30 April 2008

Dr Michael Keating AC
Chairman
The Independent Pricing and Regulatory Tribunal of NSW
Level 8, 1 Market Street
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Dear Dr Keating

Review of prices for Sydney Water Corporation’s services
Supplementary Submission

In our submission to the Tribunal dated 18 April, we made extensive reference to a paper entitled “Assessment of IPART’s estimate of Long Run Marginal Cost for Sydney Water” which we had commissioned from NERA. The paper gives an exposition on the application and calculation of Long Run Marginal Cost (LRMC) with particular reference to the Tribunal’s review of Sydney Water pricing. The paper also reports the results of calculations performed by NERA and includes two indicative ranges for the LRMC of supply to Sydney Water. These are $1.73 to $3.11/kL ($2007-08) using the Average Incremental Cost (AIC) method, and $2.14 to $2.30/kL using the preferred Turvey perturbation approach.

NERA’s calculations were based on an extension of the simplified assumptions adopted by the Tribunal in its calculation of LRMC. In particular, NERA assumed that all growth in demand over the period of the analysis will be met by successive 250ML/d increments in desalination capacity with costs as assumed by the Tribunal in its calculation.

Since we made our submission, an error has been detected in the spreadsheet that NERA used to perform the calculations reported in their paper. NERA and Alinta have advised the Tribunal’s secretariat of this discovery and NERA have now revised their calculations. They have also undertaken further analysis of the Turvey method as it applies to the calculation of LRMC for Sydney Water. This work is presented in the attached revised paper from NERA which replaces the previous version.

NERA confirm that the Turvey method is theoretically superior to the AIC method and that to make a reliable estimate of LRMC by either method, a rigorous analysis of demand growth and least cost supply options should be undertaken. NERA’s additional analysis shows that, in the present case where the calculation is based on an extension of the Tribunal’s simplified assumptions, results for the Turvey method are particularly sensitive to the key assumptions namely, the timing and magnitude of the assumed demand perturbation, and the capacity and cost of the future increments of desalination capacity. As a result of this analysis, NERA conclude that:

- a rigorous study of the forward capital program necessary to equate demand and supply should be undertaken to allow the Turvey approach to be applied to estimate LRMC. In the
absence of such a detailed study, the Turvey approach is likely to produce unreliable estimates given its sensitivity to the assumptions used;

- the AIC method is a simplification of the Turvey approach where detailed information is unavailable, and will provide the best indication of the range of LRMC in the circumstances; and
- the corrected indicative range for the LRMC applying the AIC approach is $1.84 to $3.36/kL.

Our conclusions in relation to LRMC and hence the level at which the usage (variable) charge for potable water should be set, remain essentially unchanged from those in our submission of 18 April. The value of LRMC calculated by the Tribunal ($1.90/kL in $2007-08) is close to the lower end of the indicative range for LRMC and there is a reasonable likelihood that the Tribunal’s estimate of LRMC and the usage charge proposed by the Tribunal are below the true LRMC and therefore inefficient. The usage charge should be higher than that proposed by the Tribunal in the draft determination – somewhere towards the middle of the range $1.84 to $3.36/kL would be appropriate. As a point of reference, a price of $2.40/kL, which is at the middle of the third quartile of that range, would be consistent with estimates of the actual average cost of water to be produced from the Kurnell facility.

Higher, rather than lower, consumption charges for potable water will provide an environment where:

- supply-side alternatives such as recycling will be more attractive both for investors and consumers so that those alternatives will be more likely to reach their full potential with lower levels of subsidy;
- consumers will be better able to control their water bills; and
- relaxation of restrictions can and should be considered.

In our initial submission we recommended that the Tribunal adopt different values for several variables in the WACC calculation. We also note that the Tribunal proposes to base its final determination of WACC on values of market variables as they are at that time. Given that LRMC is a function of WACC, the value of LRMC should be recalculated so that it is consistent with the WACC that the Tribunal adopts for its final determination.

Yours sincerely

Sandra Gamble
Group Manager Regulatory

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30 April 2008

Assessment of IPART’s estimate of Long Run Marginal Cost for Sydney Water
A report for Alinta LGA Ltd

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1. Introduction

NERA Economic Consulting (NERA) has been asked by Alinta LGA Ltd to review the Independent Pricing and Regulatory Tribunal’s (IPART’s) approach to estimating the long run marginal cost of water supplied by Sydney Water Corporation (Sydney Water). The estimate is used by IPART as the basis for its determination of water usage charges to apply to Sydney Water for the period 1 July 2008 to 30 June 2012.

IPART released its draft determination and report outlining proposed prices for Sydney Water’s water, sewerage and stormwater services on 27 March 2008. IPART is proposing that the Tier 1 water usage charge be $1.54/kL from 1 July 2008, rising to $1.83/kL (in constant, 2008 prices) by the end of the regulatory period.¹

The purpose of this paper is to set out the economic principles underlying the setting of water usage charges that promote economic efficiency, including to explain the distinction between short run marginal cost (SRMC) and long run marginal cost (LRMC). In addition, we were asked to review IPART’s methodology for estimating the LRMC for water supplied by Sydney Water.

This paper has been prepared in a very compressed time frame and so the estimates of LRMC presented later in it are, at best, illustrative of a best estimate of the LRMC of water supplied by Sydney Water. Our intention however, has been to highlight the uncertainty surrounding estimates of LRMC and its sensitivity to the estimation approach and assumptions used, and to draw out the implications of our analysis for the approach adopted by IPART.

The remainder of this paper is structured as follows:

Ø Section 2 provides a very brief summary of the concept of marginal cost and its relationship to the determination of water prices. We define SRMC and LRMC and explain why water prices that reflect LRMC will most likely lead to efficient outcomes;

Ø Section 3 outlines the two main approaches used to estimate the LRMC for water supply – the Turvey approach and the average incremental cost approach;

Ø Section 4 provides our assessment of IPART’s approach to estimating LRMC and presents an illustrative range of LRMC estimates applying both the average incremental cost and Turvey approaches; and

Ø Section 5 concludes.

In Appendix A we also set out the assumptions used and sensitivities considered for our estimates of the LRMC.

¹ IPART, (2008), Review of prices for Sydney Water Corporation’s water, sewerage, stormwater and other services, Draft Determination and Draft Report, March.
2. Marginal cost pricing for water

Marginal cost is a measure of the change in total costs as output either increases or decreases. It is an important concept in economics because of the general principle that setting price equal to marginal cost presents a consumer with the opportunity costs of their consumption decisions, which in turn leads to an efficient allocation of society’s resources. Where price exceeds marginal cost consumption will be less than the efficient level because some consumers who would have consumed the good if price had reflected marginal cost, no longer choose to do so. The benefit of this consumption is therefore lost. Similarly, where price is set less than marginal cost then a consumer does not pay the full opportunity cost of producing the good or service and will consume at a level that is higher than efficient.

In this section we briefly discuss the importance of the concept of marginal cost for setting water usage charges. We then draw a distinction between short run and long run marginal cost and explain why LRMC is the relevant benchmark against which water usage charges should be set.

2.1. Why is marginal cost important?

Setting price equal to marginal cost is expected to lead to an efficient allocation of society’s resources. This is because consumers face the opportunity cost associated with consumption and society will consume up to the point where the marginal benefits are equal to the price. All other things being equal, this will lead to efficient consumption of any good or service, including water. Setting water usage charges equal to marginal cost also provides incentives for water businesses to undertake efficient levels of investment to prevent leakage and engage in water conservation where the cost of doing so is less than its opportunity cost from selling water to consumers, as represented by the water usage charge. It also provides incentives to invest efficiently in alternative water sources, where the cost is less than the water usage charge.

Importantly, marginal cost is a forward looking concept. In other words, the relevant costs are those that would be expected to be incurred to supply an additional unit of output, or alternatively the costs that would be expected to be avoided if output decreases in the future. In practice, estimating these forward looking costs often involves assessing historic marginal costs and considering how they may vary in the future.

However, setting water usage charges equal to marginal cost may not be sufficient to allow a water business to recover all relevant costs associated with supplying water. This is because some fundamental elements of the water supply chain exhibit strong economies of scale, such that the marginal cost of supplying water may be less than the average cost. This means that setting price equal to marginal cost may not allow for the recovery of the total costs associated with the supply of water.

To remedy any such deficiency in total revenue, it is usual for costs that are not able to be recovered through usage charges to be recovered in a way that minimises any distortions in consumption that might arise. The usual approach for addressing this problem amongst utility industries is through the use of two-part tariffs. This involves setting a usage charge that is based on the marginal cost of supply, and also a fixed charge to recover any remaining revenue needs.
Finally, to determine what costs should properly be included in marginal costs, it is relevant to consider the causal relationship between water usage and the costs of the water business. As Alfred Kahn puts it:\textsuperscript{2} 

> the essential criterion of what belongs in marginal cost and what not, and of which marginal costs should be reflected in price, is causal responsibility. All the purchasers of any commodity or service should be made to bear such additional costs – only such, but also all such – as are imposed on the economy by the provision of one additional unit.

The principle of causal responsibility implies that any costs that are sunk, ie, are not incurred to supply an additional kilolitre of water, should not be included in marginal cost. This means that any costs that are not a function of water use, such as depreciation and scheduled maintenance, should not be included in a measure of marginal cost.

It follows that, as a forward looking measure of costs caused by additional usage, a long run marginal cost estimate includes the change in future capital costs that are incurred as a consequence of a change in future usage exceeding current capacity limits. The important distinction between LRMC and SRMC is explained further below.

### 2.2. The distinction between short run and long run marginal cost

In economics, a distinction is drawn between the short run – where a firm is unable to adjust one or more factors of production – and the long run – where all factors of production are variable. Applying this distinction to the concept of marginal cost for water supply allows for the definition of:

- short run marginal cost – as the change in the total cost of water supply due to an increase (or decrease) in output, where at least one factor of production, such as water supply capacity is fixed; and
- long run marginal cost – as the change in the total cost of water supply due to an increase (or decrease) in output, where all factors of production, including water supply capacity can be changed so as optimally to balance supply and demand.

The key distinction between these concepts is whether water supply capacity is treated as fixed or is allowed to vary. LRMC therefore includes the marginal cost of future capital that is required to provide sufficient water supply capacity to meet an increase in water output. In other words, because future capital costs will vary according to demand given current capacity, these future capital costs should properly be included in the marginal costs upon which water usage charges are based.

It follows that by setting water usage charges equal to LRMC, consumers face the opportunity cost of their water usage decision, including where this gives way to a need to expand supply capacity in the future. This is expected to lead to the efficient use of resources for both the supply of water in the short term, and also for the supply of future capacity in the long term.

Where there is sufficient existing supply capacity, the short run marginal cost should include:

- future energy costs associated with pumping water;
- future chemical costs for water treatment;
- the cost of marginal wear and tear to the water supply system resulting from a change in water demand; and
- the cost of additional bulk water to meet a change in water demand.

Relaxing the assumption that existing supply capacity is sufficient to meet demand causes this concept to shift from one focused on the cost of supplying more (which, once at capacity, is no longer possible), to the cost of curtailing demand in order to ensure demand and supply is balanced. The amount that the marginal user would be willing to accept to reduce his or her demand will equal the value of water to that user.

In practice, setting water usage prices equal to SRMC will likely lead to charges being relatively low in times of abundant supplies of raw water – reflecting the small proportion of truly variable costs in the total cost for supplying water – until demand reaches existing supply capacity, at which time charges would need to increase significantly in order to balance supply and demand. Setting water usage charges at SRMC would therefore result in periods where demand would have to be constrained, to provide sufficient surplus revenue to encourage investment in new supply capacity. Given that significant variability in water prices is usually considered undesirable, setting charges equal to LRMC where variable future capacity costs are included, may be more appropriate.

The LRMC should therefore include:

- the long run marginal operating cost of meeting the additional demand, namely:
  - the future energy costs;
  - chemical costs arising from water treatment;
  - the cost of marginal wear and tear on the water supply system; and also

- the long run marginal capital cost associated with providing sufficient capacity to meet the additional demand.

Future long run marginal operating costs (LRMOC) therefore include those costs incurred as a result of an increase in demand given existing capacity, i.e., the SRMC, plus any marginal operating costs associated with future capital projects. The relevant operating costs are all those with a causal relationship to demand and associated with the delivery of bulk water to customers, including the marginal costs of operating the water supply system.

The long run marginal capital costs (LRMCC) include those future capital costs that are caused by an increase in demand above that which can be supplied through existing capacity. By including LRMCC in the water usage charge, customers face a price that includes the future marginal capital costs that would be avoided or incurred if demand decreased or increased, respectively. This approach therefore preserves an incentive for consumers to make efficient decisions on water use.
In section 3 we outline the methodologies that can be used to approximate the LRMC for water supply.
3. Methods for estimating LRMC

In principle, marginal cost is simply the first derivative of the water supply cost function with respect to output. However, in practice the value of the LRMC is usually approximated by estimating future long run operating costs and considering how future capital costs would change if expected demand changes.

The best approach for estimating LRMC was developed by Ralph Turvey, and involves considering how the value of a least cost capital program to equate demand and supply would vary due to an increment or decrement in water demand. The average incremental cost (AIC) approach is also commonly used to estimate LRMC, and requires less analysis to apply compared to Turvey’s approach.

In this section we describe how each approach is applied and briefly discuss their relative merits.

3.1. The Turvey approach

The Turvey approach estimates the LRMCC by:

- forecasting unconstrained water demand over a medium to long term time period, say 20 to 30 years;
- considering existing water supply capacity and assessing its scope to supply unconstrained water demand over the same period;
- developing a least cost program of capital projects and demand management options that equate water supply with unconstrained water demand over the same period;
- increasing or decreasing forecast unconstrained demand by a small but permanent amount and recalculating the least cost capital program to equate demand and supply.
- calculating the LRMCC as the present value of the change in the least cost capital program divided by the present value of the revised demand forecast compared to the initial unconstrained demand forecast.

The Turvey approach can be expressed algebraically as follows:

\[
LRMCC(Turvey) = \frac{PV(revised \ optimal \ capex - optimal \ capex)}{PV(revised \ demand - unconstrained \ demand)}
\]

To estimate the LRMC it is also necessary to estimate the long run marginal operating costs (LRMOC) associated with the incremental change in demand. The Turvey approach to estimating the LRMOC is analogous to the LRMCC estimate and can be summarised as follows:

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### Assessment of IPART’s estimate of LRMC for Sydney Water

Methods for estimating LRMC

- forecast unconstrained water demand over a medium to long term time period, say 20 to 30 years;
- forecast marginal operating costs over the relevant time horizon;
- recalculating marginal operating costs according to the change in the least cost capital program resulting from an increment or decrement in demand; and
- calculating the LRMOC as the present value of the change in marginal operating costs divided by the present value of the increment or decrement of demand considered.

Algebraically, this is represented as follows:

\[ LRMC(Turvey) = \frac{PV(\text{revised marginal operating cost} - \text{marginal operating cost})}{PV(\text{revised demand} - \text{unconstrained demand})} \]

To estimate the LRMC, the LRMOC is simply added to the LRMCC, estimated by applying the above approach.

The main features of the Turvey approach, consistent with the marginal cost pricing principles are:

- it more closely approximates marginal costs because the capital costs represent the change necessary to respond to a specified change in demand. These costs are more likely to resemble those that could be avoided should demand change and therefore would provide improved incentives to end-use customers of the ‘true’ opportunity cost of water supply;
- forward looking, as it is based on anticipated capital and demand management investments necessary to balance supply and demand; and
- it incorporates only those costs, and all costs, that are caused by demand growth above existing capacity.

A concern with the Turvey approach is the need to forecast likely capital and demand management projects that would be the least cost approach to meeting demand over a 20 year period. Estimating the cost of future capital projects and demand beyond ten years is likely to be particularly uncertain.

### 3.2. Average incremental cost approach

The average incremental cost approach includes many of the same initial steps as for the Turvey approach, namely:

- forecasting unconstrained water demand over a medium to long term time period, say 20 to 30 years;
- considering existing water supply capacity and assessing its scope to supply unconstrained water demand over the same period; and
developing a least cost program of capital projects and demand management options that equate water supply with unconstrained water demand over the same period.

The LRMCC can then be estimated as the present value of the least cost program of capital and demand management, divided by the present value of the change in demand supplied through the program of capital projects, or saved through respective demand management programs. Importantly this measure of demand is not the same as the water supply capacity associated with the capital projects. This is because the AIC method is seeking to estimate the marginal cost of a change in output caused by a change in demand by customers. It would make no sense to simply divide cost by capacity in the years it is available as that would not represent the marginal cost per unit of future consumption.

The AIC approach can be represented algebraically as follows:

$$LRMCC(AIC) = \frac{PV(water\ supply\ capital\ and\ DM\ programs)}{PV(additional\ demand\ served)}$$

To estimate the LRMC, it is necessary to also estimate the LRMOC associated with the change in demand. The AIC approach to estimating the LRMOC is as follows:

1. forecast unconstrained demand over a medium to long term time period, say 20 to 30 years;
2. forecast marginal operating costs over the relevant time horizon; and
3. divide the present value of marginal operating costs by the present value of the change in demand supplied by the proposed capital program and demand management program.

Algebraically, this is represented as follows:

$$LRMOC(AIC) = \frac{PV(marginal\ operating\ cost)}{PV(additional\ demand\ served)}$$

The LRMC is finally calculated by the addition of LRMCC and the LRMOC.

The main features of the AIC approach to estimating the LRMC consistent with the principles of marginal cost pricing are:

1. it is forward looking, as all capital projects and water demand projects necessary to equate supply with demand into the future are captured; and
2. it incorporates only those costs, and all costs, that are caused by demand growth above existing capacity.

The principal concern from this approach is that it uses average capital costs to approximate the likely marginal costs associated with a change in demand. In addition, the estimate will likely be sensitive to the demand forecasts used. Forecasting water demand over a 20 year time horizon is likely to be very uncertain.
4. Assessment of IPART’s approach to estimating LRMC for Sydney Water

This section provides a brief summary of IPART’s approach to estimating LRMC before assessing whether its approach is consistent with the principles of marginal cost pricing, as outlined in section 2. To highlight how different assumptions and methodologies affect the estimate of LRMC, we report some illustrative estimates of LRMC by applying the Turvey and the AIC approaches.

4.1. Overview of IPART’s approach

To estimate the LRMC for the draft determination, IPART adopted what it called an AIC approach to calculating marginal cost, where the AIC is given by:

\[
AIC = \frac{\text{Least cost investment to equate demand and supply}}{\text{Incremental output resulting from the capacity expansion}}
\]

This is a departure from the usual AIC formulation as described in section 3.1, since incremental output is used as the denominator, rather than determining what demand will be met by the capacity expansion.

To estimate the capital expenditure that will be required to equate demand and supply, IPART do no make any explicit reference to demand growth and what this means for the supply-demand balance and any investment in new capacity required over the planning horizon (other than acknowledging that tranche 2 is unlikely to be required before 2015 at the earliest). IPART therefore ignores any future investments that may be required to balance demand and supply over the medium term, apart from the tranche 2 desalination costs.

Other assumptions used by IPART to estimate the LRMC are:

- capital expenditure:
  - Tranche 2 costs are assumed to be $1,026 million;
  - Operating costs are assumed to equal $55 million/tranche/year (where 30 per cent of these costs are fixed, and the remainder, variable);
- desalination plant life of 30 years; and
- weighted average cost of capital of 7.1 per cent, in pre-tax real terms.

The IPART approach also excludes all tranche 1 costs ($1,918 million) on the basis that these costs are not considered avoidable.

IPART uses capacity of the desalination plant as its output measure, adjusted by an assumed average utilisation of 75 per cent in each year, with the exception of the first two years where assumed utilisation is 100 per cent. The plant is also assumed to operate for 365 days a year.
Based on this approach IPART has set a managed price path that results in a water usage charge of $1.83 by 2011-12, the last year of the regulatory period covered by the determination.

4.2. Assessment of IPART’s approach

In summary, IPART’s approach to estimating the LRMC is an approximation of the usual AIC methodology (which is in turn a simplification of the Turvey approach) as it only considers the cost of tranche 2 of the desalination plant, divided by the additional water supply capacity that tranche is expected to deliver given an assumption about likely utilisation. This is a unique formulation of the AIC approach to estimating LRMC and would only be a reasonable estimate of LRMC in rare circumstances, if ever.

In practice, estimating LRMC is an inherently uncertain exercise. The estimate will be affected by the methodology used and the accuracy of the forecasts of future unconstrained water demand and the associated least cost program to balance supply and demand. These forecasts will be particularly uncertain for periods beyond five to ten years.

Acknowledging this uncertainty means that any estimate of the LRMC will necessarily be just that. For this reason estimates of LRMC are usually presented as a range, where the sensitivity of the estimate to the various assumptions made is explicitly considered.

In addition, the estimate of LRMC will be strongly influenced by when the estimate is made, since this affects what known future costs can be treated as avoidable. As we outline in section 3, the LRMC should include all future costs that are caused by a change in demand, to provide signals to users on the opportunity cost of their usage decisions. That said, only those costs that can be avoided should be included in the estimate of LRMC. Where future water supply augmentation projects have been committed to but not built, it is therefore necessary to determine how much of the expected costs of the project could be avoided in the event that demand were to change such that it would be appropriate to delay or bring forward the project. This suggests that the fact a project has been committed to, but not completed, is not sufficient to conclude that the costs cannot be avoided and should be excluded from the estimate of LRMC.

The relevant question to ask to determine what future capital project costs to include is, how much of the project costs could be avoided if demand was to change? It is therefore incumbent on the person estimating LRMC to turn their mind to what future capital costs might be avoided. In practice, prior to a project actually being built, it is possible to reverse a decision if water demand circumstances changed sufficiently so as to warrant delay to a capital project. The importance of price being set in line with LRMC is to provide efficient usage signals. This means that any and all of these potentially avoidable costs should be properly included in charges to ensure that optimal investment decisions can be made.

LRMC estimates are therefore sensitive to when they are calculated, as the extent to which required forward capital investment can be considered avoidable, and therefore should rightly be included in the LRMC estimate, will change with time. For example, if LRMC was being estimated prior to any commitment by Sydney Water to the proposed desalination plant, say one year ago, all of the costs of both tranche 1 and tranche 2 would have been included within the estimate of LRMC. Water usage charges would therefore currently be
significantly higher than the estimate derived by IPART. Applying IPART’s methodology they would now fall because of the lower expected cost of tranche 2. Given that LRMC estimates will vary according to when they are calculated, it follows that there is merit in including at least some allowance for the marginal costs being imposed by the tranche 1 investment in desalination, in current water usage charges. It follows that efficiency would be enhanced by users being presented with those tranche 1 costs that could potentially be avoided.

Finally, we have concerns about IPART using desalination capacity as the denominator for estimating LRMC under the AIC methodology. In a very limited review of the literature on estimating LRMC we have been unable to find any study that has adopted an approach that uses supply capacity as the denominator. The usual formulation of the AIC divides capital costs by the incremental demand met by the new supply capacity. In other words, it assumes that the new future supply capacity is the marginal water source, meaning that it will only be used once all other cheaper water sources have been dispatched to meet demand. The relevant increment for calculating LRMC will therefore be the difference between forecast demand and base demand where existing capacity is fully utilised.

The intuition in favour of using incremental demand instead of supply capacity for estimating LRMC is clear. As we highlight earlier in this paper, the relevant costs for estimating LRMC are those future costs that are caused by a change in demand. Given that investment in new supply capacity would only arise where demand exceeded existing supply, the total cost associated with the new supply capacity should only be attributed to demand that exceeds existing supply, because it is only that demand which causes the new supply capacity to be built. It is therefore appropriate to estimate the marginal cost by dividing the capital costs by the incremental demand.

In summary, a more realistic estimate of the LRMC for Sydney Water will likely differ from the estimate calculated by IPART because:

- it does not explicitly consider the extent that the cost of tranche 1 of the desalination plant could be reasonably avoided and should therefore be properly included in the cost base for the purpose of estimating the LRMC;
- IPART inappropriately divides the estimated capital costs by the tranche 2 desalination capacity modified by an assumed load factor, instead of dividing by the incremental demand satisfied by the new supply capacity; and
- it does not consider what other capital investments or demand management program costs would be the least cost approach to managing the demand and supply balance over the medium to long term future.

In the following two sections we develop some illustrative estimates of LRMC for Sydney Water using the usual formulation of the AIC and Turvey approach, to provide an illustration of how LRMC estimates can vary because of the assumptions made and methodology applied.
4.3. Applying the Turvey approach

To demonstrate how LRMC estimates can vary given different assumptions and estimation methodologies, we have calculated illustrative LRMC estimates. These estimates have been calculated using both the Turvey and AIC approaches that we define in section 3. From a methodological perspective our estimates are therefore superior to the approach adopted by IPART. To apply these methodologies we have had to make assumptions about the least cost capital and demand management program to satisfy a forecast level of demand growth. Given the limited time available, we have made assumptions based on the desalination cost information used by IPART and its forecast of water demand. We acknowledge that these assumptions are highly simplified, but we believe that it highlights how estimates of LRMC can vary according to the assumptions and estimation methodology used.

To apply the Turvey approach to estimate LRMC for Sydney Water, we have had to make the following simplifying assumptions, namely:

1. Demand is assumed to equal that adopted by IPART over the forthcoming regulatory period, after which it increases at a rate of 1.5 per cent per annum, calculated as the average annual growth in demand over the 5 years from 2007-08;\(^4\)

2. The least cost program of projects to equate demand and supply is assumed to involve expanding the existing desalination plant at a cost and supply capacity equal to that estimated for tranche 2, over a 30 year time horizon;

3. The portion of tranche 1 desalination costs that are forecast to be spent after 1 July 2008 (approximately 55 per cent\(^5\)) are assumed to be potentially avoidable; and

4. The marginal operating costs are assumed to include those costs for operating desalination that vary with demand and are based on IPART’s assumptions, plus the water delivery system operating costs that are also assumed to vary with changes in water demand\(^6\).

The main difference between the Turvey approach and the AIC approach is how these assumptions are translated into an estimate of the LRMC. Unlike the AIC approach, the Turvey approach requires reconsideration of the least cost program of projects to equate demand and supply that arises from an increment or decrement in forecast water demand over the assumed time horizon. Our approach in this paper has been to consider a number of alternative demand increments and decrements around that used in the AIC approach, and to then determine how the timing of the future desalination plant expansions are affected. The

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\(^4\) We have calculated the rate of water demand growth using data for 2007-08 and the four years of forecast demand for the regulatory period, as calculated by Sydney Water and endorsed by IPART as part of their draft determination. This growth rate forms the basis for all future water demand assumptions.

\(^5\) This is based on Table 4.2, Sydney water submission to IPART for the 2007 price determination, and assuming tranche 1 costs of $1,918 million.

\(^6\) Our approach to the estimation of LRMC is not a strict application of the Turvey approach because of information and data limitations. To apply the Turvey methodology as set out in Section 3.1 one would need to understand how operating costs vary with demand, so an accurate estimate of the NPV of the change in operating costs pre and post the change in demand could be developed. This is highly uncertain in this instance because of the limited information available on the relationship between demand and desalination plant operating costs. This issue is discussed further in Appendix A.
LRMCC is then simply the difference in the present value of the change in costs between these two capital programs divided by the present value of the additional demand supplied by the marginal supply source over the time horizon.

To consider how the LRMC estimate may vary with the use of different assumptions we also considered a number of sensitivities as outlined in Appendix A. This has allowed us to present a range for the LRMC estimate, albeit with some qualifications given the capital program assumptions adopted.

Applying the formulation of the Turvey approach as described in Section 3.1 above, the LRMCC is estimated to range between $1.06 with a 27GL increment, $0.89 with a 22GL increment and $1.60 with a 17GL increment, per kilolitre. The LRMOC is estimated to be $0.50-0.53/kL. This generates a range of possible LRMC estimates of $1.39-2.13/kL. The variability of these results highlights the sensitivity of the Turvey approach to the choice of increment or decrement in demand, both in terms of the size of the increment and the timing of its application in the context of the planning horizon. The results are also sensitive to the assumed size and cost of the desalination plant increments. This variability is a direct result of the simplified assumptions that we have used, where the forward capital expenditure program is a new desalination plant required for every 91GL increase in demand. The intuition in our illustrative example is that LRMCC falls until the change in the size of the demand increment affects the present value of capital costs. The variability in the LRMCC estimate is therefore directly related to the lumpy nature of our assumed forward capital program.

The issue of volatility with respect to the Turvey methodology is discussed further in Appendix B, where we provide an example of how the LRMC estimates vary with changes to the size and timing of the assumed change to demand. This analysis underscores the importance of undertaking a proper estimate of the forward capital program necessary to equate demand and supply, as the basis for applying the Turvey method. In the absence of this detailed analysis, the AIC methodology is likely the next best approach, although with the limitations discussed below.

To obtain a reasonable estimate of the LRMCC using the Turvey approach, it is necessary to consider the forward capital expenditure program to equate demand and supply before and after the assumed change in demand. If time were to permit a more informed and sophisticated estimation of LRMCC, this least-cost forward capital expenditure program would likely involve continuous demand management measures, thereby avoiding the sensitivity of the estimate to the lumpy capital investment required in our illustrative analysis.

4.4. Applying the average incremental approach

To estimate the LRMC using the AIC approach, we have used some of the same assumptions as for our estimate using the Turvey approach, namely:
¥ demand is assumed to equal that adopted by IPART over the forthcoming regulatory period, after which it increases at a rate of 1.5 per cent per annum, calculated as the average annual growth in demand over the 5 years from 2007-08;\textsuperscript{7}

¥ the least cost program of projects to equate demand and supply is assumed to involve expanding the existing desalination plant at a cost and supply capacity equal to that estimated for tranche 2, over a 30 year time horizon;

¥ a portion of tranche 1 desalination costs that are forecast to be spent after 1 July 2008 (approximately 55 per cent) are assumed to be potentially avoidable;\textsuperscript{8} and

¥ the marginal operating costs are assumed to include those costs for operating desalination that vary with demand and are based on IPART’s assumptions, plus the water delivery system operating costs that are also assumed to vary with changes in water demand.

To consider how the LRMC estimate varies with the assumptions used, we also consider sensitivities for water demand, the likely cost of subsequent desalination tranches acknowledging that it is unlikely that additional desalination capacity could be purchased at the same cost as tranche 2, and the choice of the weighted average cost of capital. These assumptions and sensitivities are summarised in Appendix A.

Using our formulation of AIC as described in section 3.2 and the above assumptions, the LRMCC is estimated to range between $1.39 and $2.66 per kilolitre. The LRMOC ranges between $0.45 and $0.70 per kilolitre, resulting in a range for the LRMC using the AIC approach of between $1.84 and $3.36 per kilolitre. Further detail of how this range was calculated is set out in Appendix A.

### 4.5. Summary of LRMC estimates

Table 4.1 presents a summary of the illustrative LRMC estimates that we have estimated using the AIC and the Turvey approaches, and compare these to the estimate developed by IPART. We believe that applying the Turvey approach is theoretically superior to using the AIC approach and that IPART has incorrectly applied the AIC methodology by using capacity as the denominator and not considering a time horizon for the estimate. Applying the Turvey approach would require further consideration of the least cost program of capital investments necessary to equate demand with supply. Whilst we acknowledge that our estimates have been based on simplifying assumptions on the least cost capital program to meet forecast incremental demand, in our view they highlight how different methodologies and assumptions will likely affect the LRMC estimate.

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\textsuperscript{7} We have calculated the rate of water demand growth using data for 2007-08 and the four years of forecast demand for the regulatory period, as calculated by Sydney Water and endorsed by IPART as part of their draft determination. This growth rate forms the basis for all future water demand assumptions.

\textsuperscript{8} This is based on Table 4.2, Sydney water submission to IPART for the 2007 price determination, and assuming tranche 1 costs of $1,918 million.
Table 4.1
Summary of LRMC estimates

<table>
<thead>
<tr>
<th>Method</th>
<th>LRMC ($ 07/08)/kl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turvey approach</td>
<td>1.39 – 2.13⁹</td>
</tr>
<tr>
<td>AIC approach</td>
<td>1.84 – 3.36</td>
</tr>
<tr>
<td>IPART estimate (not including tranche 1)</td>
<td>1.90</td>
</tr>
<tr>
<td>IPART estimate (including tranche 1)</td>
<td>2.37</td>
</tr>
</tbody>
</table>

The reasons for the difference between our estimates of the LRMC using the AIC and Turvey approaches and the IPART estimate include:

» we have assumed that some of the cost of tranche 1 of the desalination plant is potentially avoidable, despite Sydney Water having already committed to the project. While Sydney Water would likely incur some costs if it chose not to proceed with the project, we do not believe that all of the tranche 1 costs should be treated as sunk for the purpose of estimating LRMC;

» we have used demand in excess of that capable of being met by Sydney Water’s existing supply capacity as the basis for calculating LRMC, as compared to the capacity of tranche 2 modified by an assumed load factor; and

» we have included capital projects and estimated incremental demand over a time horizon of 30 years, in accordance with the usual application of AIC and the Turvey approaches.

To obtain a more reasonable estimate of the LRMC for Sydney Water, it will be necessary to address our methodological concerns, examine the demand forecast assumptions more closely, and develop a least cost capital and demand management program to meet anticipated demand.

⁹ Our illustrative Turvey estimates are sensitive to the size and timing assumed for the increment/decrement used in the analysis and should not be relied on as an estimate of the LRMC in the absence of a proper review of the least cost forward capital expenditure program to equate demand and supply.
5. Conclusions

This paper briefly explains the importance of setting price equal to marginal cost and also why LRMC is the relevant measure of marginal cost to use for setting water usage charges. We highlight that the key characteristics of marginal cost are that it:

- is forward looking; and
- only includes future costs that are causally related to demand, i.e., costs that are unavoidable in the future should not be included.

The best approach for calculating LRMC is that developed by Turvey. The AIC approach is a simplified approximation to the Turvey approach where information is limited. Importantly, any approach for estimating the LRMC is at best an approximation based on the underlying assumptions used, and therefore it is usual to examine the sensitivity of any LRMC estimate to the key assumptions.

All measures of LRMC usually involve:

- forecasting unconstrained water demand over a medium to long term period, say 20 to 30 years;
- considering existing water supply capacity and assessing its scope to supply unconstrained water demand over the same period; and
- developing a least cost program of capital projects and demand management options that equate water supply with unconstrained water demand over the same period.

The key difference between the Turvey and AIC approaches is how this information is translated into an estimate of LRMC. For the AIC approach, LRMC is simply the present value of the capital program divided by the present value of the additional water demand met by this capacity expansion. For the Turvey approach, the LRMC is estimated by considering how the value of the least cost capital program to equate supply and demand changes in response to a permanent increment or decrement in water demand. The LRMC is then simply the present value of this change in cost divided by the present value of the change in demand which led to this augmentation to the capital program.

To illustrate how LRMC can vary depending on the estimation approach used we calculate the LRMC for water supply by Sydney Water using simplified assumptions based on those used by IPART. Based on the AIC methodology, our results indicate that the LRMC for Sydney Water could range between approximately $1.84 and $3.36 per kilolitre, depending on the assumptions and estimation approach used. This highlights that IPART’s estimate is likely to be towards the lower end of a likely range of LRMC estimates. Specifically:

- by not including any of the potentially avoidable cost of tranche 1, the LRMC estimated by IPART is likely to be lower than the ‘true’ LRMC for the purpose of setting an efficient water charge; and
by dividing the cost by the tranche 2 capacity – albeit modified by a load factor assumption – rather than considering its contribution to meeting demand in excess of existing capacity at the margin, IPART’s approach is likely to underestimate the LRMC.

If a complete least cost program of capital projects and demand management programs were developed and the above methodology concerns were addressed, we conclude that a sensible range for the LRMC for water supplied by Sydney Water would be greater than that estimated by IPART for the draft determination.
Appendix A. Assumptions and Sensitivity Analysis

A.1. Common assumptions

In deriving the estimates for LRMC presented in this paper, a number of simplifying assumptions were made that are common to both the AIC and Turvey approaches. These assumptions are:

- additional desalination plant capacity will provide the optimal least-cost solution to satisfy any future demand growth in excess of prevailing supply capacity;
- specifically, for every 91 GL increase in demand, there is a need to install an additional 250 ML/day desalination plant;\(^{10}\)
- each desalination plant is assumed to cost the same as tranche 2 (ie, $1,026 million in constant 07/08 dollars), and has the same operating cost characteristics;
- the weighted average cost of capital is 7.1 per cent;
- the ratio of fixed to variable operating costs is 0.3:0.7;
- demand is assumed to equal IPART’s forecasts for the forthcoming regulatory period, after which it increases at the rate of 1.5 per cent each year, calculated as the average annual growth in forecast demand over the five years from 2007-08 (where this assumes level 2 and 3 water restrictions will be lifted during 07-08, level 1 water restrictions will apply in 2008-09, and permanent water savings will apply after 2009-10);
- theoretically, an estimate for long run operating cost should be derived by taking the total variable costs incurred by operating the plant at the required level to equate supply and demand, divided by the additional demand that is met by the supplies made available through investment in the desalination plant. In practice calculating total operating costs is complicated by the information available to us on these costs (ie, the IPART determination only notes that operating costs would be $55m/year for a 250ML plant operating at full capacity, which does not allow investigation of variable costs on a per unit of consumption basis). For simplicity, we assume that total operating costs in any one year are a function of capacity, and subsequently apply a fixed load factor of 75 per cent, as a proxy for actual operating costs incurred;
- a 30 year time horizon is considered, and all desalination plant is assumed to have a 30 year asset life; and
- no allowance is made for demand management savings except those incorporated indirectly through Sydney Water's demand forecast information, which assumes that Sydney Water will meet its operating licence demand management targets over the forecast period.

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\(^{10}\) This assumption is conservative because any future desalination capacity expansion beyond tranche 2 at Kurnell would likely require acquiring a new site and undertaking inlet and outlet construction, which would be more in line with the estimated tranche 1 costs.
A.2. The AIC approach

Applying the AIC approach using the above assumptions leads to a LRMCC value of $1.83/kL and LRMOC value of $0.54/kL, giving an estimate for LRMC of $2.37/kL.

The sensitivity of this value to changes in the input parameters is set out in Table A.1 and indicates that this estimate is generally quite robust:

<table>
<thead>
<tr>
<th>Parameter change</th>
<th>LRMC</th>
<th>Change ($/kL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalination plant costs (post tranche 2) increase by 10%</td>
<td>2.38</td>
<td>0.01</td>
</tr>
<tr>
<td>Desalination plant costs (post tranche 2) decrease by 10%</td>
<td>2.35</td>
<td>-0.02</td>
</tr>
<tr>
<td>Annual demand growth 1.0%</td>
<td>2.94</td>
<td>0.57</td>
</tr>
<tr>
<td>Annual demand growth 2.0%</td>
<td>2.06</td>
<td>-0.31</td>
</tr>
<tr>
<td>WACC 6%</td>
<td>2.13</td>
<td>-0.24</td>
</tr>
<tr>
<td>WACC 8%</td>
<td>2.58</td>
<td>0.21</td>
</tr>
</tbody>
</table>

In summary:

- Increasing (decreasing) the capital expenditure cost of those tranches being built post-tranche 2 by 10 per cent leads to roughly a 1-2 per cent increase (decrease) in LRMC;
- Assuming smaller annual demand growth over the period (1.0% p.a) leads to a higher LRMC (25%);
- Assuming larger annual demand growth (2.0% p.a) leads to a lower LRMC (13% lower);
- Reducing the WACC lowers LRMC; increasing the WACC increases the LRMC; and
- Reducing asset life to 20 and 15 years, raises the LRMC to $2.62/kL and $2.91/kL respectively.

The directional impact on LRMC of change in parameter values is summarised in Table A.2.

<table>
<thead>
<tr>
<th>Increase in parameter value</th>
<th>Impact on LRMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs of desalination investment (tranche 3 onwards)</td>
<td>Increase</td>
</tr>
<tr>
<td>Annual demand growth</td>
<td>Decrease</td>
</tr>
<tr>
<td>WACC</td>
<td>Increase</td>
</tr>
<tr>
<td>Asset life</td>
<td>Decrease</td>
</tr>
</tbody>
</table>

On the basis of these results an upper and lower bound for LRMC can be derived by assuming a simultaneous change (of sensible magnitude) in all of the parameters in the direction that would increase (decrease) the LRMC.
Table A.3: Upper and lower bound estimate of LRMC using the AIC approach

<table>
<thead>
<tr>
<th>Lower bound for LRMC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs (post tranche 2)</td>
<td>$923.40m</td>
</tr>
<tr>
<td>Annual demand growth</td>
<td>2.0%</td>
</tr>
<tr>
<td>WACC</td>
<td>6.0%</td>
</tr>
<tr>
<td>Asset life</td>
<td>30 years</td>
</tr>
<tr>
<td>LRMC</td>
<td>$1.84/kL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Upper ground for LRMC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs (post tranche 2)</td>
<td>$1128.60m</td>
</tr>
<tr>
<td>Annual demand growth</td>
<td>1.0%</td>
</tr>
<tr>
<td>WACC</td>
<td>8.0%</td>
</tr>
<tr>
<td>Asset life</td>
<td>25 years</td>
</tr>
<tr>
<td>LRMC</td>
<td>$3.36/kL</td>
</tr>
</tbody>
</table>

A.3. The Turvey approach

Applying the Turvey approach with the assumptions outlined above, and assuming an exogenous shock to demand that increases demand by between 17 and 27 GL (essentially shifting the demand curve ‘up’ by a step change, after which demand continues growing at the forecast rate), generates a range of values for the LRMC of between $1.39/kL to $2.13/kL.

While these results are generally stable the LRMCC value is sensitive to the size of the demand increment considered, as well as its timing. This is discussed further in Appendix B.
Appendix B. The sensitivity of the Turvey methodology

In order to understand the sensitivity of the Turvey-estimated LRMC values reported in this paper, we considered how the Turvey LRMC estimate changes in response to variations in the size and timing of the increment or decrement to demand that is applied. Our approach included the following steps:

- the base case, or ‘pre-demand change’ scenario continues to be the scenario developed based on the parameters and assumptions set out in Appendix A;
- an increment to demand was then applied at 4 different points over the planning horizon – namely 2010, 2015, 2020 and 2025; and
- changes in demand of between 1 and 16 GL were considered, (where LRMC is calculated for every 0.5GL increment within this range) for each of these 4 years.

Doing this generates four separate LRMC profiles that show how the LRMC estimate varies with the size of the increment to demand that is applied in that given year. Figure B.1 illustrates these results.

**Figure B.1: Sensitivity of LRMC to change in demand assumption using the Turvey approach**

This chart demonstrates how widely our illustrative estimate of LRMC can vary depending on the parameter values applied. The sensitivity of the LRMC estimate is a function of the assumptions we have had to use in the time available. To rely upon the Turvey approach for estimating LRMC it would be necessary to undertake a more detailed examination of the forward capital expenditure program.
Assessment of IPART’s estimate of LRMC for Sydney Water

Figure B.2 below shows how the LRMC paths presented in figure B.1 shift according to changes in the plant capacity assumption. To illustrate this, we have changed the desalination plant capacity assumption from 250ML/day to 248 ML/day. The chart demonstrates how the range of LRMC values can change significantly as a result of the capacity assumption used.

**Figure B.2: Sensitivity of LRMC to change in capacity assumption using the Turvey approach – Capacity of Tranche 2 and subsequent plants = 248 ML/day**