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Lake Grace

A cost benefit analysis for water management
incorporating data from KBR, DAWA and the Shires

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Executive summary

This report presents the results of economic analyses looking at the costs and benefits of various surface water management options in Lake Grace. The three options considered are those under the terms of reference for this project as stated by KBR (2005)[1].

Option 1: Utilise the existing sports dam and sports dam catchment for irrigation within Lake Grace town.

Option 2a: Capture storm water runoff from the town and farmland east of Kulin-Lake Grace Rd (east of town site) via a sump then pump it into the existing dam for storage.

Option 2b: Capture storm water runoff from the town and farmland east of Kulin-Lake Grace Rd (east of town site) site via a sump then pump it to a new dam for storage.

Option 3: Capture storm water runoff from two catchments, east of Kulin-Lake Grace Rd (east of town site) and north of Stubbs Rd (north of town site) into drainage channels by-passing the town site to alleviate water logging/inundation problems in town.

In addition the costs and benefits arising from the current use of the existing town dam are estimated to calculate net benefits and a breakeven water price.

More specifically, the analyses outlined in this report stems from a systems model designed to evaluate net benefits from water harvesting, treatment and water reuse. As the model is not an optimisation model, the optimal strategies are determined for different scenarios through a series of model runs. The model allows the user to simulate different water management options and to provide management strategies so as to determine the optimal management regime to implement.

Results derived from the model are contingent upon the assumptions driving them and should be interpreted accordingly. The specific assumptions for each option are outlined in the report proper. Furthermore, the analyses are dependant on data provided in scientific reports completed within the Rural Towns Liquid Assets project.

General assumptions pertain to each of the options. Surface water harvested in Lake Grace and in its current state, would be fit for irrigation purposes only. The existing town dam in Lake Grace is capable of yielding 19ML of water each year. Water yield is based on the rainfall record, 1994 to 2004, and hence is an estimate of likely yield in any one year. Varying the yield in sensitivity analyses will provide an indication of how changes in rainfall over the

[1] Kellogg Brown and Root Pty Ltd (KBR) was appointed in 2005 to undertake engineering analysis of water management options for the Rural Towns Liquid Assets project and with reference to this report, for the town of Lake Grace.

time of the analyses, could affect the overall outcome. The time period for all analyses is 20 years. Based on analyses completed by KBR (2005), it is expected that total requirement for irrigation water in Lake Grace is 50.4ML per year. In this report it is assumed that if necessary, scheme water will supplement the water available from the dam and all 50.4ML will be used.

Costs used in this study are based on work done by KBR together with information from the Department of Agriculture, Western Australia and the Shire of Lake Grace. All details are presented in KBR (2005). This report also complements scientific reports produced by others involved in the project and therefore will not duplicate contents found in these reports or that of KBR.

Two scenarios are investigated for Option 1. The first relies on data provided by KBR (Option 1a) and the second by DAWA and the Shire of Lake Grace (Option 1b). Options 2a1 and 2b1 include cost estimates from KBR, while Options 2a2 and 2b2 are based on costs provided by DAWA and the Shire of Lake Grace. Option 3a is contingent upon data from KBR while Option 3b relies on information provided by DAWA and the Shire of Lake Grace. All data is reported in KBR (2005).

Option 1 deals with improving the reliability of the existing sports dam for irrigation within Lake Grace by increasing the dam catchment. Analyses showed that dam water could be sold below the current scheme water price of $1.20/kL for Option 1 to be a viable proposition. More than reasonable increases in costs or decreases in water yield are required to push the breakeven dam water price over the scheme water price. As the analysis has been completed on delivering the total water yield and not just the additional yield over and above that produced currently, consideration should be given to the breakeven water prices when only the 'new' water is included as for both Options 1a and 1b, the breakeven water price is above the scheme water price. Otherwise, the prices found for the base case scenario may be underestimated. The average water price combining water produced via this option and scheme water is around $1.00/ML for both options

In Option 2 the plan is to capture storm water runoff from the town site via a sump then pump it into the existing sports dam for storage (Option 2a) or to the new dam for storage (Option 2b). Results from the analyses suggest that product water provided by Option 2a2 could be sold below the scheme water price while that calculated for Option 2a1 is almost equivalent to that for scheme water. For Options 2b1 and 2b2 dam water would have to be sold above the current scheme water price for it to be a viable proposition. The results are sensitive to water yield decreases and cost increases for Option 2a1. In addition, if benefits from damage reduction within the town site are included in the analyses, Option 2a1 and 2b2 become a better proposition than scheme water. If the capital costs are linked specifically to the 'new water' produced in Option 2a then the breakeven water price is underestimated in the base analysis.

Based on the assumptions outlined in this document, the 'do nothing' option is ranked highly in the list of alternatives (Table 1). However, the costs were assumed and there may be a greater risk in supply being achieved over the 20 year period. Of the base case options considered that add improvements to the current water management plan, the lowest price that product water must be sold at so as to break even is for Option 2a2. This option is the highest ranked alternative when assessing it from a total yield or marginal yield perspective (Table 1). Options 1a and 1b could also be sold below the scheme water price of $1.20/kL and still be viable propositions. Although, when looking at marginal yield only, the outcome for both options does not appear to be a better proposition than purchasing scheme water. Options 2b1 and 2b2 were essentially not considered viable alternatives when these options were considered independently of the other options.

Table 1. Ranking the Options in ascending order of water price required to break even

Option	Water Price $/kL (assumed costs to supply total yield)	Option	Water Price $/kL (assumed costs to supply marginal yield)	Option	Water Price $/kL (assumed combined with Option 3b)
Option 2a2	0.38	Option 2a2	0.52	Current	0.01
Option 1b	0.63	Current	0.63	Option 2a2	0.21
Current	0.63	Option 1b	1.37	Option 1b	0.30
Option 1a	0.99	Option 2b2	1.46	Option 1a	0.66
Option 2a1	1.24	Option 2a1	1.70	Option 2a1	1.07
Option 2b2	1.46	Option 1a	2.16	Option 2b2	1.13
Option 2b1	3.98	Option 2b1	3.98	Option 2b1	3.66

As water is not generated for sale, Option 3 is assessed on benefits arising from reduced damage to infrastructure. Unless benefits derived from the diversion of surface water are significantly greater, or costs are substantially less, the costs do not outweigh the benefits for Option 3a. However, given the benefits arising from reduced damage within Lake Grace, Option 3b appears to a reasonable option. The only scenario where the breakeven water price is below that of scheme water is when Option 3a is combined with Option 2a2. However, when Option 3b is combined with the option for the existing dam, it is ranked first (Table 1). All other options combined with Options 3b produce breakeven water prices below the scheme water price except for Option 2b1 (Table 1).

Understanding the scope of this project is important for interpreting the results derived from the analyses. This work will not automatically calculate which strategy is 'best'. The strategies have been evaluated using experimentation and 'trial and error'. Furthermore, generally the analyses do not represent year-to-year variation in weather, potential yield or water output. However, general changes can be manually placed in the model.

Even though great care has been taken in data collection and model development so as to create a robust model, there are always opportunities for changing parameters to reach alternative outcomes. Also, as the values included in this analysis are representative of a specific town in Western Australia, model parameters will need adjusting for other towns and for other regions.

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Chapter 1

Introduction

The analyses presented in this report are designed to provide information to decision makers who will be considering three options aimed at improving water management in Lake Grace. In addition the costs and benefits arising from the current use of the existing sports dam will be estimated so as to calculate net benefits of this activity and hence provide additional information to decision makers.

More specifically, the analyses outlined in this paper stem from a systems model designed to evaluate net benefits from water harvesting, treatment and water reuse. As the model is not an optimisation model, the optimal strategies are determined for different scenarios through a series of model runs. The model allows the user to simulate different water management options and to provide management strategies so as to determine the optimal management regime to implement.

Terms of reference

Under the terms of reference for this project as stated by KBR (2005), the following options will be considered within an economic framework and detailed in this report.

Option 1: Utilise the existing sports dam and sports dam catchment for irrigation within Lake Grace town.

Option 2a: Capture storm water runoff from the town and farmland east of Kulin-Lake Grace Rd (east of town site) via a sump then pump it into the existing dam for storage.

Option 2b: Capture storm water runoff from the town and farmland east of Kulin-Lake Grace Rd (east of town site) site via a sump then pump it to a new dam for storage.

Option 3: Capture storm water runoff from two catchments, east of Kulin-Lake Grace Rd (east of town site) and north of Stubbs Rd (north of town site) into drainage channels by-passing the town site to alleviate water logging/inundation problems in town.

Assumptions

Results derived from the model are contingent upon the assumptions driving them and should be interpreted accordingly. The specific assumptions for each option are outlined in the proceeding chapters. Furthermore, the analyses are dependant on data provided in scientific reports completed within the Rural Towns Liquid Assets project.

General assumptions that pertain to each of the options are discussed here. It will be assumed in this report that surface water harvested in Lake Grace and in its current state, would be fit for irrigation purposes only. The existing sports dam in Lake Grace is capable of yielding 19ML of water each year. Water yield is based on the rainfall record, 1994 to 2004, and hence is an estimate of likely yield in any one year. Varying the yield in sensitivity analyses will provide an indication of how changes in rainfall over the time of the analyses, could affect the overall outcome.

The time period for all analyses is 20 years. Based on analyses completed by KBR (2005), it is expected that total requirement for irrigation water in Lake Grace is just over 50ML per year.

In this report it is assumed that scheme water is a direct substitute for water available from the dams and all 50ML will be used.

This report

This report will complement scientific reports outlining the physical requirements associated with the specific water management plan for Lake Grace as well as the KBR[2] report (see KBR 2005) detailing costs for various options for this plan. Hence such information will not be duplicated in this report. Instead this document is designed to provide readers with a complete overview of a series of cost benefit analyses completed using a model developed in Microsoft®Excel. We present details regarding the general economic analyses in Chapter 2. An economic overview of current water use is presented in Chapter 3, and analyses focussing on Options 1, 2 and 3 are detailed in Chapters 4, 5 and 6 respectively. The options are compared in Chapter 7 and the capacity of the work discussed in Chapter 8.

[2] Kellogg Brown and Root Pty Ltd (KBR) was appointed in 2005 to undertake engineering analysis of water management options for the Rural Towns Liquid Assets project and with reference to this report, for the town of Lake Grace.

Chapter 2

Economic Analysis

As the aim of this work is to compare the costs and benefits of each of the options as outlined in the terms of reference the economic framework will involve cost benefit analyses. As alluded to in Robison and Barry (1996), long-term investments can be analysed by adding all present costs and benefits for each year of the project and using a discounting approach to calculate the net present value. For the purpose of this report this methodology will be used in its simplest form so will not include differing inflationary effects associated with inputs and/or outputs, revenue earned from interest on profit or tax implications.

As it is assumed from the outset that at least one of the specified options will not necessarily be better than the status quo, the 'do nothing' option will also be considered in this report. By running various simulations the net benefits for the various options under different conditions will be found.

Costs

Capital costs

The current costs associated with each option are used as default values. However, to account for specific changes in costs that may occur in any one year, these costs can be independently increased or decreased for that year. Should this be necessary for any options, the actions taken will be reported in the relevant proceeding chapters. It is further assumed that 95% of capital costs are incurred in year 1 with the rest being annualised over the 20 years. Even so, in the spreadsheet model it is possible to vary this ratio depending on how these costs are likely to be financed. The combined opportunity cost of money and the cost of capital are also presented as an annual cost per kilolitre of product water.

Total variable costs

The total variable costs per year are found by summing all operational costs. These costs will also be presented as annual operating costs per kilolitre of product water. However, such figures should be used with caution as capital costs and benefits are also important when comparing the viability of any options.

Indirect costs

Costs, arising from the establishment of any of the options that impose upon an external party can be referred to as indirect costs. Such costs may be derived from forms of pollution, or a change in water allocation.

Benefits

Revenue

Revenue may be accrued directly from the sale of the water or other actions directly related to the resources produced. Even if the water is not literally sold and hence cash is not exchanged between two parties (primarily because the council may not buy the water from itself if it owns the infrastructure) in order to estimate the benefits of the water a 'selling price' is attached to the product water and it is referred to as being sold. Specific revenue will be described along with each of the three options.

Reduction in damage to infrastructure

By removing or at least reducing water from the ground and/or surface, the costs of maintaining infrastructure such as buildings and roads should decline. The benefit of this reduced damage is estimated using physical and economic data and is specific for each option.

Evaluation of the salinity risk associated with infrastructure damage and subsequent damage costs are described in Barron *et al.* (2005a). The level of risk is estimated in accordance with the soil saturation level one meter below the surface and is based on the long term average groundwater level for the shallow observation bores. These bores only cover a portion of the town and therefore the extent of the salinity risk area considered in this study is confined by the extent of the observation bores in the town.

Barron *et al.* (2005a) calculate the town infrastructure damage costs using the USEAP model[3]. This model is based on the simultaneous analysis of the salinity risk and infrastructure type within each land parcel, where surface types, area and structures have been identified. Land parcels are divided into six key groups in USEAP: residential housing, commercial/offices, ovals/playing fields, public open space sealed roads and unsealed roads. Each category has an assigned annual damage cost assuming a 100% impact. This impact is then moderated based upon estimated degree of soil saturation so that damage falls as soil saturation falls. The average salinity risk of each land parcel is estimated, and using an algorithm adapted, damage can be calculated (Table 1).

Table 1. Damage Costs derived from USEAP for specific urban land parcels

Land parcel	**Units**	**Cost ($)**
Residential Building	per/household	563
Commercial Building	per/1000sqm	663
Oval	per/Hectare	1,900
Open Space	per/Hectare	685
Sealed Road	per/1000m	400
Unsealed Road	per/1000m	200

[3] For further details regarding USEAP and the associated methodology see RTMC (2001).

It is important to note that these damage costs are an indication of actual costs, and that only a part of the gazetted town site is considered. Furthermore, it is assumed that the water level is at equilibrium. If the intention is to identify the impact of changes in management, then an assessment of those areas that may feasibly be impacted by that management need only to be considered. It is also important to note that these costs represent the MAXIMUM cost reduction that could be achieved if management options were introduced that completely ameliorated the problem. It is almost certainly the case that such total amelioration options will not be achieved and hence are not considered in the water management plans[4].

However, these damage costs provide a basis on which to estimate the overall infrastructure damage problem within the town. The salinity risk for Lake Grace is concentrated in the south eastern end of the town site. Assuming a water management plan is not implemented, the estimated damage cost for each infrastructure type has been calculated by Barron *et al.* (2005b) as an annual damage cost (Table 2). As this annual damage cost is a maximum, sensitivity analyses will be completed using reduced levels of infrastructure damage costs.

Table 2. Infrastructure damage costs estimated for Lake Grace

Infrastructure type	Annual cost ($)
Industrial	2,584
Parks & Recreation	552
Public Purposes	414
Railway	43
Residential	14,889
Special use	193
Town centre	2,478
Roads	907
TOTAL	22,060

Indirect revenue

Indirect revenue may arise if benefits accrue to a third party and or the environment due to implementation of a water management plan. Flow-on effects from a water management option to the local community can be used as a proxy for general indirect benefits should they emerge. To calculate these benefits, input-output multipliers can be used. It is assumed that if any new businesses emerge as a result of a greater availability of water, for every $1 spent on wages, a fair amount, e.g. $0.25, will be spent locally. And for the wage earner, for every $1 earned, an amount, e.g. $0.25, will be spent locally. Without having completed further research using e.g. non-market valuation methodology addressing the environmental benefits that may arise from implementation of an option is difficult. Therefore in this report environmental benefits may be acknowledged but a value will not be assigned to them.

[4] For more information regarding this methodology see Barron *et al.* (2005a).

Total benefits

Total benefits are calculated by summing all benefits as outlined above. While it is assumed that benefits are constant over time, as with costs if a specific benefit accrues in any one year it is possible to alter the value of that benefit for that year.

Simple net benefits

To calculate the net benefits, for any one year, the total costs are subtracted from the total returns for that year. However, this calculation does not directly include inflation, interest or tax as the analyses is a social cost benefit analysis as opposed to a private analysis.

Accounting for risk

There is uncertainty associated with supply of water due to unpredictable climatic variations as well as demand for water as it is contingent upon population growth and/or behaviour. While the discount rate could be altered to account for uncertainty, it assumes constant uncertainty over time, which may not be the case. Instead, the impact of risk associated with relevant parameters in the model will be assessed by varying those parameters in a sensitivity analysis so as to determine the importance of these changes on the overall outcome.

Time

The model integrates economic (e.g. cost of water bought for irrigation or household use) and physical components (e.g. flow volumes and timing). For economic aspects, the time step is annual. For physical processes, input can be varied and so the length of time depends on management plans set in place. Nevertheless, the analyses are based on a 20 year time period. At the end of this period is assumed that all benefits derived from each option would have been realised. Furthermore, extending the time period beyond 20 years results in benefits and costs after this time being significantly discounted and hence the impact of these values do not weight heavily on the overall outcome.

Discount rate

Discounting is necessary in CBA because people value things (such as money) more highly now than in the future. $1,000 now could be put to another use e.g. invested and return $80 (at 8% p.a. interest). Also, there is the issuer of uncertainty. Faced with a choice of being given $1,000 now or $1,000 in a year, a person will likely take it now; to avoid any risk (whether small of large) that something might happen during that year for the money not to be delivered.

To take account of this, therefore, costs and benefits for very year after year 1 are discounted to be equivalent to year 1, or present, values. So when costs are taken away from benefits, we get the net present value. It is convention that the discount rate should be equivalent to the real bank interest rate and so for the purpose of this analysis it will be set to 4%. However as the time period is relatively long, higher rates of 7% will be considered in sensitivity analyses to determine the effect on the overall outcome.

Decision criteria

In cost benefit analyses, decision criteria can be presented as the net present value (*NPV*), the internal rate of return (*IRR*), or as the benefit cost ratio. To calculate the *NPV* for the period of the project, the total costs are subtracted from the total returns for each year, summed and discounted. The option with the highest NPV will likely be the preferred option, although NPV is a tool and the final outcome rests with the decision maker. That is, the decision maker can choose an option with a lesser NPV if he or she feels it includes a benefit that wasn't able to be included in the CBA (wasn't able to have a dollar value placed on it. The *IRR* is calculated as the discount rate when the *NPV* is set to equal zero. A strategy would be preferred if the *IRR* is greater than the discount rate. The benefit cost ratio is simply the net benefits divided by the net costs and if greater than zero it indicates that benefits derived from the project are greater than the costs.

In this project harvested water is not traded in the market price and hence price of this water is not available. Hence calculating the *NPV* is not a straight forward process. Therefore perhaps the most informative information for decision makers would be to determine the price of harvested water so as to 'break even'. That is when the *NPV* is zero or the *IRR* is equivalent to the discount rate.

Chapter 3

Current water use

Currently the existing sports dam is providing 19ML of water annually and used on the oval. As total requirement for irrigation water in Lake Grace is just over 50ML per year (KBR 2005), the remaining water is provided by scheme water. The aim of this chapter is to present an analysis outlining the potential costs and benefits of providing water from the existing sports dam for irrigation purposes.

Costs

Capital costs

It is assumed that there is an existing pump and for the purpose of this analysis a new supply pump will be replaced in year 11 at a cost of $27,230. This costing is in line with the expected cost of a pump for the new dam as estimated in DAWA/Shire rates[5] for Option 2b and reported in KBR (2005).Contingencies amount to $5,000 in year 1. It is assumed that over the 20 year period no further capital costs are required. Opportunity cost of money and capital costs per kilolitre of product water amount to $0.09/kL.

Annual operating costs

Pump operating is assumed to cost $5,783 per year and repairs and maintenance total $4,480 annually giving a total annual operating cost of $10,263. Annual operating costs per kilolitre of product water equates to $0.54/kL.

Benefits

Water sales

Benefits from water sales are calculated by multiplying the sale price by the quantity of water sold over a year. It is assumed that the price of water is not contingent upon demand and hence remains constant over the year.

[5] DAWA (Department of Agriculture, Western Australia) and the Shire of Lake Grace provided supplementary costings as described in KBR (2005).

Other benefits

It is assumed that no other benefits arise from the presence of this dam.

Risk

Life of the dam and water yield

It is assumed that the sports dam in its existing state will remain in a viable state for the 20 year period of this analysis and will maintain a consistent yield of 19ML/yr. As minimal allowances have been made for repairs and maintenance it is possible that the dam will yield less than the expected amount. Furthermore, it is assumed that rainfall will remain reasonably consistent so ensuring yield is reliable which may not be the case. Therefore sensitivity analyses will be completed with the yield at plus and minus 10% of the expected water yield.

Water price and net benefits

Given the assumptions outlined above, water must be sold by the 'water enterprise' for at least $0.63/kL for the project to break even given a discount rate of 7%. However, if 19ML of water was purchased annually for the oval and park at this price, and the remaining 31.4ML of water required was purchased from the scheme at $1.20/kL, the average cost of water would increase to $0.98/kL.

Sensitivity analyses

Discount rate

Decreasing the discount rate to 4% results in the water price falling very slightly to $0.628/kL in order for the 'water enterprise' to break even.

Yield of product water

With a discount rate of 7%, increasing the volume of product water by 10% results in the break even water price falling to $0.57/kL. However, a decrease of 47.3% in water volume, so giving a total yield of 9.98ML annually, would result in a breakeven price of $1.20. In addition, with the inclusion of scheme water in this scenario so as to make up the shortfall in supply of 31.4ML, the average price of water was $0.98/kL.

Change in costs

With a discount rate of 7%, decreasing all costs by 20%, as suggested by KBR (2005), would mean the price of water could decrease to $0.50/kL, for the dam enterprise to break even. Increasing costs by 30% results in the water price having to increase to $0.82/kL so as to break even. Costs could be increased by up to 90% and still the project would be viable if water was to be sold at $1.20/kL.

Including Option 3

Including the surface water management as suggested by KBR (2005) for Option 3 means that capital costs would increase by $529,600 for Option 3a and by $62,406 for Option 3b[6]. Annual operating costs for each option would increase by $4,480. With a discount rate of 7%, water would have to be sold for $2.33/kL if Option 3a was included with the base case scenario defined for this option, and for $0.01/kL if Option 3b was instead included with this option.

Conclusions

Under the assumptions outlined in this chapter, water provided by the existing sports dam could be sold well below the current scheme water price and still be a viable proposition. Furthermore, as this option generates net benefits, consideration of minor upgrades could be made to this dam over the 20 year period and harvesting surface water would still work out to be a better proposition than buying scheme water. Decreasing water yield or increasing costs by a reasonable amount did not alter the outcome for these results. Water yield would have to be decreased by almost half before the price of harvested water was equivalent to the scheme water price. Furthermore, when the price of scheme water was included in this analysis to make up the shortfall in supply, the average price of water was still below $1.00/kL. Including Option 3a with this scenario resulted in a breakeven water price well above the scheme water price. However, including the costs for Option 3b with the costs for this scenario resulted in a water price just above $0.00/kL. Nevertheless, care must be taken in considering these results as the costs used in this analysis are based on estimations.

[6] See Chapter 6 below for full details of costs

Chapter 4

Option 1

The aim of Option 1 is to determine the net benefits of ensuring structural integrity and performance of supply from the existing sports dam. The benefits include delivery of 35ML[7] of water annually to the oval in Lake Grace. For this option it is assumed that if the capital expenditure was not spent on the sports dam then there could be no guarantee that 19ML of water would be supplied each year. As surface water is not directed out of the town it is assumed that there aren't any benefits from reduced damage to town infrastructure for Option 1 alone. Two scenarios are investigated in this chapter. The first relies on data provided by KBR (Option 1a) and the second by DAWA and the Shire of Lake Grace (Option 1b).

Costs

Capital costs

Initial capital costs are presented in Table 3. In addition the pump will be replaced in year 11 at a current cost of $30,770 for Option 1a and $27,230 for Option 1b[8]. It is assumed that over the 20 year period no further capital costs are required. Opportunity cost of money and capital costs per kilolitre of product water amount to $0.70/kL for Option 1a and $0.34/kL for Option 1b.

Table 3. Initial capital costs required for the existing sports dam

Description of capital cost	Option 1a	Option 1b
Increase size of town dam roaded catchment	$109,800	$91,500
Upgrade inlet structure for existing town dam	$2,800	$500
Upgrade outlet structure for existing town dam	$4,283	$500
Upgrade overflow structure for existing town dam	$14,310	$2,960
Allowances, fees and contingencies	$114,400	$0
Total	$245,593	$95,460

Source: KBR (2005)

[7] As estimated by KBR (2005)

[8] As estimated for Option 2b (see Chapter 5)

Annual operating costs

Based on KBR (2005), pump operating is assumed to be $5,783 per year and repairs and maintenance total $4,480 annually giving a total annual operating cost of $10,263. Annual operating costs per kilolitre of product water equates to $0.29/kL.

Benefits

Water sales

Benefits from water sales are calculated by multiplying the sale price by the quantity of water sold over a year. It is assumed that the price of water is not contingent upon demand and hence remains constant over the year.

Other benefits

It is assumed that no other benefits arise from the presence of this dam.

Risk

Water yield

It is assumed that rainfall will remain reasonably consistent so ensuring yield is reliable which may not be the case. Therefore sensitivity analyses will be completed with the yield at plus and minus 10% of the expected water yield.

Net benefits and water price

Given the assumptions outlined above, water must be sold for at least $0.99/kL for Option 1a and $0.63 for Option 1b so that the project breaks even (given a discount rate of 7%).

Sensitivity analyses

Discount rate

Decreasing the discount rate to 4% results in the water price falling to $0.86/kL for Option 1a and $0.58 for Option 1b so as to break even

Yield of product water

With a discount rate of 7%, reducing the volume of product water by 10% would mean the price of water would have to increase to $1.11/kL for Option 1a and to $0.70 for Option 1b so as to break even. A 10% increase in water volume (to 38.5ML) would see the price for Option 1a fall to $0.90/kL and that for Option 1b falling to $0.57/kL. Water production would have to decrease by just over 17% to give 29ML annually for Option 1a to be a better option than simply using scheme water. For Option 1b, the decrease would need to be just over 47%, thereby giving a total product of 18.4ML of water per year for this scenario to be considered as a better alternative to scheme water.

A 54% reduction in water volume is approximately equivalent to assuming that the total costs have been attributed only to the 'new' water produced from these capital works (16ML). Or in other words, none of the additional capital costs are required to produce the 19ML of water that is currently available from the existing dam each year. If this is actually the case then for Option 1a the breakeven water price would be $2.16/kL and for Option 1b, $1.37/kL.

In addition, with the inclusion of scheme water in this scenario so as to make up the shortfall in supply of 15.4ML, the average price of water would have to increase to $1.06/kL for Option 1a and to $0.80/kL for Option 1b for these options to still be viable propositions.

Change in costs

Given a discount rate of 7%, increasing costs by 30% would mean the price of water would have to increase to $1.29/kL for Option 1a and to $0.85 for Option 1b before breaking break even. However, if costs were decreased by 20% then the price of water required to break even would decrease to $0.80/kL for Option 1a and to $0.49 for Option 1b. To give a breakeven dollar value equivalent to that of scheme water, costs would have to increase by just over 20% for Option 1a and by around 74% for Option 1b.

Including Option 3

Including the surface water management as suggested by KBR (2005) for Option 3 means that capital costs would increase by $529,600 for Option 3a and by $62,406 for Option 3b[9]. Annual operating costs for each option would increase by $4,480. With a discount rate of 7%, water would have to be sold for $1.92/kL if Option 3a was included with Option 1a and for $0.66/kL if Option 3b was instead included with this option. Likewise if Option 3a was included with Option 1b, water would have to be sold for $1.56/kL to make the proposition viable and for $0.30/kL if Option 3b was included instead of 3a. Note it is assumed that benefits from damage reduction are set at 100% for this scenario.

Conclusions

Given the assumptions outlined in this chapter, water provided by the existing dam with additional roaded catchment could be sold below the current scheme water price of

[9] See Chapter 6 below for full details of costs

$1.20/kL for each option and still be viable propositions. Achieving a reasonable decrease in costs or increase in the water yield would not alter this conclusion for Option 1b. However, increasing the costs by perhaps a feasible amount could see purchasing scheme water being a sound alternative to Option 1a. It must be noted that the analysis has been completed on delivering the total water yield and not just the additional yield over and above that produced currently. As a consequence, the prices found for the base case scenario may be underestimated. If the costs pertained to the 'new water' only, then for Option 1a, the breakeven water price would need to increase by more than $1/kL over the base case and by around $0.75/kL for Option 1b. In both cases the price of product water would be greater than that for scheme water. In addition, when the price of scheme water was included in this analysis to make up the shortfall in supply, the average price of water was below $1.10/kL for both options. Including Option 3a with these scenarios resulted in a breakeven water price above the scheme water price. However, including the costs for Option 3b with the costs for both options resulted in water prices well below $1.20/kL.

Chapter 5

Option 2

Option 2 involves capturing surface water runoff from within the Lake Grace town site and pumping it into the existing sports dam for storage (Option 2a) or pumping the water into a new dam for storage (Option 2b). The cost of upgrading the existing sports dam as described for Option 1 is also applicable for Option 2a. A new dam will be constructed as part of the plan for Option 2b and hence relevant costs associated with this dam will be included in this option. Costs associated with integrating a sump into the water management plan will be included in both options. Based on explanations produced in KBR (2005), Options 2a1 and 2b1 include cost estimates from KBR, while Options 2a2 and 2b2 are based on costs provided by DAWA and the Shire of Lake Grace.

It is anticipated that Option 2a will provide 69ML of water annually because surface runoff is pumped back into the existing sports dam and hence combines with the water captured from the roaded catchment. Option 2b is expected to yield 36ML of water per year derived from the surface runoff flowing into the new dam but as this dam does not have roaded catchment connected to it, yield will be 15ML lower than that for Option 2a[10]. This water will provide direct benefits for the town as well as indirect benefits in terms of reduced damage to infrastructure.

Costs

Capital costs

Initial capital costs for Options 2a and 2b are presented in Table 4.

In addition, for both Options 2a and 2b, the two pumps will be replaced in year 11 at the same current cost as stipulated in Table 4. It is assumed that over the 20 year period no further capital costs are required. Opportunity cost of money and capital costs per kilolitre of product water amount to $1.08/kL for Option 2a1, $0.22/kL for Option 2a2, $3.76/kL for Option 2b1 and $1.24/kL for Option 2b2.

[10] As a note, available water yield does not equal surface runoff, which is expected to be 17.8ML per year, due to evaporation and leakage from the dams, and the requirement for the water to be at least 0.5m deep so that the pumps work

Table 4. Initial capital costs required to facilitate Options 2a and 2b

Description of capital cost	Cost of Option 2a1	Cost of Option 2a2	Cost of Option 2b1	Cost of Option 2b2
Upgrade inlet structure for existing sports dam	$3,200	$500	$0	$0
Upgrade outlet structure for existing sports dam	$4,283	$500	$0	$0
Upgrade overflow structure for existing sports dam	$14,310	$2,960	$0	$0
Upgrade drainage channel Kulin-Lake Grace Rd	$48,500	$1,000	$48,500	$1,000
New culverts at CBH	$57,906	$57,906	$57,906	$57,906
New dam	$0	$0	$303,550	$269,458
Reticulation line from new dam to oval	$0	$0	$11,550	$7,690
Pump from new dam to oval	$0	$0	$30,770	$27,230
New sump	$220,980	$28,727	$227,980	$28,727
Pump from new sump to existing sports/new dam	$30,770	$26,980	$30,770	$27,230
Pipe from new sump to existing pipe route/new dam	$22,110	$12,874	$30,700	$27,130
Allowances, fees and contingencies	$356,699	$0	$664.617	$0
Total	$758,758	$131,447	$1,406,343	$446,371

Source: KBR (2005)

Annual operating costs

Annual operating costs for Options 2a and 2b are detailed in Table 5. Annual operating costs per kilolitre of product water equates to $0.16/kL for Option 2a and $0.22 for Option 2b.

Table 5. Annual operating costs for Options 2a and 2b.

Description of annual operating costs	Cost of Option 2a	Cost of Option 2b
Operation of pump to oval	$5,783	$2,892
Operation of pumps from sump	$1,102	$551
Repairs and maintenance	$4,480	$4,480
Total	$11,365	$7,923

Source: KBR (2005)

Benefits

Water sales

Benefits from water sales are calculated by multiplying the sale price by the quantity of water sold over a year. It is assumed that the price of water is not contingent upon demand and hence remains constant over the year.

Other benefits

There may also be benefits from reduced damage to infrastructure within the townsite due to this water management option. Therefore so as not to miss any potential benefits, results incorporating benefits arising from reduced damage will be presented in the sensitivity analyses below.

Risk

Water yield

It is assumed that rainfall will remain reasonably consistent so ensuring yield is reliable which may not be the case. Therefore sensitivity analyses will be completed with the yield at plus and minus 10% of the expected water yield.

Net benefits and water price

Given the assumptions outlined for Option 2a1, water must be sold for at least $1.24/kL for the project to break even with a discount rate or IRR at 7%. Likewise for Option 2a2 water should be priced at $0.38/kL. Assuming Option 2b is considered independently of any other options, the price of water must be at least $3.98/kL for Option 2b1 and $1.46/kL for Option 2b2 (also assuming a discount rate of 7%).

Sensitivity analyses

Discount rate

For Option 2a1, decreasing the discount rate to 4% would result in the water price falling to $1.03/kL so that the project breaks even and for Option 2a2 to $0.34/kL. Likewise, the water price would fall to $3.22/kL for Option 2b1 and to $1.22/kL for Option 2b2.

Yield of product water

With a discount rate of 7%, reducing the volume of product water by 10% would mean the price of water would have to increase to $1.38/kL for Option 2a1 and to $0.42/kL for

Option 2a2. For Option 2b1 if the same decrease in volume was incurred then the price would have to increase to $4.42/kL and for Option 2b2, to $1.62/kL.

A 10% increase in water volume to 75.9ML would result in the price of water falling to $1.13 for Option 2a1 and to $0.35 for Option 2a2. The same percentage increase for Option 2b to give a total water volume of 39.6ML would result in the price of water dropping to $3.62 for Option 2b1 and to $1.32 for Option 2b2. Increasing the water volume by just 3.5% to 71.4ML for Option 2a1 would result in a breakeven price equivalent to that of scheme water. However, for Option 2a2, the volume could fall by just over 68% to 21.8ML per year and still be a better option than purchasing scheme water. So as to sell water at $1.20/kL and ensure the option is viable, the increase in water volume required for Option 2b1 would be just under 232% (i.e. a total water volume of 119.4ML annually would have to be produced). For Option 2b2, an increase of 21.5% or a total water volume of 43.7ML per year would be required for this scenario to be a better option than the purchase of scheme water.

Decreasing the volume of product water by 27% for Option 2a is approximately equivalent to assuming that the total costs have been attributed only to the 'new' water produced from these capital works. Or in other words, none of the additional capital costs are required to produce the 19ML of water that is currently available from the existing dam each year. If this is actually the case, then for Option 2a1, the breakeven water price would be $1.70/kL and for Option 2a2, $0.52/kL. Incidentally, this same amount of product water equates to annual demand. Hence if the additional water could not be used effectively and therefore the value of it was $0.00/kL then the same breakeven prices would apply.

With the inclusion of scheme water in the scenario for Option 2b so as to make up the shortfall in supply of 23.2ML, the average price of water would decrease to $2.89/kL for Option 2b1 and to $1.36/kL for Option 2b2 for these options to still be viable propositions

Change in costs

With a discount rate of 7%, increasing costs by 30% would mean the price of water would have to increase to $1.62/kL for Option 2a1, to $0.49/kL for Option 2a2, to $5.18/kL for Option 2b1 and to $1.90/kL for Option 2b2. With a 20% decrease in costs for Option 2a1, the breakeven price for water would drop to $0.99/kL, for Option 2a2, to $0.30/kL, for Option 2b1, to $3.19 and for Option 2b2, to $1.17kL. So as to breakeven at a water price of $1.20/kL, the cost of producing water in Option 2a1 would have to fall by just over 3%. Like wise the costs would have to increase by 216% for Option 2a2 to breakeven at $1.20/kL. In the case of Option 2b2, costs would have to fall by almost 70% and for Option 2b2, by just under 18% so that water can be produced at a price equivalent to that of scheme water.

Benefits from reduced damage to infrastructure

As explained in Chapter 2, the maximum benefit from reducing damage to infrastructure amounts to $22,060 per year (assuming a discount rate of 7%). If this total value is included in Option 2a1 the water must be sold at $1.18/kL, a drop of $0.06/kL on the base price reported above. Assuming that the benefits amount to 72% of the damage costs the breakeven water price increases to $1.20/kL. As the breakeven water price for Option 2a2 is well below the scheme water price of $1.20/kL, include benefits arising from damage reduction will not alter the overall outcome of the results of this scenario.

With regard to Option 2b1, so as to break even, the price of water would have to sell at $3.87/kL when 100% of the damage costs were included as benefits. Even though this equates to $0.11 drop from the base case, the price of water is still well in excess of that for scheme water. A similar situation arises for Option 2b2 with the price of water falling to $1.35/kL when 100% of the damage benefits are included.

Including Option 3

Including the surface water management as suggested by KBR (2005) for Option 3 means that capital costs would increase by $529,600 for Option 3a and by $62,406 for Option 3b[11]. Annual operating costs for each option would increase by $4,480. With a discount rate of 7%, water would have to be sold for $1.71/kL if Option 3a was included with Option 2a1 but for only $0.85/kL if it was combined with Option 2a2. Including Option 3b with Option 2a1 resulted in a breakeven water price of $1.07/kL and with Option 2a2, a price of $0.21/kL. While the overall outcome was not changed for Option 2a2, Option 2a1 became a better alternative to scheme water once it was in combination with Option 3. Combining Option 3 with Option 2b did not reduce the viable water price to below $1.20/kL except for Option 2b2 together with Option 3b where the water price fell to $1.13/kL. However, Note it is assumed that benefits from damage reduction are set at 100% for this scenario.

Conclusions

Allowing for the assumptions outlined in this chapter, product water provided by the Option 2a2 could be sold below the scheme water price of $1.20/kL and still be viable propositions. Option 2a1 could be a viable alternative with the inclusion of reasonable decreases in costs, increases in water production or recognition of benefits from reduced damage to town infrastructure. Options 2b1 and 2b2 were essentially not considered viable alternatives when these options were considered independently of the other options. Changing the water yield, discount rate or costs by a reasonable amount did not affect the general outcome of any options except for Option 2a1. This was also the case when benefits from reduced damage to infrastructure were included, where appropriate, in the analyses. Furthermore, if the capital costs are linked specifically to the ‘new water’ produced in Options 2a then the breakeven water price would be greater than the price of scheme water for Option 2a1 but still less than this price for Option 2a2.

As Options 2a will provide water in excess of the current water requirements for Lake Grace, this extra water will be worth nothing unless it can be utilised. While Option 2a2 would still be a viable alternative to scheme water, Option 2a1 would be an even worse alternative than the base case. It could be assumed that uses could be found for excess irrigation water for industry or for beautifying the town if it was viable to do so. Alternatively Option 2b will provide less than the required water for the town and therefore when the breakeven price of water for this option was combined with the

[11] See Chapter 6 below for full details of costs

scheme water price the average price fell but as expected to a level above that of scheme water.

Including Option 3a with these scenarios did not alter the overall outcome for any of the scenarios except when Options 2a1 and 2b2 were combined with Option 3b. In both incidences the price of product water was reduced to a level below $1.20/kL.

Chapter 6

Option 3

The purpose of investigating Option 3 is to determine the net benefits that arise from installing drainage channels within the Lake Grace town site and directing the water to the lake system west of the town. As the water is discarded there won't be any benefits from selling the water. However, there should be benefits from reduced infrastructure damage. Based on explanations produced in KBR (2005), Option 3a includes cost estimates from KBR, while Option 3b is based on costs provided by DAWA and the Shire of Lake Grace.

Costs

Capital costs

Initial capital costs are presented in Table 6. It is assumed that over the 20 year period no further capital costs are required.

Table 6. Initial capital costs required to facilitate Option 3

Description of capital cost	Option 3a	Option 3b
Upgrade drainage channel Kulin-Lake Grace Rd	$48,500	$1,000
New culverts at CBH	$57,906	$57,406
Install drainage channel Boulton St & Dewar St	$176,500	$4,000
Allowances, fees and contingencies	$246,694	$0.00
Total	$529,600	$62,406

Source: KBR (2005)

Annual operating costs

Based on KBR (2005), annual operating costs total $4,480 for both options and account for repairs and maintenance.

Benefits

Water sales

As noted above there aren't any water sales in this scenario.

Other benefits

It is expected that there will be benefits from reduced damage to infrastructure within the townsite due to this water management option. In the base case scenario it is assumed that 100% of the damage costs will be transferred into benefits. As these benefits have been calculated using a 7% discount rate, this rate will be used for all of the analyses presented below.

Net benefits and water price

With a discount rate of 7% and given the assumptions outlined above, the net present value for Option 3a would be -$342,955 with a benefit cost ratio of 0.69, while for Option 3b, the net present value would be $123,903 with a benefit cost ration of 29%

Sensitivity analyses

Increase in benefits from reduced damage

For Option 3a, benefits from reducing damage to infrastructure within the town site would have to increase to $54,450 or by two and a half times the original estimation of $22,060. Alternatively for Option 3b, benefits would have to decrease by a little over half to $10,370 before the project produced negative returns.

Decrease in costs

Given the assumption mentioned in this chapter, costs would have to decrease by just over 223% (certeris paribus) for Option 3a to be a viable proposition. For Option 3b, if costs increased by around 80% this scenario would still be a viable option to consider.

Conclusions

As water is not generated for sale, this option is assessed purely on benefits arising from reduced damage to infrastructure. Unless benefits arising from reduced damage costs are increased significantly or capital and operating costs are reduced, Option 3a is not a viable alternative. However, Option 3b should be considered as a viable water management option in Lake Grace as the benefits of this option out weight the costs despite more than reasonable changes in the parameters.

Chapter 7

Comparison of Options

In this chapter each of the options are summarised and ranked in order of highest net benefits. However, decision makers should have full understanding of the reasons for ranking them in such an order so that they can use these ranking effectively when making their decisions.

Overview of the cases

Acknowledging the assumptions stated, the current supply of water provided by the existing sports dam could be sold below the current scheme water price and still be a viable proposition. Even if costs were increased by almost 100% or the quantity of water reduced by around 47%, the breakeven water price would be below the scheme water price of $1.20/kL. Averaging the price for total water required by the town to include this water and scheme water did not result in a price over $1.00/ML

Option 1 deals with improving the reliability of the existing sports dam for irrigation within Lake Grace by increasing the dam catchment. Analyses showed that dam water could be sold below the current scheme water price of $1.20/kL for Option 1 to be a viable proposition. More than reasonable increases in costs or decreases in water yield are required to push the breakeven dam water price over the scheme water price. As the analysis has been completed on delivering the total water yield and not just the additional yield over and above that produced currently consideration should be given to the breakeven water prices when only the 'new' water is included as for both Options 1a and 1b, the breakeven water price is above the scheme water price. Otherwise, the prices found for the base case scenario may be underestimated. The average water price combining water produced via this option and scheme water is around $1.00/ML for both options

In Option 2 the plan is to capture storm water runoff from the town site via a sump then pump it into the existing sports dam for storage (Option 2a) or to the new dam for storage (Option 2b). Results from the analyses suggest that product water provided by Option 2a2 could be sold below the scheme water price while that calculated for Option 2a1 is almost equivalent to that for scheme water. For Options 2b1 and 2b2 dam water would have to be sold above the current scheme water price for it to be a viable proposition. The results are sensitive to water yield decreases and cost increases for Option 2a1. In addition, if benefits from damage reduction within the town site are included in the analyses, Option 2a1 and 2b2 become a better proposition than scheme water. The capital costs are linked specifically to the 'new water' produced in Option 2a then the breakeven water price is underestimated in the base analysis.

As water is not generated for sale, Option 3 is assessed on benefits arising from reduced damage to infrastructure. Unless benefits derived from the diversion of surface water are significantly greater, or costs are substantially less, the costs do not outweigh the benefits for Option 3a. However, given the benefits arising from reduced damage within Lake Grace, Option 3b appears to a reasonable option. The only scenario where the breakeven water price is below that of scheme water is when Option 3a is combined with Option 2a2. However, when Option 3b is combined with the current options plus Options 1a, 1b, 2a1, 2a2 and 2b2, the resulting breakeven water price is below the scheme water price.

Ranking of the options

Based on the assumptions outlined in this document, the 'do nothing' option is ranked highly in the list of alternatives (Table 7). However, the costs were assumed and there may be a greater risk in supply being achieved over the 20 year period. Of the base case options considered that add improvements to the current water management plan, the lowest price that product water must be sold at so as to break even is for Option 2a2. This option is the highest ranked alternative when assessing it from a total yield or marginal yield perspective (Table 7). Options 1a and 1b could also be sold below the scheme water price of $1.20/kL and still be viable propositions. Although, when looking at marginal yield only, the outcome for both options does not appear to be a better proposition than purchasing scheme water. Options 2b1 and 2b2 were essentially not considered viable alternatives when these options were considered independently of the other options.

Table 7. Ranking the Options in ascending order of water price required to break even.

Option	Water Price $/kL (assumed costs to supply total yield)	Option	Water Price $/kL (assumed costs to supply marginal yield)	Option	Water Price $/kL (assumed combined with Option 3b)
Option 2a2	0.38	Option 2a2	0.52	Current	0.01
Option 1b	0.63	Current	0.63	Option 2a2	0.21
Current	0.63	Option 1b	1.37	Option 1b	0.30
Option 1a	0.99	Option 2b2	1.46	Option 1a	0.66
Option 2a1	1.24	Option 2a1	1.70	Option 2a1	1.07
Option 2b2	1.46	Option 1a	2.16	Option 2b2	1.13
Option 2b1	3.98	Option 2b1	3.98	Option 2b1	3.66

When Option 3a was included with any of the other options, only the combination with Option 2a2 proved to be a viable alternative. Alternatively, all options, except for Option 2b1, produced breakeven water prices lower than the scheme water price when combined with Option 3b (Table 7).

Chapter 8

Capacity of this work

Understanding the scope of this project is important for interpreting the results derived from the analyses. This work will not automatically calculate which strategy is 'best'. The strategies have been evaluated using experimentation and 'trial and error'. Furthermore, generally the analyses do not represent year-to-year variation in weather, potential yield or water output. However, general changes can be manually placed in the model.

Even though great care has been taken in data collection and model development so as to create a robust model, there are always opportunities for changing parameters to reach alternative outcomes. Also, as the values included in this analysis are representative of a specific town in Western Australia, model parameters will need adjusting for other towns and for other regions.

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