0.53	Average decremental cost for all increments 0-20%

Appendix E: Case Study "ModOcean" Worked Example *continued*

The long run avoided cost using the LRMC Marginal Incremental/Decremental Cost approach for decrements between 0% and 20% (for all segments other than transmission) is an average of $0.53/kL.

Building Block Cost

The Building Block approach calculates total annual cost as:

Annual operating and maintenance expenditure (including support costs)

plus Optimised Replacement Cost Depreciation

plus A Return on the Depreciated Optimised Replacement Cost equal to the Weighted Average Cost of Capital

The Building Block cost for the "ModOcean" case study is shown in Table 22.

Table 22: Building Block Cost for "ModOcean"

		($'000 pa)
(A1) Depreciated Optimised Replacement Cost		141,495
(B1) Current year operating expenditure		6,037
(C1) Optimised Replacement Cost Depreciation		5,089
(D1) ROA	= (A1) * 6%	8,490
(E1) Total Cost	= (B1) + (C1) +(D1)	19,615
(F1) Volume (ML) - current year		7,487
(G1) Cost/kL	**= (E1) / (F1)**	**2.62**

Results

The result of the three cost calculations for the "ModOcean" case study (as shown in Table 14 of the main document) are summarised as follows:

Scheme	LRMC (Increment) $/kL	LRMC (Avoided) $/kL	Building Block $/kL
ModOcean	1.67	0.53	2.62

Appendix F: Results Disaggregated by Scheme and Load

The cost of each scheme disaggregated into cost drivers is shown in the tables 23 to 25.

Table 23: Long Run Marginal Cost By Scheme and Load

Scheme	Peak	Volume	BOD	SS
ModOcean	$44.89 /kL day	$0.29 /kL	$1.76 /kg	$0.89 /kg
MOLoWWF	$106.82 /kL day	$0.28 /kL	$1.54 /kg	$0.76 /kg
MO10yrscap	$29.81 /kL day	$0.20 /kL	$1.30 /kg	$0.65 /kg
MoHiTrans	$44.89 /kL day	$0.29 /kL	$1.76 /kg	$0.89 /kg
ModInland	$99.71 /kL day	$2.99 /kL	$5.38 /kg	$3.18 /kg
HiRecycl	$162.45 /kL day	$5.03 /kL	$6.48 /kg	$3.54 /kg
Total	$98.32 /kL day	$2.00 /kL	$3.58 /kg	$1.93 /kg

Table 24: Avoided Cost* By Scheme and Load*

Scheme	Peak	Volume	BOD	SS
ModOcean	$3.55 /kL day	$0.15 /kL	$0.79 /kg	$0.37 /kg
MOLoWWF	$11.89 /kL day	$0.15 /kL	$0.79 /kg	$0.37 /kg
MO10yrscap	$2.07 /kL day	$0.11 /kL	$0.63 /kg	$0.26 /kg
MoHiTrans	$3.55 /kL day	$0.15 /kL	$0.79 /kg	$0.37 /kg
ModInland	$22.51 /kL day	$2.41 /kL	$3.36 /kg	$2.03 /kg
HiRecycl	$13.72 /kL day	$5.22 /kL	$3.62 /kg	$2.05 /kg
Total	$9.16 /kL day	$1.91 /kL	$1.87 /kg	$1.02 /kg

Note: Avoided Cost case studies assume that transmission costs are unavoidable

Table 25: Building Block Allocation By Scheme and Load

Scheme	Peak	Volume	BOD	SS
ModOcean	$79.26 /kL day	$0.38 /kL	$2.63 /kg	$1.35 /kg
MOLoWWF	$166.64 /kL day	$0.35 /kL	$2.12 /kg	$1.06 /kg
MO10yrscap	$79.26 /kL day	$0.38 /kL	$2.63 /kg	$1.35 /kg
MoHiTrans	$79.26 /kL day	$0.38 /kL	$2.63 /kg	$1.35 /kg
ModInland	$130.23 /kL day	$0.77 /kL	$4.49 /kg	$2.32 /kg
HiRecycl	$295.30 /kL day	$4.01 /kL	$11.53 /kg	$5.83 /kg
Total	$158.32 /kL day	$0.68 /kL	$4.14 /kg	$2.13 /kg

Appendix G: Determining Volume and Load Distribution for "ModOcean"

1. LRMC (See Appendix D)

(A) LRMC Capital (0-20% increment)	0.95	/kL
(B) LRMC Operating (0-20% increment)	0.72	/kL

2. Business Segment Breakdown

	PV Capital "Base Case" (C1)	PV Operating "Base Case" (C2)	PV Capital % (D1)	PV Operating % (D2)	Cap LRMC (E1) = (D1) x (A)	Op LRMC (E2) = (D2) x (A)
Transmission	18,578	11,336	64%	66%	0.61	0.48
Treatment (Non-recycling)	5,069	4,920	18%	29%	0.17	0.21
Disposal	5,170	53	18%	0%	0.17	0.00
Treatment (Recycling)	-	-	0%	0%	0.00	0.00
Retail	-	865	0%	5%	0.00	0.04
TOTAL	28,817	17,174	100%	100%	0.95	0.72

Note: PV "Base Case" is a proxy only. Segment breakdown for 0-20% increment unavailable.

3. Volume and Chemical/Biological Load breakdown

CAPITAL

	Peak Day (F1)	Annual Vol (F2)	BOD (F3)	SS (F4)	Other (F5)	TOTAL (F6)	Peak Day (G1) =(E1)x(F1)	Annual Vol (G1) =(E1)x(F2)	BOD (G1) =(E1)x(F3)	SS (G1) =(E1)x(F4)	Other (G1) =(E1)x(F5)	TOTAL (G1) =(E1)x(F6)
Transmission	60%	0%	20%	15%	5%	100%	0.37	0.00	0.12	0.09	0.03	0.61
Treatment (Non-recycling)	15%	13%	31%	26%	15%	100%	0.03	0.02	0.05	0.04	0.03	0.17
Disposal	15%	13%	31%	26%	15%	100%	0.03	0.02	0.05	0.04	0.03	0.17
Treatment (Recycling)	0%	45%	5%	5%	45%	100%	0.00	0.00	0.00	0.00	0.00	0.00
Retail	0%	0%	0%	0%	100%	100%	0.00	0.00	0.00	0.00	0.00	0.00
							0.42	0.04	0.23	0.18	0.08	0.95

OPERATING

	Peak Day (H1)	Annual Volum (H2)	BOD (H3)	SS (H4)	Other (H5)	TOTAL (H6)	Peak Day (I1) =(E2)x(H1)	Annual Vol (I2) =(E2)x(H2)	BOD (I3) =(E2)x(H3)	SS (I4) =(E2)x(H4)	Other (I5) =(E2)x(H5)	TOTAL (I6) =(E2)x(H6)
Transmission	40%	20%	25%	15%	0%	100%	0.19	0.10	0.12	0.07	0.00	0.48
Treatment (Non-recycling)	3%	6%	58%	24%	10%	100%	0.01	0.01	0.12	0.05	0.02	0.21
Disposal	3%	6%	58%	24%	10%	100%	0.00	0.00	0.00	0.00	0.00	0.00
Treatment (Recycling)	0%	45%	5%	5%	45%	100%	0.00	0.00	0.00	0.00	0.00	0.00
Retail	0%	0%	0%	0%	100%	100%	0.00	0.00	0.00	0.00	0.04	0.04
							0.20	0.11	0.24	0.12	0.06	0.72

TOTAL

	Peak Day (I1) =(G1)+(I1)	Annual Vol (I2) =(G2)+(I2)	BOD (I3) =(G3)+(I3)	SS (I4) =(G4)+(I4)	Other (I5) =(G5)+(I5)	TOTAL (I6) =(G6)+(I6)	Business Segment %
Transmission	0.56	0.10	0.24	0.16	0.03	1.09	65%
Treatment (Non-recycling)	0.03	0.03	0.17	0.09	0.05	0.37	22%
Disposal	0.03	0.02	0.05	0.04	0.03	0.17	10%
Treatment (Recycling)	0.00	0.00	0.00	0.00	0.00	0.00	0%
Retail	0.00	0.00	0.00	0.00	0.04	0.04	2%
	0.61	0.15	0.47	0.30	0.14	1.67	100%
Volume and Chemical/Biological Load %	37%	9%	28%	18%	8%	100%	

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