Economics of Water Infrastructure Options to Address Salinity Damage in Western Australian Rural Towns

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ABSTRACT

Dryland salinity is one of the most serious natural resource issues facing Australia. Clearing of native vegetation after European settlement led to groundwater tables rising, bringing with them naturally occurring salts that degrade agricultural land, broader landscapes and rural town infrastructure. Affecting large amounts of Western Australia's Wheatbelt, forecasts are that this damage will inevitably worsen over coming decades due to actions already taken. A great deal more is known about the causes and impacts of salinity than the effectiveness and economic viability of remediation. Substantial research has been done into the economics of remedial action for agriculture, but very little has been done on rural towns. This research examined the economic viability of remedial action on WA rural town infrastructure by applying cost benefit analysis to a case study in the town of Wagin. The findings suggest that groundwater abstraction, desalination and water sale for reuse is economical, but only where waste water is disposed of into existing salt lakes rather than purpose-built evaporation ponds. The results also suggest that a much smaller project involving simply pumping groundwater from Wagin and disposal without treatment directly into existing salt lakes, could be economically viable. It should be noted, however, that environmental and social impacts were not part of the calculations, the inclusion of which could change the result. Externalities and property rights are key concepts both in explaining how this situation developed, and how we could learn from history and avoid similar situations in the future.

Acronyms

ASR	Aquifer Storage and Recovery
BCR	Benefit cost ratio
CBA	Cost benefit analysis
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industry Research Organisation
CSO	Community service obligation
IRR	Internal rate of return
OECD	Organisation for Economic Cooperation and Development
NPV	Net present value
RTLAP	Rural Towns Liquid Assets Project
USEAP	Urban Salinity Economic Analysis Package
UWA	University of Western Australia
WTA	Willingness to accept
WTP	Willingness to pay

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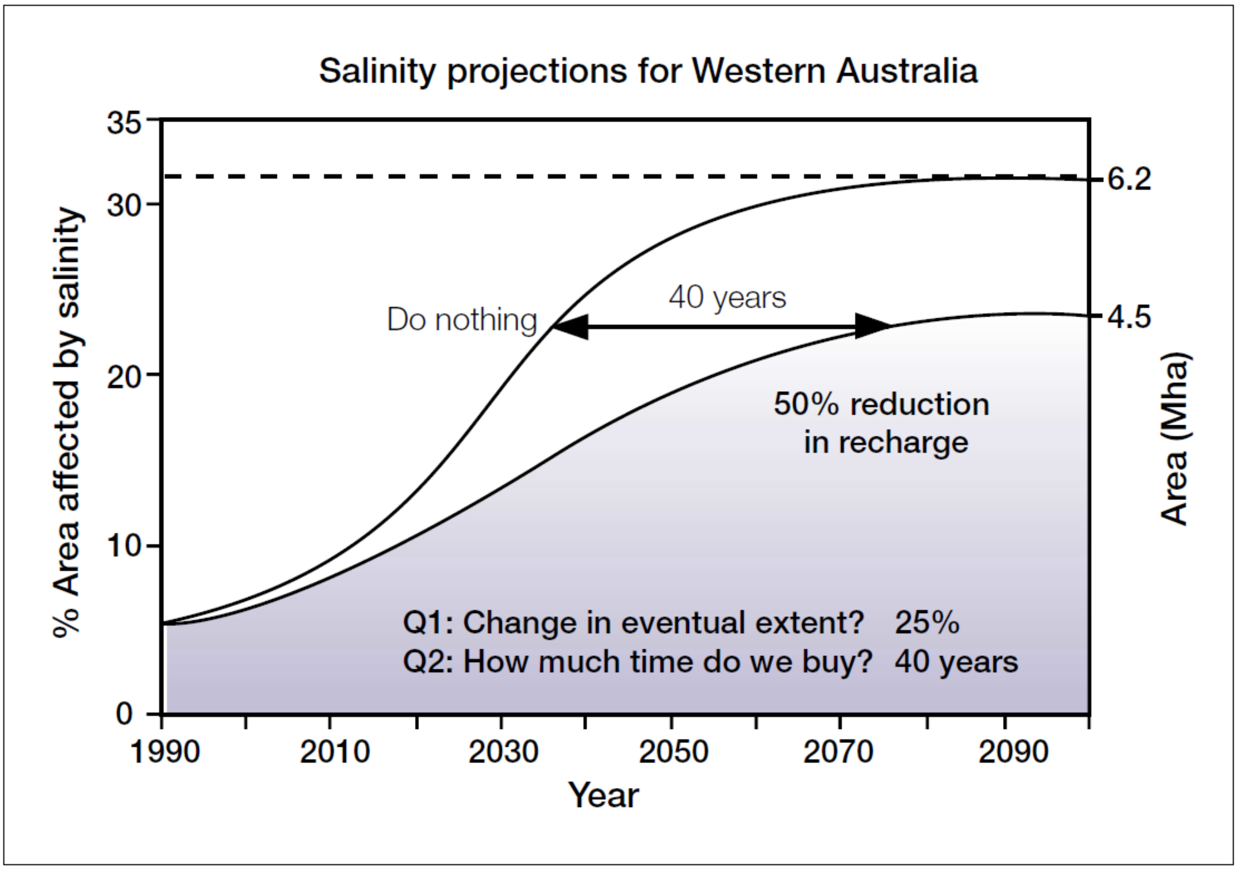
1. Introduction

Dryland salinity is one of the most serious natural resource management issues in Australia (State Salinity Council , 2000) (Pannell., 2002), with Western Australia having by far the greatest affected area in the nation (Auditor General, 2018). By the 1990s dryland salinity had become the State's greatest environmental and economic threat, with almost every stream and river in the Western Australian Wheatbelt affected. Evidence suggests the situation will inevitably get worse, as shown in Figure 1.1, due to land-use decisions that have already been made. If left unchecked, the amount of land affected could more than double to approximately five million hectares by 2100 (Auditor General, 2018).

Figure 1.1: Salinity projections for Western Australia



Source: (State Salinity Council , 2000)

Throughout the 20th century, most attention on the effects of salinity was given to its impacts on agriculture and productivity (House of Representatives Standing Committee on Science and Innovation, 2004; Pannell., 2002) or landscapes and waterways generally from the perspective of overall environmental health and ecosystem function (Williams, Walker, & Hatton, 2000). Completely recovering the landscape would likely take many decades and would come with significant impacts of its own. It is estimated that re-planting 80 per cent of the

Wheatbelt (to native vegetation) would be required, making broad scale agriculture, as it exists, impossible (Auditor General, 2018).

It is now appreciated that the non-agricultural implications will be at least as severe (Frost, Hamilton, Lloyd, & Pannell, 2001). Substantially more is known about the causes of salinity than the effectiveness and economics of various remediation options (Frost, Hamilton, Lloyd, & Pannell, 2001). While accurate estimates of impacts on infrastructure such as railways, roads and buildings are unavailable, local governments estimate the life of roads can be halved by salinity (Madden, Hayes, & Duggan, 2000). The National Land and Water Resources Audit (2001) identified 220 towns at risk from salinity. The question by this thesis is: is it worth investing to address damage and reduce future impacts, and if so, to what extent?

In response to this question, the WA Government, through the Department of Food and Agriculture, instituted the Rural Towns Liquid Assets Project (RTLAP), in collaboration with the CSIRO Land and Water under the Water for A Healthy Country Flagship, the University of WA and local governments (Pluske & Burton, 2005). The main aims of the initiative were to analyse whether there were economical ways to alleviate increasing salinity risk and damage, while concurrently identifying productive uses for excess water (URS, 2001). It was judged from analysis of similar situations that revenue from sale of this water would be required to tip intervention projects above an economic threshold that would make them viable. The RTLAP sought to make use of local water by beneficial diversion and capture of surface water and pumping of groundwater for re-use, rather than dispose of it, but in many cases it was in fact necessary to sell the water to a local customer in order to make interventions economically viable (e.g. Turner, et al., 2008).

Research at the time recommended undertaking cost benefit analysis (CBA) to determine the viability of groundwater pumping to protect public and private assets, including rural towns (URS, 2001; NSW Select Committee on Salinity, 2002). While there have been substantial economic evaluations of the net benefits of reallocation of water within the agriculture sector (Freebairn, 2001), economic analyses of water allocation to rural towns have been scarce and mainly in the form of overall Economic Regulation Authority reviews and the RTLAP.

Our knowledge of salinity management in rural town settings is a work-in-progress and estimates of costs associated with infrastructure repair, maintenance and replacement need to be improved (URS, 2001), with few studies estimating the economic desirability of remedial works (Hajkowicz & Young, 2000). Between 2003 and

2008 state and federal governments invested hundreds of millions of dollars in salinity remediation in Western Australia, however analysis on its effectiveness has not been done (Auditor General, 2018).

Detailed analysis needs to be done to determine the viability of specific interventions in specific towns. This thesis is a contribution to this body of work by applying CBA to remediation actions in the town of Wagin.

Ex-post CBA would have been an interesting analysis but there was not enough data on the actual costs and benefits to make this feasible. This thesis, therefore, considers what might be economical through the eyes of the decision-makers at the time with the information they had. As such, some references are current, illustrating that the problem still exists, but many of the references are the state of knowledge at the time.

Chapter 2 outlines the history of natural resource management in the Wheatbelt of WA that has resulted in rural towns suffering salinity damage. The chapter continues with a summary of key environmental economics concepts relevant to this situation, options to address salinity damage in rural towns and concludes with an introduction of the Wagin case study. Chapter 3 introduces CBA as a tool, including its theoretical foundations and key steps for implementation. Chapter 4 outlines the methodology used for the Wagin calculations, including where cost and benefit information was sourced, with results following in chapter 5. Discussion and interpretation of results take place in chapter 6, which elaborates on some of the key findings. Concluding remarks are in chapter 7.

2. Salinity and water management in Western Australia

Salt occurs naturally in the Australian landscape, having been carried inland by prevailing winds with rainfall and dust and deposited in small amounts, accumulating over many thousands of years (State Salinity Council , 2000). Enormous amounts of salt have been trapped over time, with the continent being very flat with a slight slope inland, meaning most of our rivers and groundwater systems are sluggish with little ability to move salts and drain the continent (Williams, Walker, & Hatton, 2000).

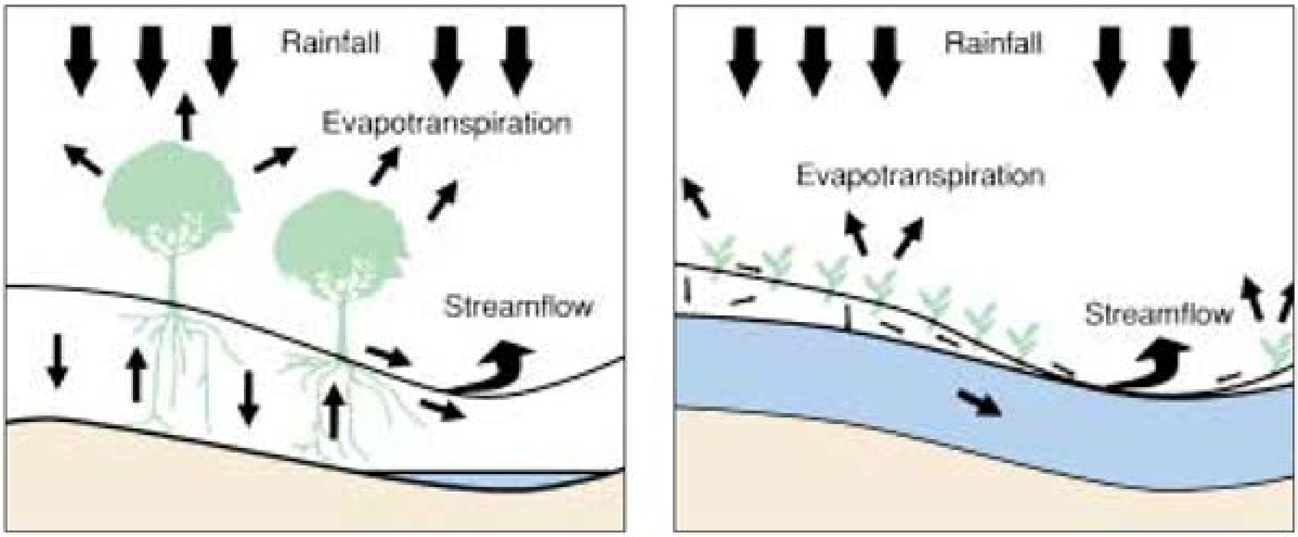
Figure 2.1: Salt affected landscape in the WA Wheatbelt showing dead trees and scorched earth.

Source: Department of Primary Industries and Regional Development (WA)

Low, variable rainfall means Western Australia has one of the lowest runoff to rainfall ratios in the world (State Salinity Council , 2000), with groundwater tables being in long-term equilibrium prior to European settlement (Pannell., 2002). Deep-rooted native vegetation has become particularly adept at taking full advantage of the limited, variable water available, with minimal water leaking past the root-zone. Over thousands of years this minimal leakage has caused aerially transported and deposited salts to accumulate below the root zone (State Salinity Council , 2000). This native vegetation evolved such that deep drainage, or leakage beneath the root zone into the landscape's internal drainage system was approximately balanced by the discharge rates from the landscape. Hence healthy native ecosystems and landscapes are in salt and water balance. Due to clearing and changes in catchment hydrology, more water began entering groundwater beneath towns than could be discharged (Frost, Hamilton, Lloyd, & Pannell, 2001), resulting in groundwater tables rising, as shown in Figure 2.2, bringing with them dissolved accumulated salts.

Given Australia's geological history and catchment characteristics, it was inevitable that clearing of native vegetation would lead to significant salinisation of land and water resources (Pannell., 2002). Once saline water reaches the surface, salinity is exacerbated by evaporation (Shimojima, Tamagawa, Horiuchi, Woodbury, & Turner, 2013) (Shimojima, Tamagawa, Horiuchi, Woodbury, & Turner, Observation of water and solute movement in a saline, bare soil, groundwater seepage area, Western Australia. Part 2: Annual water and solute balances, 2016), concentrating the salt where it is readily washed into waterways (polluting them) or in the case of rural towns, as soon as the salt gets to the surface or close enough to the surface, it makes contact with and degrades infrastructure. Rural town water management needs to be adjusted to bring it in line with the way the hydrology cycle operates (Wentworth Group, 2002).

Figure 2.2: Typical changes in water balance after clearing of native vegetation

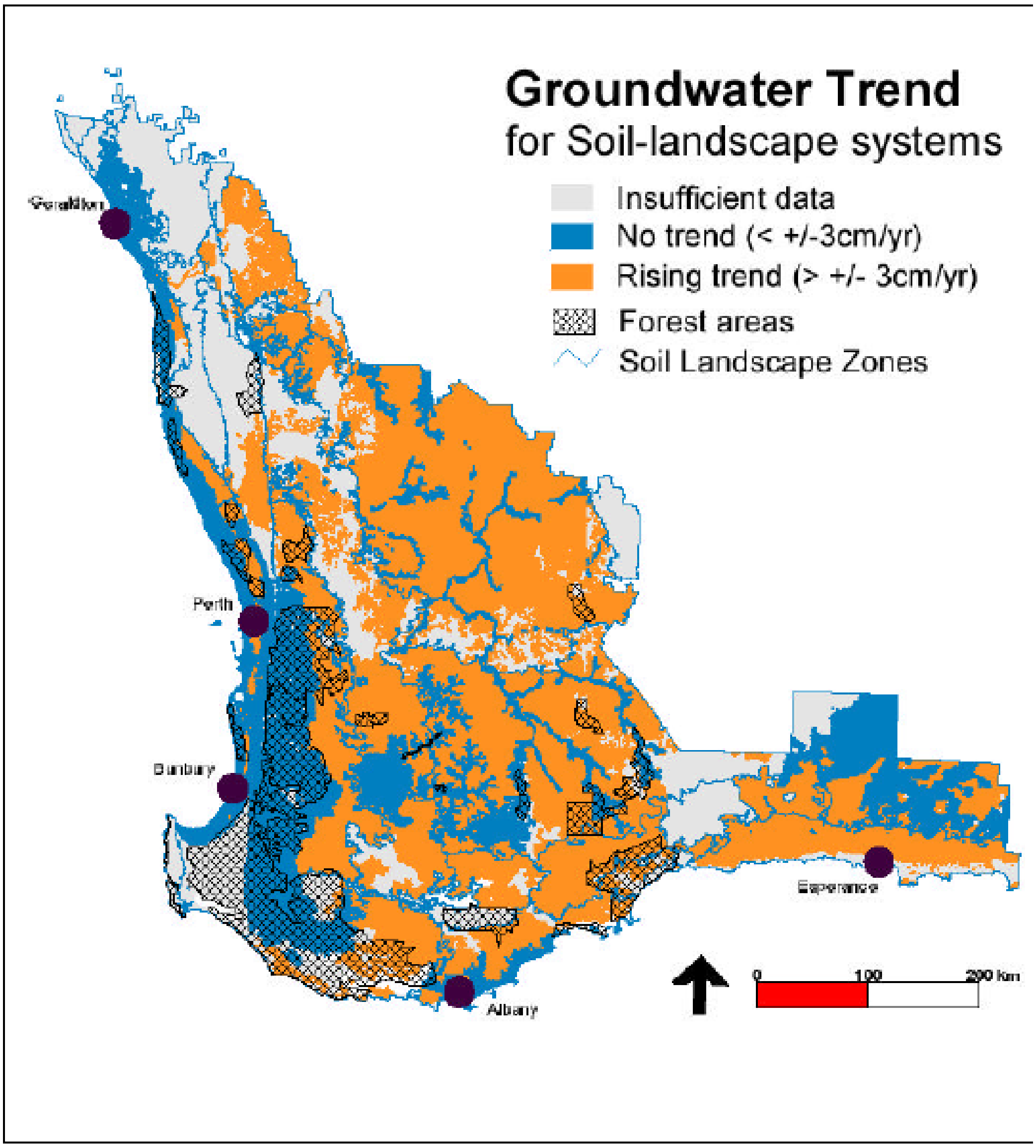


Source: (State Salinity Council , 2000)

In many parts of Australia, such as the Murray Darling Basin and Great Artesian Basin, groundwater levels are declining, risking the health of groundwater dependent ecosystems (Frost, Hamilton, Lloyd, & Pannell, 2001). In most Wheatbelt towns, on the other hand, groundwater levels were in fact rising, well into the 21st century.

Groundwater levels and salinity remediation works are generally related to topography and soil type, with groundwater levels deepest in the highest parts of the catchment (Heaney, Beare, & Bell, 2001). While valley floors were once the most productive part of the agricultural landscape, they are rapidly becoming the least productive (Thomas & Williamson, 2001). Most bores showed a rising trend, with water having already reached the surface in many cases (State Salinity Council , 2000). No systems had significant falling trends as of 2001, as shown in Figure 2.3 below.

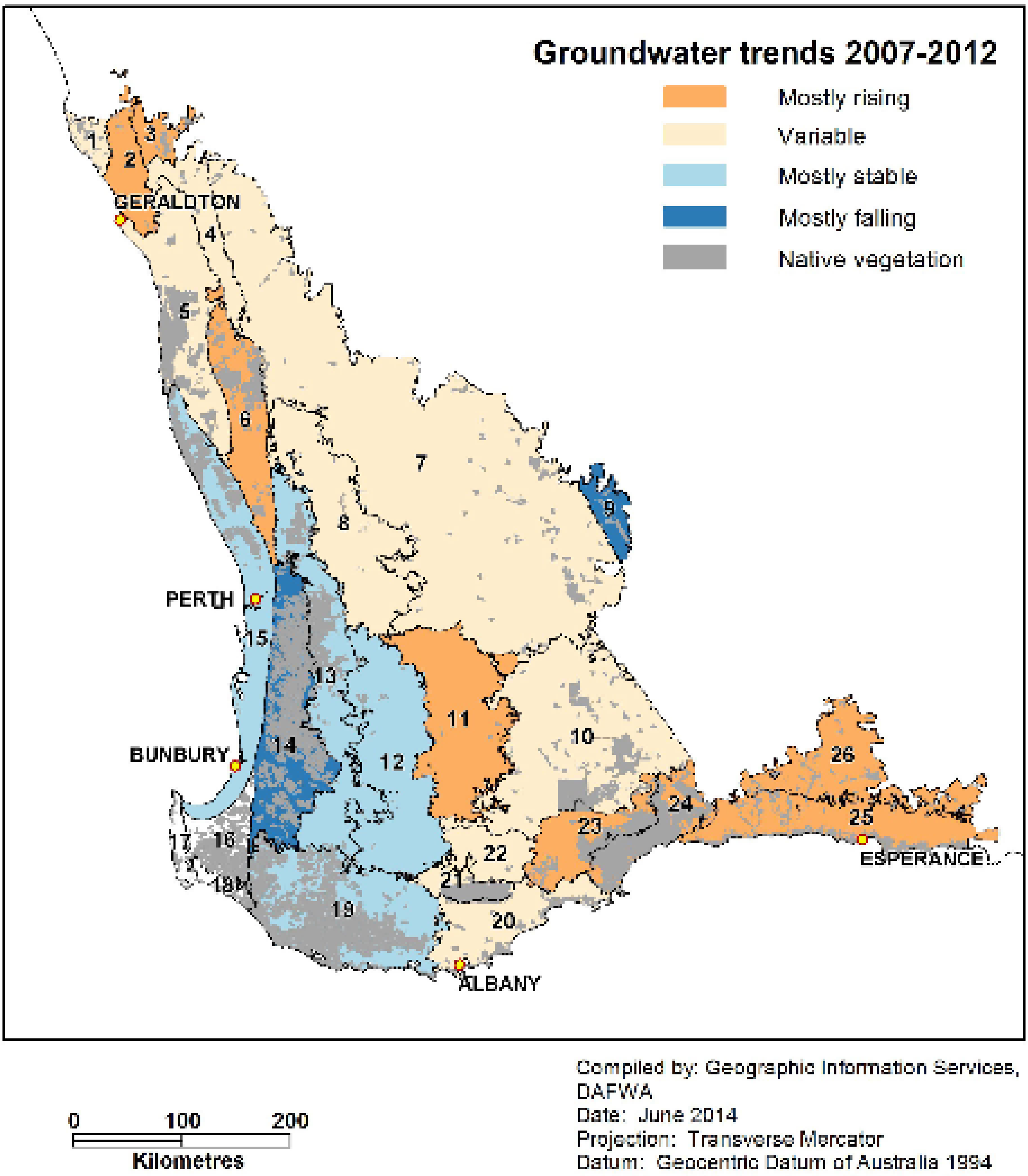
Figure 2.3: Groundwater Trend in South-West Western Australia up to 2001



Source: (Grant & Sharma, 2005)

More recent data shows these trends continuing, with 2007 to 2012 data displayed in Figure 2.4.

Figure 2.4: Groundwater Trends in South-West Western Australia 2007 to 2012



Compiled by: Geographic Information Services, DAFWA
Date: June 2014
Projection: Transverse Mercator
Datum: Geocentric Datum of Australia 1994
Grid: Map Grid of Australia 1994 Zone 50

Source: (Department of Agriculture and Food (WA), 2014)

Salinity measures to date have been shown to be almost an order of magnitude less than required and spread across the community for often little or no salinity remediation (Madden, Hayes, & Duggan, 2000), rather than targeted where efforts can have the greatest impact. Due to salinity being spread unevenly its impacts vary across the landscape (Auditor General, 2018). The protection of high value public assets such as town buildings, as well as supporting the community's social and economic capacity to manage salinity impacts, are expected to result in the highest benefit (Frost, Hamilton, Lloyd, & Pannell, 2001).

Successful interventions in the Denmark and Kent River catchments have seen reductions in salinity levels. For numerous other rivers in the South West such as the Blackwood, Avon, and Lort, salinity levels continue to increase (Frost, Hamilton, Lloyd, & Pannell, 2001).

2.1 History of WA regional development and Wheatbelt towns

There is an extensive history of salinity impacting rural town water supply, dating back to the early 1900s when railway engineers noticed increased salinity levels in dams and waterways (URS, 2001). Most rail networks were constructed in the lowest, flattest parts of the landscape, with towns emerging adjacent to rail lines to support agricultural products flowing to and from major cities and ports (URS, 2001). Wheatbelt towns are therefore in landscapes with little relief with most of the high value assets on the valley floor (Matta, 2000).

Due to local surface and groundwater being of generally poor quality, shires began to be supplied with water from Perth, through one of the most significant infrastructure projects in regional WA history, the C.Y. O'Connor pipeline (scheme water), completed in 1903. Inland WA was then opened up for mining and farming (Department of Treasury and Finance, 2004), and agriculture overtook gold as the state's major export.

With the pipeline, railway lines and government subsidies to wheat (including cheap land), large-scale land clearing took place during the first decade of the 20th century. Cleared adjacent farmland has led to substantially higher surface water run-off and town flooding, ponding and recharge and in turn damage to townsite infrastructure of roads, bridges and buildings (Heaney, Beare, & Bell, 2001). The Wheatbelt town of Moora, for example, experienced three 1-in-100 year floods in 1999 alone (URS, 2001).

The clearing of deep-rooted native vegetation in the wider catchment, while the central factor in catchment-wide dryland salinity, was considered a minor factor influencing the groundwater depth in towns, although it did mean higher surface-water runoff into towns from high in the catchment during peak rainfall events (Ohlsen, et al., 2005).

Replacement of native deep-rooted vegetation with hard surfaces such as roads and building roofs means substantially increased runoff and therefore flood risk, which in turn, leads to more rapid groundwater recharge, or flooding and pooling where ground is already saturated, particularly in lower lying areas of town.

Some dams constructed for water supply have seen watercourses feeding these dams become salinised and the dams needing to be abandoned (Thomas & Williamson, 2001). Environmental impacts in towns are quite different to the impacts in the broader catchment, however, given towns' ecosystems have been completely altered from their natural state. In addition, rural towns constitute a very small amount of their catchments, so there are not necessarily issues of habitat loss and impact on environmental flows in rural towns as there are in agricultural areas or large cities (Freebairn, 2001).

For decades of development from the 19th well into the 20th centuries, negligible consideration was given to environmental water uses, and their external effects. Governments funded the construction of dams and water distribution networks. In the first half of the 20th century, roads and railways were built significantly above ground. As road construction expanded in the latter half of the 20th century, techniques were taken for granted and roads were built at ground level (Vorobieff, 2001).

Motives of promoting population growth and agricultural, mining, and regional development, plus the electoral appeal of water infrastructure, overshadowed any formal economic or environmental assessment of the worth of projects. While the potential for salinity was recognised as early as 1907, it would be many years before it was acknowledged as a serious threat to sustainability of rural land use and remediation steps were taken (Department of Treasury and Finance, 2004).

The price of water, which despite being considered high by shires (Dogramaci S. , 2004), nevertheless receives heavy subsidies from the State Government through the Community Service Obligation (CSO). The outcomes from the introduction of any new water management initiative to address salinity, therefore, may be limited by the water pricing policy (URS, 2001). The CSO is a policy response to remote towns throughout arid Western Australia encountering high cost for additional water supply. Subsidised scheme water has led to large amounts of imported scheme water being used overwatering parks and playing fields, exacerbating groundwater recharge in rural towns (Barron, et al., 2010). In the case of Corrigin, the introduction of scheme water at the expense of groundwater use has contributed to a rise of 20 metres in the watertable (State Salinity Council , 2000).

Recharge causes are summarised in **Table 2-1**.

Table 2-1: The causes of soil saturation and recharge in towns include:

Recharge source
• Direct from the surrounding landscape (rainfall)
• Indirect From creeks and waterways
• Man-made influences such as garden irrigation, leaking pipes
• Leakage from water mains and septic tanks
• Imported water through overwatering of lawns and gardens
• Seepage from unsealed and partly sealed waterways
• Leakage from drainage lines from the wider catchment
• Roofs, roads and other hard surfaces from within towns
• Reduction of evapotranspiration within the townsite (due to clearing of vegetation)

Source: (URS, 2001) (Matta, 2000)

Brackish water can be used in some circumstances for irrigated agriculture, although some yield loss is likely. In some towns the groundwater may be stratified (see Table 2.2), in which case groundwater pumping of the relevant stratification would yield fresh water that could be used to substitute for scheme water (Thomas & Williamson, 2001).

Uses of water at different ranges of salinity are listed in Table 2-2. Salt concentration and potential uses for water are inversely correlated. The Australian Drinking Water Guidelines limit for safe drinking water is 500mg per litre, with high concentrations of salt being harmful to most plants and animals (Wheatbelt NRM, 2015). Groundwater salinity in the wheatbelt ranges from moderately saline in shallow parts of the landscape, to much higher concentrations than sea water in deep slow-moving aquifers. Most rural towns have salinity of 600 to 44,000 mg/L (URS, 2001), placing them in the range marginal to hypersaline.

Table 2-2: Salinity levels and uses

Description	Salinity (mg/L)	Suitable Use
Fresh	<500	All purposes, domestic and irrigation. Maintaining water quality is of high priority
Marginal	500-1,000	Most purposes. Maintaining water quality is of high priority
Brackish	1,000-1,500	Most purposes. Upper limit for drinking water. Maintaining water quality is of high priority
Brackish	1,500-3,000	Limited irrigation, all livestock. Maintaining water quality is of high priority
Saline	3,000-7,000	Most livestock. Ore processing.
Saline	7,000-14,000	Upper limit for livestock. Ore processing.
Saline	14,000-35,000	Limited industrial use. Ore processing.
Hypersaline	35,000-100,000	Limited industrial use. Ore processing.
Brine	>100,000	Brine production. Ore processing.

Source: (State Salinity Council , 2000)

Land is considered saline when groundwater rises to within one metre of the soil surface (URS, 2001). According to Nulsen (1981) and Heaney (2001) salinity begins to damage infrastructure when groundwater reaches a trigger level of 1.8m to 2m below the surface. Critical groundwater depth in NSW towns has been reported as 1.5m (Buckland, 2005).

For various WA soils the trigger depth may vary. Sand over clay (duplex) soils in the WA Wheatbelt contain enough clay for a capillary fringe to reach up to 3m, which indicates the requirement for the maximum depth of the groundwater table under building foundations to be deeper. In some cases this level needs to be drawn at 5 m below the surface (if building basements need to be protected).

Critical depths will differ depending on infrastructure. Cemeteries and underground tanks of petrol stations will be affected sooner than surface infrastructure such as buildings with concrete slabs, railways or playing fields. (URS, 2001). Table 2-3 lists the key groundwater depths in the WA Wheatbelt for the purposes of this study. Depth to groundwater in most rural towns was 2 to 7 m in the late 1990s (URS, 2001).

Table 2-3: Key groundwater depth and infrastructure damage

Groundwater depth (m)	Infrastructure damage
3	little or no damage
1.5	costs will be incurred for some damage to infrastructure
0.5	high costs incurred and possible eventual abandonment

Source: (URS, 2001)

The effect of salinity on plant growth is exacerbated when the soil is waterlogged. This is relevant to parks and gardens in rural towns. With a change in landscapes outlined above, groundwater is moving towards a new equilibrium. The threshold depth to groundwater for roads is considered to be 0.5m below the road structure.

While the RTLAP initially assumed that rural town infrastructure damage was from rising groundwater alone, further investigations demonstrated that surface-water management, waterlogging, and recharge were also central in most cases (URS, 2001). Some infrastructure damage, therefore, was being attributed to rising groundwater, when in fact it was due to surface water issues such as:

- Discharge of roof run-off directly into ground adjacent to buildings
- Run-off from hard surfaces being allowed to accumulate beneath and adjacent to buildings

2.2 Town Infrastructure damage and cost

Rising groundwater is affecting regional infrastructure in WA rural towns (State Salinity Council , 2000) (Eow, 2013). Extensive damage is being done to townsite infrastructure including buildings, sporting grounds, roads and railways, concrete structures such as dams and reservoirs. Indeed, the very existence of many rural towns is being threatened (Thomas, Gomboso, Oliver, & Ritchie, 1997). Damage to building materials (bricks, concrete) occurs as a result of their saturation with saline water. Salt concentrations are usually higher in the source material, than in the saline water entering roads; so the damage is exacerbated due to poor construction material and methods (Barron, et al., 2010) (State Salinity Council , 2000).

Concrete, cement and bricks may become significantly damaged by saline water (Grant & Sharma, 2005). If buildings are not equipped with vapour or moisture membranes, saline water following the capillary force migrates from soil through the building material and evaporates at the building surface exposed to the air. The effect of saline water aggression may be seen as weathering of bricks and concrete in the lower part of building structures, as shown in Figure 2.5. Degradation of parks, sports fields and other recreational facilities may result from waterlogging or salt accumulation in the root zone (State Salinity Council , 2000) (Barron, et al., 2010). In the absence of waterlogging, however, many plants are able to withstand high levels of salinity.

Figure 2.5: Salinity damaged building in rural towns

Source (Auditor General, 2018)

A study in the NSW town of Wagga Wagga found town damage costs of \$183m (Hill C. , 2000). Of this, \$88m (about 50 per cent) was water and stormwater infrastructure damage, and a further \$56m (30 per cent) was road damage. Severe effects of rising saline groundwater have been documented in NSW towns (Buckland, 2005). For a brick house on ground level, watertable depth of within half a metre was estimated to cost \$2,000 in maintenance and an additional \$6,000 three years after that for drainage repair work (Buckland, 2005). In some cases, lack of sealed drains or poor domestic water management, rather than rising groundwater, were considered responsible for damage (Frost, Hamilton, Lloyd, & Pannell, 2001).

Roads are the biggest cost to towns (Frost, et al., 2001), with sealed road life expectancy being reduced by up to 75 per cent by salinity. Repair costs have been estimated to be \$200,000 - \$400,000 per km, with total reconstruction costs for WA of \$50m-\$100m conservatively predicted between 2000 and 2020 (McRobert & Foley, 1999).

Road infrastructure damage is mainly related to waterlogging and to a lesser extent water salinity (Vorobieff, 2001). Rising water tables and salinity have four main effects on roads (Vorobieff, 2001):

- Rutting, from heavy vehicles having weakened the road structure
- Losing shape, resulting in uneven roads
- Seal “blister” leading to loss of seal, water infiltration and potholing
- Increased flooding, leading to increased siltation and lower capacity to discharge water

2.3 Environmental Economics and rural town salinity

From an environmental economics perspective, rural towns salinity infrastructure damage developed due to external costs not accounted for in original works. If these impacts were properly accounted for, it is argued that different choices would be made that prevent salinity, at least to a much greater degree than has been the case. If externalities had been accounted for, historical developments would:

a. not have occurred in the first place,
b. have occurred but designed in a way to avoid salinity (either just smarter design, or more expensive if still viable),
c. have occurred with compensation to those affected (or combination of b and c)

Almost all NRM issues involve a combination of public and private cost and benefit (Pannell, 2008), with many stemming from market failure and public policy inadequacy (Madden, Hayes, & Duggan, 2000). Government has a justification to intervene in the market to correct market failure, which can be caused by (Hajkowicz, Young, Wheeler, Hatton MacDonald, & Young, 2000):

- Asymmetric information

- Imperfect competition - monopoly or monopsony power
- Public goods
- Externalities
- income disparities

The key market failures that will be the focus of this paper are public goods and externalities.

A public good in its purest form has a very strict, technical definition: it is non-rival and non-excludable (URS, 2001). Non-rival means that one person using the good does not deny others from doing so. Non-excludable means that people cannot be prevented from enjoying or consuming the good. A lighthouse is a typical example of a public good. My using it does not prevent you using it, and neither of us can be prevented from using or benefiting from it.

Further, public goods are defined by the characteristic of the good, not the beneficiary. Actions that deliver benefits purely to privately owned assets can be public goods if the benefits are non-rival and non-excludable. An equivalent action that delivers a benefit to a single individual would not fall into the class of public good because the benefits can be ‘captured’ by that individual: if the benefits from undertaking the action exceed the costs, then the individual can profitably undertake that action (URS, 2001). Implementation of major infrastructure works to address groundwater rise, particularly pumping and sealed drains, can only be done realistically by government. Shires will need to design effective funding regimes that account for this (URS, 2001).

Externality is the term economists use to describe impacts of one economic agent on others (Pannell, McFarlane, & Ferdowsian, 2000). In relation to urban water, externalities are the sub-set of non-market impacts on the environment and the welfare of third parties that result from water use (Bowers & Young, 2000). The externality in this case is the damage done to town infrastructure from salinity as a result of changed hydrology and hydrogeology. Environmental standards and externalities change with our increased knowledge: the discharge of secondary sewage into a river system was once considered acceptable but the increasing occurrence of algal blooms has triggered the requirement of tertiary treatment (Bowers & Young, 2000). If this model were to be followed, landscape change and historical water use could have been acceptable until its link to salinity was discovered. This is a policy issue that will be picked up later in the paper.

The externality of salinity is a market failure due to the public good nature of environmental quality. Because of the free rider problem (you pay for groundwater pumping on your land and I benefit without paying for it), markets will under allocate water to public good uses. Also, from a government intervention perspective, individuals do not have an incentive to reveal their preferences and this gives rise to government failure as well as market failure (Heaney, Beare, & Bell, 2001). Environmental valuation techniques such as contingent valuation are only partially successful in assessing social values for public goods.

An externality can be negative, like water pollution, or positive, like the view of your neighbour's beautiful garden. What makes an externality negative or positive is dependent on society's definition of who has rights to use natural resources and the environment (Young M. , 2000). There is no right to return water to the environment in a lesser quality than it was taken, and no right to use water in a way that causes waterlogging, salinity or other problems (Young M. , 2000).

Society can encourage change through positive incentives or discourage change through negative incentives. Which approach is taken is based on who has property rights, which is a political decision (Pannell D. , 2008). A project may generate a combination of negative or positive private or public net benefits.

There are also transaction costs in implementing any market intervention (tax, subsidy, etc); as well as limitations of imperfect information. So, ironically, one market failure, imperfect information, could easily impede the resolution of another, externalities. Pannell (2008) outlines a range of rules for choosing the policy mechanism depending on the combination of private and public net benefits of a situation.

Eliminating environmental subsidies such as these would ensure the people pay the true cost of their consumption decisions and therefore sustainability would be encouraged (Wentworth Group, 2002). Firms, households and irrigators taking into account all the external impacts of their choices would take society much closer to using water at an economically optimal level. In order to achieve economic efficiency, prices must reflect the costs of producing and delivering water including those costs borne by the environment and/ or others (Hatton MacDonald, 2004). Council of Australian Governments (COAG) 1994 water reform principles state that all cross-subsidies and community service obligations should be made transparent and pricing should reflect costs of supply, including environmental costs (Emerton & Bos, 2004).

The stock of capital is the combination of man-made capital (money, factories, etc) and natural capital (forests, biodiversity, etc). If exhaustible natural capital is diminished, its rent should be re-invested in other assets (roads, bridges, etc) in compensation for the natural capital's decline (Department of Finance and Administration , 2006).

Ecosystems form an important component of water infrastructure, yet are frequently not allocated enough water or funding, due initially to lack of scientific understanding and then to public good characteristics (Young M. , 2000). Ecosystem decline is a result of a long history of unsustainable land use, government policy and of soils, water and vegetation being undervalued by markets (Madden, Hayes, & Duggan, 2000). Salinity in towns is a fundamental failure to value and protect natural assets and the ecosystem services they provide. Changed landscapes have removed natural assets, such as deep-rooted native vegetation, which had been providing the ecosystem service of keeping saline water tables low under towns. Total costs of salinity to the landscape tend not to include:

- The cost to the Australian economy of natural asset degradation
- The extent to which these ecosystem services are bases for industries such as commercial fishing and tourism
- Environmental costs, such as amenity, biodiversity and others - which are inherently difficult to monetise

At present, water users in rural towns are not paying the full cost of water use due to un-costed environmental impacts associated with extraction through to disposal. Therefore, an environmental externality is a subsidy because the impacted party (neighbour, rest of the community) is paying part of the cost of a development or action, making the project seem cheaper. Projects (buildings) and behaviours (over-watering) in past decades have paid some of their costs but did not pay the cost of salinity, which manifests itself decades after the action.

The CSO is a further subsidy to rural town water use. Paying too little normally means users use too much water, with imported water and its disposal/ recharge, being a central issue in rural towns. In addition, the wastewater might not be considered reusable or a resource and too much may end up being disposed of back into the environment with associated consequences.

Therefore not only is there an implied subsidy (because the price is not being corrected for the market-failure of the externality), but also an explicit subsidy of the CSO[1].

In situations where externalities mean that the market may fail to achieve the social optimum, government intervention of some sort is potentially justified. However, the effectiveness of intervention programs to reducing salinity will be sensitive to various factors such as the level and timing of treatment impacts and the value of assets being damaged. Pannell (2002) illustrates that the costs of salinity remediation projects are frequently

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[1] The Economic Regulation Authority conducted a Country Water Pricing review in 2006 and water prices have increased since this time, but after decisions were made regarding salinity remedial action.

higher than the benefits, and it may only be for the protection of high value assets that remediation is economical.

There are numerous references to “no economical remedies to salinity existing” (Nott, Pridham, Roe, Ibbott, & Leeson, 2004) (URS, 2001). This is largely because the issue came about in the first place due to externalities and now it’s that external cost that has to be met before the town can proceed with remediation; any project is beginning from a negative balance: a previous project or behavior received the benefit but left some of the cost. This is the same concept as contaminated sites recovery where the legacy of soil contamination from a petrol station for example needs to be cleaned up before the land can be re-developed. Market failure therefore can be a significant impediment to redevelopment on the site, with companies taking on such sites only when commercially viable. Given the sunk cost of the previous use of the site, it may now be in the community’s interest to rehabilitate where this leads to future productive economic activity.

If the legacy issue occurred a long time ago, there is an argument for Government to use taxpayers’ funds for remediation but efforts should be made not to repeat the mistake, otherwise the cycle just begins again as a subsidy to a development, part of the cost of which is left to and borne by the community or taxpayer in the future, whether that be one year, a decade, or more. This is both inefficient (because projects proceed when they are not viable – they are not meeting all of their costs) and inequitable (people not involved in the project are paying the residual costs).

In a typical rural town scenario where the benefits enjoyed by the town are less than the costs, there is no incentive for the town to implement a scheme where the town bears the cost but part of the benefits will be enjoyed by others in the state. Without some system in place for the true benefits of the scheme to be captured by the participants, there will be an under funding of remediation options.

In the RTLAP there are legacy issues of:

- sunk costs of existing water infrastructure of scheme water from Perth
- CSO: a subsidised price of water to the town consumer that is below cost recovery
- land management and drainage design that have caused the salinity problem

While recognising historical costs and benefits are sunk, they can inform what future costs and benefits might be, in this case damage costs in rural towns.

While it may be enticing to reminisce about environmental purity pre disturbance by European settlement, we must remember that there are costs involved in returning to that state. This is a key concept in this project: while acknowledging that there is a cost, it may not always be the case that taking remedial action is justified. A base case of the status quo, therefore, can be a legitimate choice in some circumstances, as discussed further below.

Many buildings in rural towns, residential and commercial, are privately owned, with others publicly owned. A high proportion of the most economically and culturally valuable buildings, such as the town hall and court house, are public. In other situations where funding was not already available, this has implications for who pays for the work. The difference in cost burden between public and private owners becomes significant in the choice of response (URS, 2001). Given some of the benefits are private and some are public, cost sharing arrangements will often be appropriate, and may provide additional private funds that allow a project to proceed that is not justified with private or public funding alone (damage avoided benefits), as demonstrated in the Great Artesian Basin cap and pipe the bores scheme (Freebairn, 2001). Where a project has public and private beneficiaries, it may not be viable for the town to proceed if the public benefits fall short of the public costs, while a private landholder may choose not to proceed if the private benefits fall short of the private costs. However in collaboration, with costs shared, the benefits for each may outweigh the costs.

A further complication is that benefits and costs can often apply to those outside the immediate community, in neighbouring towns or the state as a whole. The RTLAP is an interesting application of the distinction between public and private benefits in that a benefit can be public or shared within the town or shared outside the town. However, there is no incentive for anyone outside the town to contribute to payment, even if they benefit, because they can free-ride on the initiative of the town.

2.4 Potential responses

There are two connected but distinct challenges to addressing salinity damage (Wentworth Group, 2002):

- stop the problem continuing to get worse; and
- restore damage already done.

Pannell (2002) argues that options for responding to salinity damage are:

- Do nothing – allow damage to continue
- Adaptation – learn to live with salinity, potentially repair future damage as it happens
- Remediation - fix (some of) the damage to date
- Prevention – take action to reduce or avoid future damage occurring

2.4.1 Do nothing – live with salinity damage

There is a mistaken belief that economically viable solutions to salinity are available for widespread implementation (House of Representatives Standing Committee on Science and Innovation, 2004). Remediation and prevention are “diabolically expensive” (NSW Select Committee on Salinity, 2002) and as such sometimes living with salinity is more economical than preventing it (Frost, Hamilton, Lloyd, & Pannell, 2001). If costs of intervention are greater than benefits, the optimal solution is for there to be no intervention, and the town to live with the costs of the rising water table (URS, 2001). In this case, additional justification is needed in order for action to be taken (Buckland, 2005), for example the social or environmental benefits, or water users downstream may choose to contribute to remediation if works remove a cost to them.

URS (2001) recommends that where immediate action is not economical, towns could implement low cost options to address causes, including a program to encourage increased water use efficiency, improved irrigation of town ovals, as well as tree planting in areas most vulnerable over the coming years, all while continuing to monitor groundwater levels, gather more data and monitor possible new technologies.

Unlike agriculture, where land can become unusable, towns can cope with shallow groundwater tables (URS, 2001). Wood-framed houses on stumps make up the great majority of houses in WA Wheatbelt towns. They tend to be well designed, by luck rather than foresight, to deal with shallow groundwater, provided there is enough room for ventilation beneath the floor. It is possible that brick houses on the ground are more vulnerable to rising groundwater, but shallow drains around houses can prevent damage. A group of 10-20 houses could install a sump and pump for localised drainage.

2.4.2 Intervention options

NRM decisions are often made with inadequate knowledge of their economic nature, the costs of their degradation and the benefits of remedial action, leading to inefficiency (Hajkowicz & Young, 2002).

At the beginning of RTLAP there was considerably more knowledge about the extent of NRM problems than about best ways to respond and the impacts of these responses (Madden, Hayes, & Duggan, 2000). There was also a high level of uncertainty associated with timing and magnitude of intervention and associated mitigation outcomes (Heaney, Beare, & Bell, 2001), making it difficult for towns to decide whether to spend money intervening (Hajkowicz & Young, 2002).

RTMC (2001), Emerton (2004) and others suggested a combination of intervention options including direct groundwater abstraction and addressing recharge through improved surface water management:

Table 2-4: Options to address rising groundwater

Surface water option	Abstraction of groundwater
• Reducing imported water into the town - Address water use behavioural issues (overwatering of ovals, total use of water, imported water and price – incentive to use more water)	
• Reducing water leaking from pipes	
• Completing sewerage connections	
• Sealing and lining drainage canals to remove surplus water before it recharges	• Planting trees
• Planting trees, capture, diversion, re-use, flood control	• Pumping

Note that planting trees was both a surface water and groundwater option, given that trees help prevent recharge as well as help directly lower the existing groundwater table.

2.4.3 Surface water management

Increasingly, rainwater, wastewater and stormwater are being seen as a recyclable resource, rather than a disposal problem (Radcliffe, 2004). In most cases, the objectives of stormwater management are ecological regeneration, pollution control, flood protection, and enhanced amenity value of stormwater (Speers & Mitchell, 2000), with well-designed surface water management systems able to manage storm water flows and slowly drain saturated soils between storms (Heaney, Beare, & Bell, 2001).

Additionally, communities are faced with costs of replacing aging existing water infrastructure built during periods of development and expansion (Heaney, Beare, & Bell, 2001). More use of local water may help avoid such costs. Reuse projects and plans for stormwater drainage are sparse, however (Dillon, 2000).

Local water does have the capacity to improve public amenity and reduce the demand for potable water, as well as reduce the release of this water into the environment (Stringer, 1997). In some cases, there may be agreement on the environmental merits of discharge choices but re-use of treated waste-water or increased investment in stormwater management may not be considered economically viable. In addition, surface water flows represent significant opportunities for new non-potable water in arid areas where such supplies have high value.

Stormwater capture and re-use can be an effective alternative water-source where the majority of rainfall is in winter, with very little in summer, in cities like Adelaide and Perth (Thomas, Gomboso, Oliver, & Ritchie, 1997), where winter stormwater stored locally is then available in summer as a useful alternative to scheme water. The extremely high evaporation rates that this is exposed to (Speers & Mitchell, 2000) can substantially be addressed by Aquifer Storage and Recovery (ASR). Additional benefits of ASR are flood control, groundwater-dependent ecosystem health and water storage for later use (Hodgkin, 2004).

The establishment of recreational surface water bodies (lakes) is one option to deal with excess water gathered during low water demand periods (Stringer, 1997) (Poulson, 2010). On-site retention on unpaved or grassed surfaces can remove contaminants from stormwater as well as assist with groundwater recharge (Thomas, Gomboso, Oliver, & Ritchie, 1997). While surface water management is important, it should be complemented by other strategies that increase water use and decrease groundwater recharge (Nott, Pridham, Roe, Ibbott, & Leeson, 2004).

The RTLAP considered that while local non-potable water sources (such as local dams and treated wastewater) were available to shires, data suggested they did not provide a sufficiently reliable resource for shire water demand (Dogramaci S. , 2004). There was a constant supply of wastewater, on the other hand, meaning wastewater reuse was more reliable than stormwater for the same sized storages (Grant & Sharma, 2005).

Additionally, while winter stormwater runoff figures were high enough to justify further assessment, large storages would have been required due to seasonal and infrequent rainfall patterns (Grant & Sharma, 2005). To address extremely high evaporation these storage sizes could have been reduced if ASR was feasible, however given the fundamental issue in rural towns was rising groundwater, ASR would actually exacerbate this and was not considered. Indeed, it was also critical that recharge be addressed, especially with Wheatbelt valleys inundated for extended periods during winter (Wentworth Group, 2002).

Rural town recharge reduction measures included (Emerton & Bos, 2004):

- Continue the replacement of septic tanks with sewer systems
- Take action to avoid surface water from ponding where it tends to contribute to groundwater recharge
- Increase water use efficiency and eliminate overwatering of parks, gardens and sports grounds
- Repair leaking drains, water pipes, dams and pools
- Return deep-rooted native vegetation to replace bare ground and imported species such as grasses and weeds
- Use local water captured from within the town (from hard surfaces such as roads and roofs) rather than imported scheme water
- Reduce water supply costs and reliance
- Reduce the amount of high-quality rain water that is wasted
- Reduce/ avoid damage to infrastructure from surface water run-off and floods

2.4.4 Tree planting

As well as helping reduce groundwater levels, trees can provide environmental benefits such as improved biodiversity and riparian and aquatic habitat. Town beautification can be a significant factor in quality of life and pride in a town (Hill C. , 2004). Land use change such as tree planting is a more passive salinity remediation action than groundwater pumping, however, and can take decades to show effects (Heaney, Beare, & Bell, 2001) (URS, 2001). Trees are likely to be most effective for prevention, where groundwater is still 2-3m below the surface, rather than areas already subject to saline and waterlogged areas (Hajkowicz & Young, 2002).

Furthermore, planting of native vegetation will often not be viable for the private landholder and therefore will often need public funds contributed, justified by external benefits, for planting to be undertaken (Hill C. , 2004). *Ipso-facto*, therefore, one could argue that tree clearing should incur a penalty for the external cost to the community. Limitations in quantifying benefits result in difficulty in including them in economic analysis (Hill C. , 2004).

Within the RTLAP, townsite beautification in the form of increased townsite vegetation, or 'leafy streets', was a priority for many rural communities, requiring additional water for irrigation (URS, 2001). In most cases, benefits from revegetation of the surrounding catchment were judged to be too little and slow to help town infrastructure (Frost, Hamilton, Lloyd, & Pannell, 2001). The RTLAP made a big effort to engage in community consultation, carried out by CSIRO's Australian Research Centre for Water in Society.

2.4.5 Engineering options - pumping

While catchment-wide groundwater reductions can take a long time, a century or more, local reductions in water tables can be achieved in a year or two with engineering options (Ohlsen, et al., 2005). It is expensive, however, and is justified only in some situations where there are high value assets to be protected (Frost, Hamilton, Lloyd, & Pannell, 2001).

The impact and therefore economics of groundwater pumping are site specific depending on drawdown distance, cost of pumping, water disposal, and the value of infrastructure protected. In addition, the lateral distance between recharge and discharge has a major influence on timing of costs and benefits (Heaney, Beare, & Bell, 2001).

In some instances, public assets need and justify highly localised treatments, adjacent to these assets, as opposed to interventions implemented more broadly in the catchment (Frost, Hamilton, Lloyd, & Pannell, 2001).

If implemented to the broader catchment alone, the results would be too little, too late to prevent asset damage (Pannell., 2002).

Pumping itself can be considered a public good. There may be multiple individuals owning assets within a single block, so if any individual installs a pump to protect their assets, they will generate non-rival and non-excludable benefits to others (URS, 2001). Even if a single block can be considered an entity, pumping under a block has an impact across the system into other blocks, through the hydro-geological linkages and it requires coordinated action to achieve its outcomes.

Although schemes have demonstrated the effectiveness of groundwater pumping to control water level rise, the system design, cost-effectiveness, environmental impact of the disposal of huge volumes of water or the effects on river or soil salinity have not been documented (McRobert & Foley, 1999). Potential environmental impacts of groundwater pumping are (Wentworth Group, 2002):

- Disposal of saline drain or bore water (where does disposal have minimal environmental impact)
- Increasing soil and water salinisation downstream, putting further pressure on vegetation
- (River bank) erosion - Difficulties in finding stable (well vegetated, non-eroding) waterways capable of receiving large volumes of saline discharge
- Sediment movement and siltation offsite (largely due to poorly designed drains) where surface water enters deep drains leading to gully erosion and drain wall erosion or even slumping
- Considerable soil excavation, which can disturb existing vegetation, saline soil disposal and encourage weeds

Engineering salinity manage options have numerous limitations, namely difficulties in identifying an intervention that will work, where to site the works and deciding what to do with the water (Department of Environment , 2003). Limiting factors to good pump or drain performance are that saline valley floors, typical in the wheatbelt, are generally flat and comprise very tight clay with poor surface drainage (McRobert & Foley, 1999).

The RTLAP observed that even in situations where there were valuable assets, engineering solutions were not always economically viable (Frost, Hamilton, Lloyd, & Pannell, 2001), as analysis showed that costs exceed benefits in numerous Wheatbelt towns (URS, 2001) (Pluske, et al., 2004).

The most important and effective treatment for salinity in towns was considered twofold: firstly surface-water actions to address recharge, either generated within the town site or flood-water from cleared land in the catchment above the town; and secondly enhance discharge in and around the town by engineering treatments such as pumping (URS, 2001). Much more comprehensive and detailed work was carried out in the DAFWA-CSIRO project (Barron & Smales, 2005).

2.4.6 Disposal

With any engineering intervention, a key challenge is the disposal of the saline water (Pemberton, 2005), usually considered a waste product. While surface water can be used without treatment, abstracted saline groundwater needs to be treated for use or disposed of.

Climate or land area requirements (both for storage and disposal) influence disposal options. Irrigated agriculture or land disposal are much more feasible for country towns, simply due to the amount of land readily available compared to major cities. Coastal cities can discharge waste water into the ocean, but inland cities do not have this option, they need to discharge onto land (Dillon, 2000). The major trade-off is the opportunity cost of land use for revegetation (agricultural production foregone, noting this would be zero if the land goes saline) against the benefits from preventing more land becoming saline (Hajkowicz, Young, Wheeler, Hatton MacDonald, & Young, 2000).

Disposing of water to constructed basins is technically sound, given there is considerable knowledge of design and performance from similar projects requiring disposal of water from groundwater pumping schemes in the Murray-Darling Basin; although this has not eliminated the salt from the system, rather relocated it somewhere else less damaging. This work (Dogramaci S. , 2004) has successfully prevented saline water entering the river and kept the groundwater level under the Murray stabilised for decades (Wentworth Group, 2002). Evaporation basins are extremely expensive, however, with Thomas (2001) reporting a cost of $10m.

Evaporation pans, or a pipe line to the sea may be alternative means of waste water disposal, but what should be included in the analysis is the least cost means of disposal (ensuring that all costs of each approach are included) (URS, 2001).

The management of the salt (high concentrations in these extreme cases) is a significant threat to the environment. While engineering solutions can frequently just shift the problem elsewhere in the context of agriculture or catchment management, where local built and natural assets are at immediate risk, it may be required and justified.

Even if social and environmental components of projects are identified and included in calculations, new information, technology and/ or social priorities can change the relative merits of various options and indeed new options can emerge over time (Heaney, Beare, & Bell, 2001).

In rural towns, most disposal had been directly into natural waterways and lakes with little consideration of impacts (Dogramaci & Degens, 2003). Dogramaci (2003) records concern about the damage this could do, so it was considered important to identify disposal options that minimise downstream impacts (Heaney, Beare, & Bell, 2001).

There was little information about the on-site and off-site impacts (Frost, Hamilton, Lloyd, & Pannell, 2001) as well as the social and economic aspects (URS, 2001). However given how dry the Wheatbelt is, rural towns' water flows were considered isolated; that is, not enough natural flow for discharge to reach, and potentially negatively impact, downstream towns (Vorobieff, 2001).

The use of disposal basins in WA had been limited by siting problems and construction costs (Dogramaci S. , 2004), so integrating the basins with productive uses for saline discharge had the potential to provide an offset to these problems. This included avoiding the need for a purpose-built evaporation basin or the environmental costs of disposing to local waterways. A water initiative project in Merredin successfully trialled groundwater abstraction, treatment (desalination) for use in road construction and provides a model for duel goals of lowering groundwater and water re-use. (Turner J. , et al., 2008)

One might immediately assume that disposal to the sea is uneconomical for Wheatbelt towns, although scheme water is piped inland (highly subsidised). With a core principle of the RTLAP being to try to find ways of productively using the water, however, rather than seeing it as a waste product to be disposed of, the prospect of piping water out to evaporate was anathema. But therein lay the challenge: cost of treatment needed to be weighed up against the potential beneficial use of the water.

2.4.7 Reuse

Most water sources in Australia are either fully or over-allocated (Radcliffe, 2004). Water re-use is usually instituted to provide supplementary water where additional supplies are not readily available (Dillon, 2000) and can avoid the need for additional extraction from rivers, dams or groundwater (Radcliffe, 2004). In WA rural towns, however, where winter rainfall normally far exceeds demand and groundwater pumping takes place for salinity control, there is excess water available for re-use if it is economical to do so.

Water with sufficiently low levels of salt can be used on turf, gardens or pasture without any prior treatment (Barron., et al., 2006). This being the case water could be pumped directly into storage for future use. Hill

(2000) assumed that abstracted groundwater could be used or shandied and used for irrigation, substituting for potable scheme water. Water quality is key to determining what the water is fit for.

Extended drought conditions have resulted in water utilities, communities and local governments considering re-use as an additional source of water (Radcliffe, 2004). Internationally, the majority of examples of large-scale re-use are in arid and dry locations, such as South Africa and the middle-east; environments similar to the WA Wheatbelt.

The use of treated effluent to irrigate parks, gardens and golf courses has been common practice in arid areas of WA small country towns since the middle of the 20th century, with scope for more wide-spread re-use (Thomas, Gomboso, Oliver, & Ritchie, 1997). Municipal areas throughout Australia have used treated wastewater for decades (Stringer, 1997), with an explosion of new water being made available from treated waste-water since the late 90s and new technology (Dillon, 2000), offering a large potential resource for economic and environmental benefit (Thomas, et al., 1997).

Possible uses for reclaimed water include:

- Agricultural Irrigation
- Urban irrigation such as recreation areas, including recreational water bodies (Poulson, 2010)
- Residential non-potable use
- Direct potable reuse – including treated water in the drinking water supply
- Indirect potable re-use – discharging treated waste-water into a waterway that feeds into a water supply
- Industrial/ commercial re-use: most commonly non-contact industrial cooling, meat and food processing
- Reuse in groundwater systems

The main factors that limit their use are:

- Variability of rainfall/ availability; even if there is enough average rainfall annually, it is often not available at the right time and place
- Limitations in storage
- Water quality

Desalinated groundwater can be used to replace scheme water irrigating town parks and gardens, and/ or to establish and supply new industries. Normally water managers need to identify catchment maximum sustainable yield and then the political debate allocates that between competing uses, especially irrigation, other agriculture (stock and domestic), environmental flows and urban use (Wentworth Group, 2002).

In rural towns, however, there was new water from under the towns (albeit not necessarily immediately usable), as well as more water from surface water catchments (not only more water from runoff capture, avoided ponding, waterlogging and groundwater recharge – diverted to dams, but also improved dams leading to reduced leakage and more of the runoff captured being available for use).

While a holistic review of water in rural towns would be valuable, this project looked specifically at changed water management to alleviate salinity damage. Desalinating groundwater was the focus of the RTLAP, therefore, rather than recycling general town wastewater.

Little was known of opportunities for safe disposal, or productive uses on salt-tolerant fodder production or in artificial saline wetlands, solar ponds or mineral extraction (URS, 2001), including the cost-benefit of these use options. The RTLAP speculated that if economically viable products, such as salts, could be ‘mined’ and so generate a revenue stream, groundwater pumping may be viable. Possible technologies included aquaculture, desalination of product potable water and salt recovery (URS, 2001).

2.4.8 Desalination

Water quality required for various re-use activities determines the suitability of a desalination technology. Costs of desalination can be offset by a combination of avoided damage and sale of new water and reduction of scheme water bills (Ohlsen, et al., 2005). Economic analysis, comparison of the costs and benefits of any management option, is very site specific, depending on current salinity threat, groundwater level, surface water management, recharge rate, infrastructure value, and other factors.

Previous projects (Nott, Pridham, Roe, Ibbott, & Leeson, 2004) had demonstrated that groundwater could be pumped out and this water could be treated to potable standard; potentially turning a problem into a resource.

Intelink (2002) found that the most appropriate salinity remediation process in Wagga Wagga and Dubbo was groundwater pumping followed by a concentration step (preferably desalination by reverse osmosis), then removal of specific salts and sale of the water, however the cost of brine disposal into the surrounding environment was not included (Hill C. , 2000). This technology could be applied to other rural towns (NSW Select Committee on Salinity, 2002). The poor understanding of the environmental impacts of saline water or brine disposal, however, makes it impossible to produce an accurate CBA (URS, 2001). There are unintended consequences with water reuse that need to be carefully considered on a site-specific basis (Dillon, 2000).

The RTLAP considered desalination an option for rural towns, particularly if done locally and product water substituted for high cost imported scheme water, or equally expensive local fresh water (Thomas, Gomboso, Oliver, & Ritchie, 1997) (Dogramaci S. , 2004). Although there were options such as aquaculture or electricity generation that can utilise saline water, there were few examples of integrating desalinisation with complementary rural enterprises.

2.4.9 Immediate action

Notwithstanding uncertainties and gaps in knowledge, there were calls for at least some immediate on-ground works to address salinity. It was stressed that this needed to be economical and actually work, however, rather than just create activity without results (House of Representatives Standing Committee on Science and Innovation, 2004). Options for immediate action included (URS, 2001):

- Improve water use efficiency and provide households and businesses with information on increasing water use efficiency, urban stormwater control including drainage, and effective use of trees needs and other occurrences
- Improve surface water and stormwater management to minimized recharge and remove ponded water from townsite as soon as possible
- Aim for complete coverage of sewer system

The RTLAP and others called for was monitoring to see what ongoing recharge reduction measures were necessary (Emerton & Bos, 2004).

2.4.10 Long term solution

Long term, an integrated system of recharge and discharge controls, tailored to each town, is essential to protect assets (Hajkowicz & Young, 2002). Issues to be considered included:

- Environmental triage: Some areas already too far gone to be saved
- Groundwater pumping for immediate relief for some high value assets that justify the expense of engineering
- Surface water intervention is critical to avoid recharge and address surface water damage
- Longer term changed water management central to avoid the problem just re-emerging
- Water pricing can be a powerful tool here for demand management to help, not just supply management, but it is acknowledged that utilities pricing is a politically sensitive issue

Groundwater needs to be addressed in the context of overall water management within towns, requiring attention to a wide range of economic, socio-political issues such as:

- Imported scheme water cost: while more expensive in rural towns than in cities, the CSO resulted in charges below the delivery cost – a cross-subsidy from metropolitan to rural customers
- Balancing against cost of water supply is the political and social value that rural towns place on water for town beautification and improving quality of life
- A focus on water use that reduces local recharge that eliminates the septic system, connects hard surface-run-off to sealed drains, modification of artificial wetlands, and more sensible garden and park watering
- The development of an appropriate cost sharing methodology, incorporating private and public costs and benefits

- Increased research into the potential use of saline groundwater for productive industrial and commercial purposes

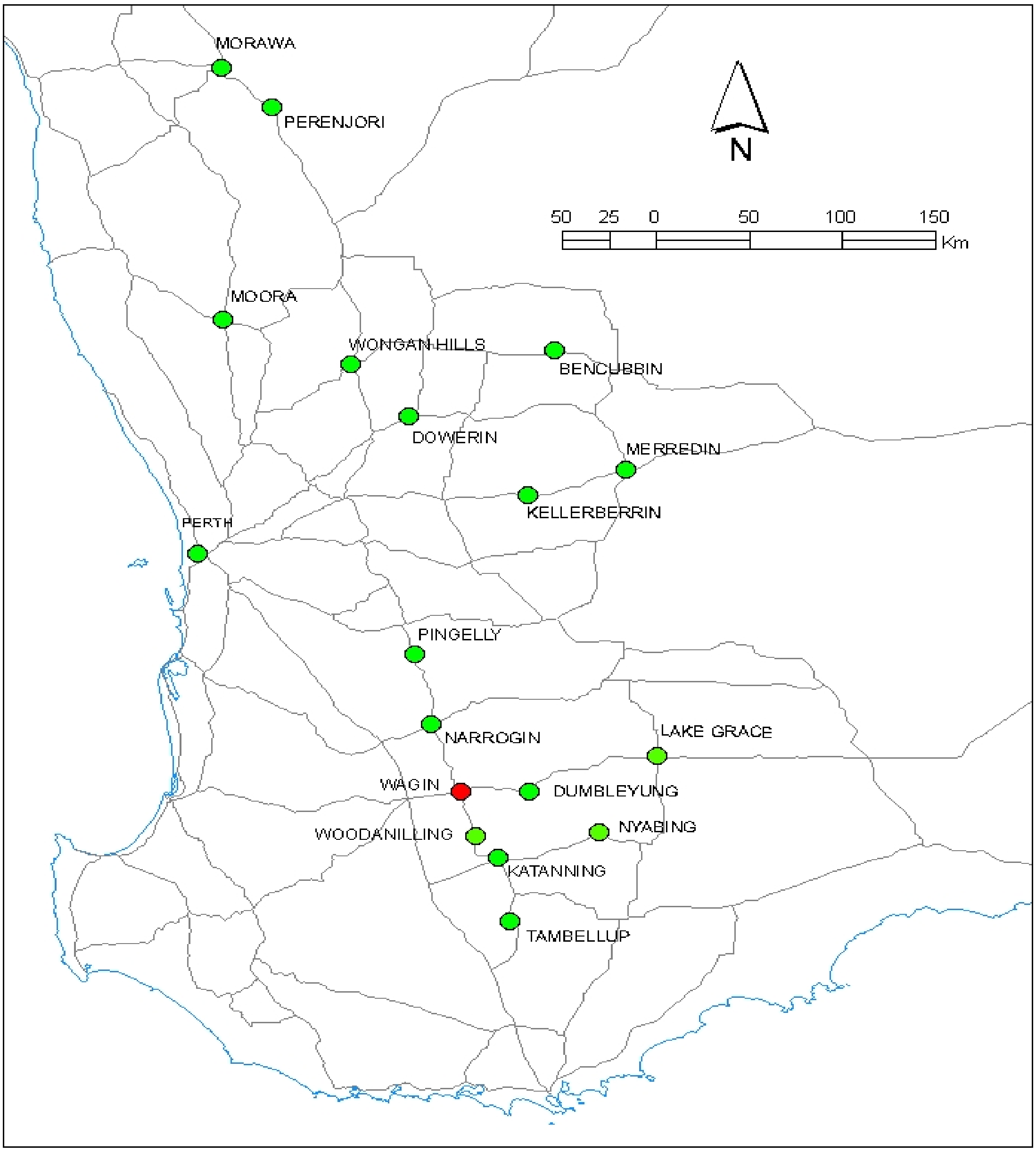
The magnitude of costs and their timing varied widely among rural towns depending on depth of groundwater, irrigation practices, rates of groundwater rise and its salinity, infrastructure type, town layout and topography.

2.5 Wagin Case-Study

Wagin is located 225 km south-east of Perth (Figure 2.6) with a population of roughly 1,400. Established due to the existence of the great southern railway, completed in 1889, the town is primarily an agricultural support centre for the district and a railway node for eastern and southern lines (Crossley, 2001).

Other towns highlighted in Figure 2.6 are Perth, and the other rural towns participating in the RTLAP.

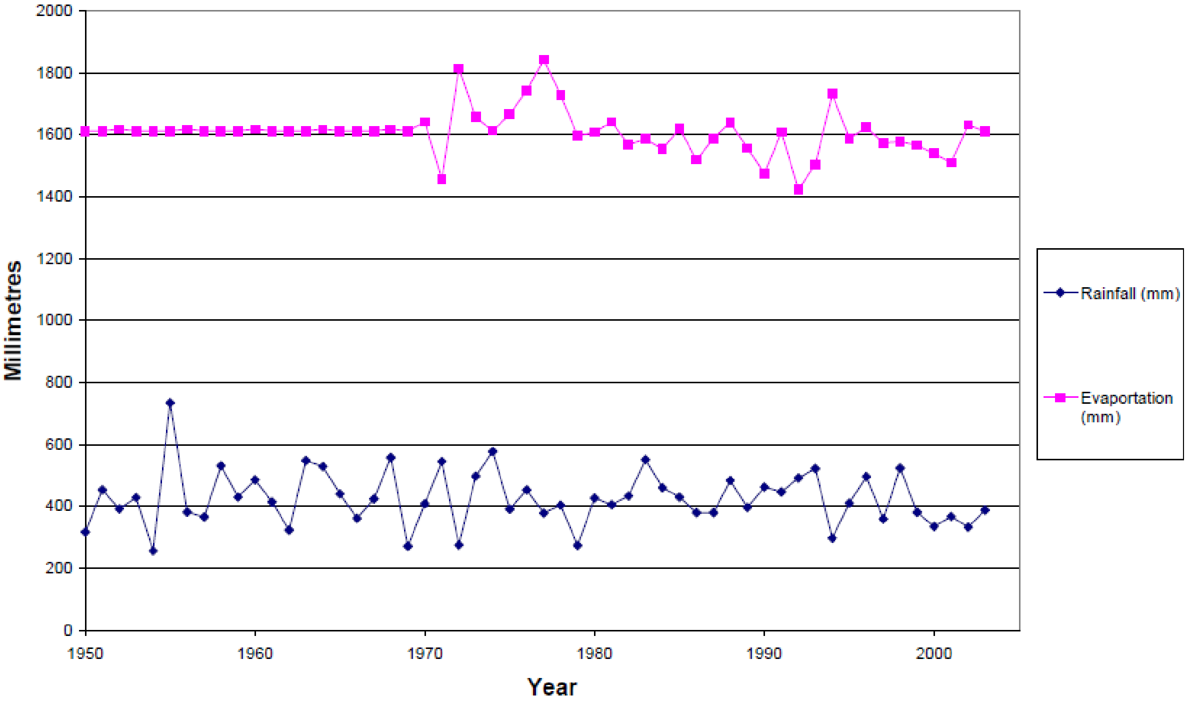
Figure 2.6: Location of Wagin and other towns participating in the RTLAP, relative to Perth



Source: (Barron., et al., 2006)

Wagin is in a medium rainfall zone, with long term average rainfall of 440mm (94 rain days per year), and average annual evaporation of 1,800mm per year (Ohlsen, et al., 2005). As Figure 2.7 illustrates, annual evaporation is many times greater than annual rainfall.

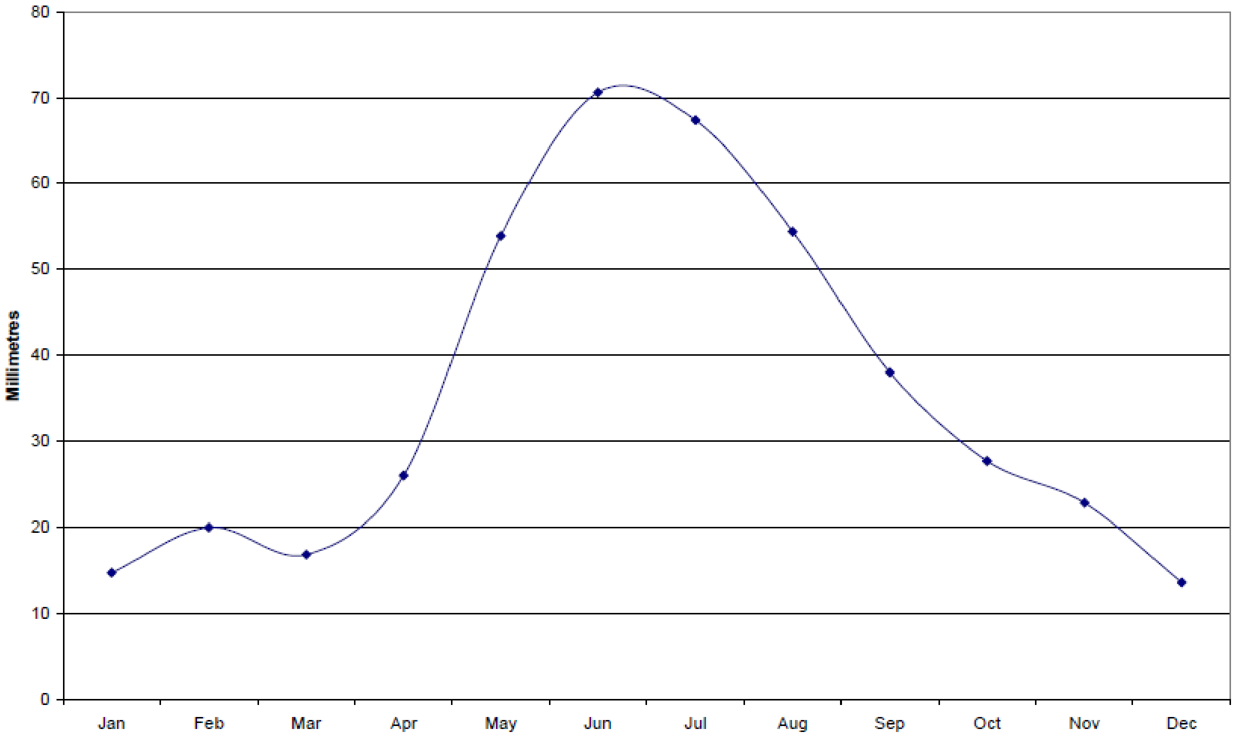
Figure 2.7: Rainfall and Evaporation for Wagin



Source: (Grant & Sharma, 2005)

As is the case across the WA Wheatbelt, summers are typically hot and dry, with winter being the wet season, as shown in Figure 2.8.

Figure 2.8 Wagin average monthly rainfall



Source (Grant & Sharma, 2005)

The townsite sits across the lower parts of a number of catchments and is elevated above the valley floor, with groundwater falling towards it (Grant & Sharma, 2005). As is the case across the Wheatbelt, winter rainfall in Wagin is typically substantially in excess of demand, meaning runoff and groundwater recharge are significant issues.

Rising damp has resulted in damage to streets and buildings, particularly on the lower slopes around the town centre. There are groundwater discharge points above the town, indicating that groundwater bodies are not connected in the upper parts of the catchment; under the town; to below the town. Lateral flow through the system is very slow, taking 5,000 years to cover 11km across town (Matta, 2000).

A substantial amount of recharge has occurred within the town, with localized flooding after rain roughly each 20 years, and bad flood events around every 50 years (Grant & Sharma, 2005). Surface water flooding, causing waterlogging and salinity has been known to badly affect road infrastructure with concrete culverts disintegrating and pavements failing.

At the beginning of the RTLAP, many low-lying areas of Wagin became inundated during the winter wet-season each year, due to poor surface drainage (Eow, 2013). Due to the flatness of the land, drainage was slow, and soils were waterlogged and significantly salinised. Surface water drained into salt-affected land such as Wagin Lake, around 1km south of the town, with watercourses on the slopes clearly defined and efficiently draining. Drainage had been augmented by a series of concrete channels emptying into local creeks. At the lower end of town, drains obstructed by salt and desilting had occurred. Salinity affected a significant area on the south-east of the town and extended up drainage lines into the town (Grant & Sharma, 2005).

In response to these water and salinity issues there were numerous options available for the town to choose from. There was an option of shandying pumped groundwater with locally captured rainwater and using this as a substitute for imported scheme water. This was complicated partly by the logistics of what concentration to shandy to in order to reach fit-for-purpose water quality for playing fields.

The town could build a larger dam and install water recycling infrastructure to augment existing supply.

While directly addressing some of the town's water management issues, however, these options would not directly address the salinity damage that needed urgent attention and was the prime focus of the RTLAP. The town had to decide whether to spend money on addressing salinity damage and if so, how much.

Groundwater abstraction was identified as an effective water management option for salinity control in the town-site (Barr, 2005), anticipated to be economical when the (avoided) costs of salinity damage were included (URS, 2001). The hydrology report for the town included a recommendation that current and future salinity costs be calculated to determine the amount of investment justified (Grant & Sharma, 2005) and that work be done to assess the cost of the pumping system, the damage it may cause and use or disposal of the pumped water. The analysis that follows is that work. Further work was subsequently done (Shimojima, Tamagawa, Horiuchi, Woodbury, & Turner, 2013) to identify the relationship between annual salt and water balances, salinisation and evaporation in semi-arid and arid regions. Meteorological and hydrological observations were recorded over three years in rural Western Australia relevant to this thesis and identified the active role of turbulent surface wind speed on vapour transfer in the dry soil layer below the ground surface.

This chapter outlined the history of natural resource management in the Wheatbelt of WA and what led to the emergence of rural town salinity damage. It summarised key concepts of environmental economics that help explain the emergence of the problem and which hold possible remedies. The chapter concluded by listing responses to townsite salinity and introduced the case study town of Wagin.

The next chapter introduces the methodology used in this paper: cost benefit analysis, its theoretical underpinnings, key steps, strengths and weaknesses.

3. Principles of Cost Benefit Analysis

3.1.1 Overview

Cost Benefit Analysis (CBA) is a process to calculate a project's economic viability (Building Queensland , 2016). It lays out all the information in a systematic, transparent way to compare alternative courses of action.

There are three core components of the methodology:

1. Net social benefit: considers net benefit for community as a whole, etc
2. Numeraire: costs and benefits are expressed in monetary terms
3. Discounting: express all values in the same year value, given costs frequently occur mostly at the beginning of a project while benefits are often spread over the life of the project

First applied in Australia to analyse Tasmania's flood mitigation actions in 1956 (Hajkowicz, Young, Wheeler, Hatton MacDonald, & Young, 2000) CBA has become a widely used analytical tool, routinely applied to investment decisions and is now widely considered essential in evaluating of environmental projects (OECD, 2018). As it is an economic analysis, however, separate social or environmental impact analyses can often be complimentary.

3.1.2 Welfare Economics and Pareto improvement

It is assumed in welfare economics that the individual is the best judge of his or her own welfare; and welfare of all individuals combined make up social welfare (Hajkowicz, Young, Wheeler, Hatton MacDonald, & Young, 2000). In this context, CBA defines benefits to be increases in human well-being, and costs as decreases in well-being (OECD, 2018). Pareto improvement is reaching a point where no one can be made better off without someone else being made worse off.

CBA is based on the Kaldor compensation criterion in that a project should go ahead if those who gain from it can fully compensate those who lose and still be better off (Department of Finance and Administration , 2006). There will remain both winners and losers, however, if compensation does not actually take place. Compensated Pareto improvement states that a project should proceed if the people who will benefit can and do overcompensate those who will lose. Complete compensation, however, rarely takes place. Potential compensated Pareto improvement is a scenario in which winners *could* compensate losers. In most cases, CBA focuses simply on whether benefits could potentially be enough for the losers to be compensated. Rarely does payment of compensation actually occur, and when it is paid, it rarely covers all losses. This improvement implies arguably the core limitation of CBA – that compensation of losers does not have to take place in order for the efficiency criteria that CBA is based on to be met (Hajkowicz, Young, Wheeler, Hatton MacDonald, & Young, 2000).

3.1.3 Allocative Efficiency

Allocative efficiency as a concept refers to *overall* efficient resource allocation and can be defined as “an economic state in which it is impossible to make any one person better off without in the process making someone else worse off” (Department of Finance and Administration , 2006); the Pareto Optimum position. It covers both whether outputs created are the highest value possible and with whether the inputs that are used in creating these outputs are least cost. Furthermore, allocative efficiency incorporates productive efficiency (the least cost of production of outputs). Productive efficiency, however, can be considered an important pursuit on its own. In CBA, the maximum value set of outputs is achieved by the highest amount that individuals would be *willing to pay* for products they consume.

Given resource scarcity, we need to assess whether the costs of a project outweigh the benefits; the efficiency test; no other method addresses this issue. Ultimately, robust CBA helps address the allocation issue — a central concept fundamental to the economics discipline i.e. allocating scarce resources among competing potential uses (Building Queensland , 2016).

3.1.4 Willingness to Pay and Willingness to Accept

Willingness to Pay (WTP) is the upper limit that someone is prepared to pay rather than forego something of value, such as environmental quality (Freeman, Herriges, & C., 2014). This is the amount of money that would mean an individual is indifferent between the two. Willingness to Accept (WTA) is the lower limit that someone is prepared to accept to forego, in this case, an improvement in environmental quality.

A market transaction will tend to satisfy both of these concepts, with both the buyer and seller benefiting, and be a Parato improvement, if one or both parties are better off, and no one is worse off (Department of Finance and Administration , 2006). CBA is a method through which this concept of efficiency can be applied to a project.

3.1.5 Property rights, distributional and equity issues

An assumption in CBA is that everyone has equal marginal utility of income. This assumption may be acceptable in some cases but is by no means universal. Most economists argue that income distribution should not be dealt with in CBA but elsewhere, such as through transfer payments, for example compensation, unemployment benefits or income taxes. Correcting for income distribution distortions in this way, however, tends to be expensive and involves efficiency losses. Only in rare circumstances and where justified with a clear basis in government policy, should CBA apply weightings for costs and benefits (Department of Finance and Administration , 2006). The political and decision-making process is responsible for trading off issues of equity and efficiency.

Valuation according to a money metric and the willingness to pay criterion are necessarily influenced by the ability of individuals to pay, which is unequally distributed. In valuing spill-over costs, those affected could be asked to nominate *either* the minimum compensation they would require in order to be restored to an externality-free level of welfare, *or* the maximum amount that they would be prepared to pay to have the externality terminated. The choice of approach depends ultimately on a judgement about where property rights lie (Department of Finance and Administration , 2006).

Take the situation of saline groundwater pumped out from under a town, disposed of into the catchment and negatively impacting a downstream town. If the downstream town has the right to salinity-free river flows (or no more saline than natural) then the calculation would be what is the downstream town willing to accept as compensation to allow this to continue. If this is more than the upstream town is willing to pay, then the upstream town finds an alternative source of disposal.

On the other hand, if the upstream town has the right to dispose of its saline water into the catchment, then the calculation is what is the downstream town's willingness to pay to stop the flow. Property rights, therefore, decide what direction compensation flows (in this example, upstream or downstream) in the event of spill-over or external effects of a project.

3.1.6 CBA and the Environment

A criticism of placing a dollar value on non-market goods is that it will reduce the item to only that value. This is an issue of recognising the limitations of CBA as a tool. The decision to use CBA in no way implies acceptance or application of reductionist utilitarianism (Hajkowicz & Young, An Economic Analysis and Cost-sharing Assessment for Dryland Salinity Management, 2000) – the value of something is not limited to its dollar value. It is based on the pragmatic argument that a value system has an increased likelihood of being promoted if the decision-maker knows about the consequences.

For years, valuation of the environment was seldom included in national level economic policies or natural resource management strategies, despite data showing long term trends in water use were unsustainable (Stringer, 1997). With the 1972 Club of Rome and 1987 Bruntland report, by the 1992 UN conference on Environment and Development, it was argued that the focus of economic development must be widened from expanding production and increasing incomes to include sustainable management of ecosystem services and natural assets (Stringer, 1997).

Furthermore, considerable debate remains about how to assess projects where fundamental understanding, let alone valuation, of natural assets is expected to remain relatively uncertain (OECD, 2018). Valuation of social and environmental impacts of changes to natural assets is invariably difficult (Buckland, 2005) and indeed has become “perhaps the crucial element in quantifying the contribution of ecosystems and biodiversity to human well-being” (OECD, 2018).

Wide differences in the extent to which projects account for environmental impacts remain. Any estimate of environmental cost and benefit is inherently uncertain due to the state of science. Despite sounding simple enough, how to aggregate social and environmental costs and benefits over time and across people within certain geographical or political boundaries, as well as people with diverse socio-economic statuses, and value systems and monetising these, remains elusive and the focus of continued research.

In order to avoid disadvantaging future generations in favour of the present generation, actual compensation needs to be paid. This departs from potential compensation of much of CBA and would require that the full current capital stock be passed onto future generations (Barbier E. M., 1990).

Incorporating sustainability into CBA can be done by setting a constraint on natural capital stock degradation. Simplistically, this could be applied such that any project with an economic net-benefit should go ahead, subject to having zero or positive impact on natural capital. Applied at the project level, however, this would be stultifying. But netted out across all projects it becomes something to consider. Applying this, each project would be accompanied by an offset-project, the purpose of which is compensation for environmental impact of the first. Internalizing a project’s environmental externalities is done by including damages in CBA calculations.

“There are a few implications of this but one of the most prominent (as well as far-reaching) is to circumscribe CBA by having it live within sustainability constraints, perhaps based on ecological criteria” (OECD, 2018). On balance, therefore, the environmental status quo must be maintained, with biodiversity offsets being one practical way of implementing this. Development being environmentally sustainable means no depletion in the stock of natural assets. In order to ensure non-depletion, natural assets need to be valued, then they can be tracked and factored into calculations to ensure total stock is not depleted (Barbier, Markandya, & Pearce, 1990). Benefits transfer can play an important role in improving CBA's suitability as a methodology for including environmental values (Kelman, 1981).

Methods of non-market valuation include stated preference techniques, such as choice modelling and contingent valuation, and revealed preference methods. In addition, a newly developed technique is subjective well-being valuation. Values for this are measured by how self-reported indicators of well-being, life satisfaction for example, are impacted by non-market goods (OECD, 2018). Further research is required into accounting for irreversible environmental harm and how to incorporate ecosystem complexity into CBA.

3.1.7 Discounting and the environment

While the social discounting theory clearly shows how the discount rate should be applied, in practice numerous questions remain, especially when considering actions that may impact future generations (OECD, 2018). Thomas (2001) illustrates the impact of discounting showing an improvement obtained being relatively small due to it taking many years to achieve, with benefits 50+ years into the future difficult to register after discounting. There is strengthening empirical and theoretical support in such contexts, for discount rates that decline over time. Weitzman (1998) argued that when discounting far into the future, perhaps centuries, the lowest possible interest rate should be used.

Given the long timescales involved in achieving some of the benefits from salinity mitigation, any divergence between social and private discount rates may have a substantial impact on evaluation of investment decisions (Pannell., 2002). There are important policy implications stemming from this around water management and other environmental issues of significance (OECD, 2018).

3.1.8 Conclusion

While CBA may provide decision-makers with valuable information, it also forms just one part of a complex set of considerations that are to be accounted for when dealing with environmental management. It is necessary to provide decision makers with flexibility as they make a decision in the best interest of the whole community, factoring in a range of values and priorities. The "theory of political economy then seeks to explain why the economics of the textbook is rarely embodied in actual decision-making and, related to this, policy-formulation processes” (OECD, 2018). Explaining the gap between theoretical and actual design, however, is not the same as justifying this gap. While there are numerous other pressures that impact decisions and it is important to improve our understanding of these, the role of CBA remains to explain how a decision looks if adopting the economic approach.

While CBA is imperfect, an alternative that uses moral judgements is actually less transparent and open to manipulation by interest groups, government agencies and those actually making the decision. “Is there a common moral standard that every regulator will magically and independently arrive at through deliberative consideration? Doubtful” (Kelman, 1981). A more likely scenario is a system where decisions reflect those in positions of influence rather than reflecting society’s preferences. If CBA was not applied, then the decision would still be left to the community in some form (frequently its representatives in parliament, or their departmental subordinates) but they would not have a transparent, systematically set-out stream of economic costs and benefits from which to start. The key for analysts providing advice and decision-makers receiving this advice is just that, that CBA is a start. A key criticism of CBA is that its influence on the eventual decision is too much, when in fact there are other issues to consider. The results of any CBA are certainly open to manipulation, but this is more of an issue for society and decision makers than the tool itself.

3.2 Key Steps in CBA

3.2.1 Identify the relevant population

The first step in a CBA is to identify who is involved in the analysis; from whose perspective the analysis will be undertaken (Department of Finance and Administration , 2006). Included should be all those whose utility will significantly be impacted by the project and all those within a relevant political boundary, including taxpayers (NSW Treasury, 2017). There are situations, however, where it is not straight forward to identify who is a loser and who a gainer (Building Queensland , 2016). A project normally has three stakeholder groups:

1. Those people who will benefit;
2. Those who pay (tax payers in the case of publicly funded projects); and
3. Those who will lose

Hajkowicz (2000) conducted CBA from landholder and social perspectives to determine the costs government would have to contribute to make the project they were studying viable for landholders and society. Many of the on-ground works required for salinity remediation are not financially viable to individual land-holders. This is because they will mostly have social (external) benefits (biodiversity, improved water quality, reduction in further land becoming saline), but largely private costs such as re-vegetation and building repair. The question becomes how much government needs to contribute for remedial action to be viable. Government should not want to invest on behalf of society if the benefits are mostly private. The study found that benefits from non-market environmental and infrastructure impacts would need to be extremely high in order to tip the NPV into positive.

3.2.2 What is the problem?

Scoping the project and its background includes identifying the objectives and beneficiaries of the project or program, its context and background.

3.2.3 What are the objectives and who are the beneficiaries?

A CBA needs to set out in some detail what the project in question is trying to achieve. This is the context for the costs required to achieve it and the benefits it might generate.

Similarly, identifying the beneficiaries is important for a range of reasons, not least of which is undertaking any analysis of where and on whom the impacts could fall.

3.2.4 Identify constraints

Constraints to achieving the objective are important to identify so that the analyst can ensure that all alternatives to the status quo being considered are feasible. Constraints can be:

- financial – price ceilings or floors, budget limits
- distributional/ equity – how benefits or costs are distributed among community groups or individuals
- managerial – limits in the human capacity to implement
- environmental – such as standards that must be met
- engineering limitations – are the options technically feasible

3.2.5 Options

Options should:

- be clearly differentiated from one another
- be likely enough to warrant analysis, and
- have data available

A **do-nothing** approach, or base-case, should always be included – because the costs of doing anything might be more than the benefits.

3.2.6 Base Case

Statement of a base case is the benchmark that all alternatives are compared against. It is not a ‘zero spend’ or ‘dummy’ option, but rather statement of the situation that will exist if the project is not approved, to account for ongoing costs that would be incurred. It should be remembered that there are costs of not changing.

Thomas (2001) compared various improvement scenarios with the base-case scenario of current trends of salinity deterioration being left unchecked. In rural towns these costs are that infrastructure will continue to deteriorate and/ or need maintenance and replacement, with associated economic and social disruption.

3.2.7 Identifying Benefits and costs

The only costs and benefits to be included in a CBA are those directly relevant. If they would occur in the absence of the project, then they should be excluded. Avoided benefits or costs should be included, provided they are directly attributable to the project. In the case of infrastructure CBAs, market values can typically be identified quite readily. Their applicability, however, “depends on whether these values reflect competitive market assumptions and comprise the full economic costs associated with private consumption and supply of infrastructure services” (Building Queensland , 2016). In addition to these, non-market values can be significant and need to be estimated and then incorporated into the CBA.

Longer-term impacts, some of which are not fully apparent for decades, should also be accounted for in any analysis of engineering options. “Balancing the short-term impacts of intervention against forecast long-term impacts if no intervention occurs remains an unresolved dilemma” (Dogramaci & Degens, Review of engineering and safe disposal options, 2003).

What benefits are included in the analysis and decision-making can be quite varied. In addition to groundwater recharge, Hill (2000) included education to reduce overwatering as a benefit to the funds invested in the initiative. This can be considered as incorporating a positive externality as many of these initiatives include education: general increased literacy of population about water, tree planting: wind breaks and town beautification. While education without action may not lead to changed behaviour, it is argued that increased awareness of salinity and water use efficiency (how not to overwater your parks and gardens) can play a significant part in changing behaviour. As discussed above, environmental values are difficult to include and frequently are not included. Thomas (2001) for example, did not calculate economic values of environmental, aesthetic and recreational benefits of salinity control.

In a Lake Eyre Peninsular basin study (Hajkowicz & Young, 2002), infrastructure and road damage costs were included, which produced two sets of results: one for society as a whole (including these public assets) and one for landholders across the basin only, with both CBAs including the same calculations. The study found that the society one including the infrastructure costs may well provide BCRs >1 if it was applied to urban areas with high value infrastructure, significantly higher than rural and natural landscapes, an interesting indicator of how society values natural landscapes. This analysis highlights the need for further study into economically feasible techniques for salinity management and remediation, including urban areas.

3.2.8 Identify benefits

Benefits typically include (Queensland Treasury, 2000):

- Avoided costs – Costs that would have been incurred under the base-case, but may be avoided if action is taken – a key focus of this project.
- Cost savings – verifiable reductions in existing expenditure if a project proceeds - such as reduced water corporation bills.
- Direct benefits – such as the value of the project's output – as sales of water.
- Indirect benefits to consumers and the broader community such as reduced externalities, increased amenity and recreation value, downstream impacts.
- Residual value of the project, such as pumps and pipes.
- Productivity savings i.e. savings in costs due to increased productivity that the project makes available.
- A reduction in unemployment.

The cap and pipe the bores scheme for the Great Artesian Basin undertook a CBA using landholder interviews to gather data. Items that landholders could not put a dollar value on were not included in the analysis (Centre for International Economics , 2003). The net benefits for this analysis were private incentives to change behaviour, rather than whole-of-community net benefits.

Hill (2004) did not include damage to infrastructure in calculations, whereas in rural towns, this is a major factor.

3.2.9 Identify costs

Costs should be stated based on opportunity costs. Usually market prices will be acceptable as they reflect the preferences of individuals given their income, personal preferences and perception of information (Building Queensland , 2016). Generally, the market price represents the amount that consumers at the margin are willing to pay. "In competitive markets, pricing at marginal cost implies that costs and benefits are equated with their opportunity costs" (Department of Finance and Administration , 2006).

Sometimes, however, market prices need to be adjusted in order to establish social costs and benefits from private ones – that is, prices that reflect actual gains or losses to the overall economy as opposed to just individuals or groups. Shadow prices “correctly reflect the value of inputs and outputs at the social optimum” (Hajkowicz et. al 2000). If there are monopoly suppliers, dominating the market or significant distortions from subsidies or taxes, prices will not equal opportunity costs and adjustments to market prices may be required to ensure a CBA is robust. A project may be commercially viable but there may be external costs that mean the costs to the community overall are greater than the benefits (Queensland Treasury, 2000). It could be argued that previous projects leading to the current salinity damage might not have taken place if decision-makers were aware of the environmental cost that would result.

URS (2001) calculated the economic impact of salinity remediation by estimating the:

- additional cost that damaged infrastructure would need through remedial work; and
- expenditure necessary for infrastructure maintenance

URS (2001) estimated that in the town of Katanning, the annual cost of managing the impacts shallow saline water table had on townsite infrastructure was $1,176/ha. It also estimated a cost of $300-$400/km of sealed road and $200/km of unsealed road in Katanning**.**

In rural towns there are two types of damage costs:

- meet ongoing damage and maintenance costs;
- abandon buildings (uses the current market value for land and buildings in the town)

If a town chooses to meet ongoing damage and maintenance costs this can include (Barron, et al., 2010):

- Costs of coping with intrusion of shallow groundwater into facilities: e.g. pumping out of cellars, or additional treatment costs if there is intrusion of saline groundwater into sewers
- Costs of coping with physical destabilisation or displacement of assets, e.g. lifting underground tanks or swimming pools by provision of additional weight to the structure
- Costs of coping with waterlogging such as construction of on-site drains around buildings
- Additional costs of repair or replacement of physical assets, e.g. more frequent and higher cost road stabilisation, more frequent renewal of saddle tappings on water supply pipes, replacement of rotting wooden poles and stumps, repair of distorted floor boards, repair of cracking masonry
- Loss of amenity, such as waterlogged vegetation, parks or sports ovals
- Loss of land from urban inundation

If a town chooses to abandon buildings, there are various social and economic implications to this (Frost, Hamilton, Lloyd, & Pannell, 2001). Not only are there economic costs and disruptions, transactions costs, of finding a new building for the activity (business, private or community activity), there are also social costs of losing a place that might be full of memories or play an important part in town social events, such as club meetings and rehearsals. It is possible that there will be other buildings readily available for these social purposes, but given some rural towns are small, it is quite feasible that there will be considerable anxiety and social tension about whether such a building is available and who pays for additional costs that might not have been associated with a previous venue. These social costs are frequently not included in an economic CBA but economics recognises their importance in community decision-making. They can be the difference between a successful transition to a new building and degraded social cohesion.

3.3 Discounting

3.3.1 Time value of money

Discounting reduces benefits or costs over time to an equivalent amount in today's dollars. It is the standard approach to valuing costs and benefits that occur at different times and is based on the concept that a dollar now is worth more than a dollar in the future: the time preference of money (Building Queensland , 2016). This is the case for several reasons: impatience, uncertainty, the concern that wealth may not in fact grow with time, and opportunities to invest for productive return. Discounting asks what return an investment could have produced in an alternative use and in-so-doing acknowledges a project's opportunity cost. The long term social discount rate's theoretical basis is the opportunity cost of capital (NSW Treasury, 2017).

An individual's preferences are influenced by their risk aversion, age and education, among other factors (Hajkowicz, et al 2000). Individuals also generally prefer to receive benefits sooner rather than later, and to defer costs as far into the future as possible: i.e. there is a social time preference. “The social time preference rate is the rate at which society values the present compared to the future” (Building Queensland , 2016).

The longer the life of the project, the greater the difference in present value, so some projects are quite sensitive to changes in discount rate. Indeed, most projects that are feasible at a certain discount rate, would have another discount rate that would mean the project falls below that threshold (Department of Finance and Administration , 2006).

Investment expenditures, typically occurring early in the life cycle of a project, are often significant outlays (Building Queensland , 2016). By comparison, annual operating and maintenance costs tend to be small. Infrastructure investments returns — project benefits — are realised over long time periods. Benefits that a project generates each year tend to be small relative to both the ongoing operational and maintenance costs and initial capital outlay.

It is argued that conventional discounting discriminates against future generations by

- depleting exhaustible resources rapidly
- transferring the burden of costs onto future generations by making them artificially cheap up front
- declining investments with long periods before benefits begin (such as forestry where it can take many years to produce a return)

To address this, zero discount rates are an option for projects that have environmental impacts (Hajkowicz, Young, Wheeler, Hatton MacDonald, & Young, 2000). Sustainable outcomes would not necessarily be guaranteed, however, simply through the use of zero or negative discount rates.

In the Wagga salinity study, Hill (2000) found that lowering the discount rate from 7 per cent to 4 per cent caused the BCR to increase from 1.11 to 1.43. Meanwhile increasing the discount rate from 7 per cent to ten per cent resulted in the BCR falling from 1.11 to 0.86.

3.4 Decision rules

When all calculations are done, CBA presents results to decision-makers in the form of the three common decision rules: Net Present Value, Benefit/Cost Ratio and the Internal Rate of Return (Department of Finance and Administration , 2006).

The Benefit Cost Ratio (BCR) is the present value of benefits divided by the present value of costs. A ratio of greater than one indicates that a project is economically viable. This simplicity carries an immediate intelligibility. Thomas (2001) calculated that salinity remediation on agricultural land in Western Australia’s Blackwood catchment had a BCR of 0.17 over a 30-year discount period or 0.19 over 45 years, so both well below one and clearly not economical for the project considered. The RTLAP (URS, 2001) speculated that salinity remediation initiatives involving higher value town infrastructure may be different.

The Centre for International Economics conducted a 2003 CBA of the “cap and pipe the bores” program; an initiative to address free-flowing bores, sunk decades ago, that just flow onto open ground, with resulting extremely high evaporation and wastage. The study incorporated net social benefit implicitly, rather than explicitly. The project acknowledged that a substantial amount of the benefit would be private but that without government assistance, net private benefit would at best be marginal. Government assistance was provided therefore, and any shortfall of BCR was considered to be society value. The decision-criteria were:

- BCR well above 1 then the private landholder is getting a substantial amount of private benefit.
- BCR close to 1 then not much public benefit is required to make the project worthwhile

The result was a BCR of around 0.8 and it was decided to proceed with the project on the above basis.

Net Present Value (NPV) is discounted total economic benefits of a project minus the discounted economic costs. Projects with an NPV greater than zero should generally be accepted on economic grounds (NSW Treasury, 2017).

Wagga Wagga City Urban Salinity Plan undertook a CBA, estimating discounted costs at $26 million and discounted benefits (which includes the costs avoided) at $29 million; a $3 million NPV.

Madden (2000) calculated that an investment of $60b into degradation of rural landscapes at a discount rate of 5 per cent had an NPV of $30b. So society would be $30b better off as a result of the investment.

The Internal Rate of Return (IRR) is the discount rate at which NPV is zero; that is, the discount rate where the present value of benefits equals the present value of costs. The IRR provides little information in addition to NPV and in cases where projects are being ranked, its contribution can in fact be misleading (Department of Finance and Administration , 2006).

3.4.1 Roles of NPV and BCR

The net present value rule is considered the primary basis for decision-making when evaluating projects (Department of Finance and Administration , 2006). BCR and NPV results can rank projects in a different order, however. When estimated properly, BCR can guide project selection when there are constraints on capital (more projects than funding can cover at a given discount rate), but the objective of maximising net present value remains. In the hypothetical scenario of an unlimited budget, every project with a positive NPV should be pursued (Pannell D. , NPV versus BCR, 2019). In a constrained budget environment, however, not all projects where BCR is greater than one can be accepted. The BCR has a bias towards smaller projects and should be used with this in mind. BCR tends to have a bias in favour of projects with smaller up-front capital costs, so it is best to be used alongside NPV in advising decision-makers (Building Queensland , 2016). It is as a result of these shortcomings that NPV is the primary tool for considering projects in CBA.

In certain cases, prioritising the projects that have the highest individual NPVs will give a lower total NPV than prioritising the projects with the highest BCRs. The most common scenario where you have to go beyond the simple rules is where you are comparing different versions of the same project. They are not separate, unrelated projects – they are mutually exclusive. If you do one of them, it rules out doing the others. This is the case in rural towns. Versions of a project with more ambitious targets can deliver greater benefits, but also incur greater costs, so it is usually not readily apparent how ambitious the project should be. This is the case for options outlined below in this paper. The first project version to be specified may or may not end up being the best version when several versions are compared. However, if you are ranking projects, and the projects you are ranking consist of multiple versions of the same project, using BCR for the ranking process will probably not give you the correct result. Pannell (2019) summarises three rules of when to use NPV and BCR, shown in Table 3-1.

Table 3-1: Rules for use of NPV and BCR

Rule
Rule 1. If you are assessing separate, unrelated projects, and the budget for funding the projects **is not** limited, you can use either NPV or BCR. They tell you the same thing.
Rule 2. If you are assessing separate, unrelated projects, and the budget for funding the projects **is** limited, you rank the projects using BCR.
Rule 3: If selecting from different versions of the same project, choose the project with the largest NPV that you can afford within the available funds.

Source: Pannell (2019)

As a general rule, projects that have a BCR higher than one and an NPV above zero should be accepted and recommended as economically viable (Building Queensland , 2016). Projects that have higher NPVs and larger BCRs are preferred over the alternative, on the basis of greater economic value. On the basis of economics alone, a project that has an NPV below zero should be rejected due to the project not producing net positive benefits to society as a whole. In situations where qualitative environmental, social, and economic impacts are seen as significant, these should be considered alongside the NPV to determine whether qualification of the decision rule is required. Despite having a negative NPV, a project could still be recommended in circumstances where the NPV result was more than offset by non-quantifiable benefits. The cap and pipe the bores CBA above is a clear example of this, with a project proceeding. Similarly, non-quantified costs of sufficient magnitude could lead to a project being rejected. Such circumstances are relatively rare, and rely upon decisions outside strict considerations of economic viability.

The Wagga study (Hill C. , 2000) produced a BCR of 1.1, but was considered considerably more favourably with significant environmental benefits in addition to the benefits quantified.

In Moora, URS (2001) estimated total present costs of $900,000 and benefits of $300,000, so remediation action was not economical.

3.4.2 Dealing with uncertainty – sensitivity analysis

Uncertainty occurs frequently in CBA: especially when applied to environmental issues and projects, with a key example being how environmental outcomes respond to various project or policy alternatives (OECD, 2018).

The key risk areas for most projects in the public sector are (Building Queensland , 2016):

- Forecasting demand
- Estimating environmental impacts
- Costs of construction - changes in input costs, labour negotiations, availability, reliability, or weather events
- Operation and maintenance costs – differ due to unforeseen circumstances
- network effects, in which an asset is part of a broader network (such as a road) and decisions made outside the project affect operations.

When taking risk into account, sensitivity analysis is a key step to identify the CBA's greatest exposure to uncertainty (Building Queensland , 2016). It aims to estimate the magnitude of deviation in results triggered by changing project driver/s.

3.4.3 Equity and distributional issues; politics and decision-making

There will inevitably be equity issues, with uneven distributions of benefits and costs, as well as environmental and other benefits and costs that are hard to quantify, let alone monetize. (URS, 2001)

Fundamentally, CBA considers costs and benefits of society as a whole and does not concern itself with who bears the costs and who reaps the benefits. Decision-makers would normally want to take account of this with a variety of other information and advice.

3.5 Conclusion

This chapter introduced cost benefit analysis as a methodology suitable for assessing the viability of various water infrastructure responses to townsite salinity damage. Its welfare economics foundations were summarised and identified the key steps and decision rules and briefly outlined some of the main strengths and weaknesses of CBA. The next chapter sets out the application of CBA to the Wagin case study for this paper, stating the source of cost and benefit data and choice of discount rate.

4. Methodology

4.1 Introduction

This chapter outlines the methodology used in the Wagin case study. CBA was used because it has been used for similar projects throughout the economics literature and has specifically been recommended in previous studies on Wheatbelt salinity.

4.2 The Population

For the Wagin CBA, the population was the entire country. This is because federal funding for the RTLAP and State funding for the CSO among others means that the population needs to be broader than just the town of Wagin. A complication of an otherwise simple CBA of water infrastructure options is the town's relationship with scheme water. A CBA for the immediate town of Wagin (Shire Council's perspective) would be different to a CBA from the perspective of the state of WA, or the perspective of the Water Corp and it's planning of works for scheme water.

4.3 The problem

The problem is set out in detail above. In short, as was the case across the Wheatbelt, Wagin was suffering infrastructure damage from rising groundwater. Without intervention groundwater levels were predicted to continue to rise and cause further damage.

4.4 Objectives and beneficiaries

For Wagin, the Project objectives were:

- reduce salinity damage
- identify opportunities for productive use of local water produced from remediation actions

The beneficiaries would predominantly be the people of Wagin through reduced infrastructure damage as well as possibly new water made available for local productive use. Lesser beneficiaries would include the State and the Nation due to reduced damage to assets of State and National cultural significance, such as heritage listed historic buildings.

4.5 Constraints

A health/ governance constraint was that the WA Department of Health guidelines prescribed that reclaimed water was not available for potable use.

Funding was provided by the federal government to help address this project, and as such, while this funding was not unlimited, it did substantially ease a much tighter financial constraint on the town had it acted alone.

In addition, there were some environmental constraints, such as where pumped water could be disposed of, which could not be included in this analysis but would need careful consideration before any final decision was made.

4.6 Options

4.6.1 Base Case

Within the 'do-nothing' option, the economic analysis assumes that the water management in the town remained unchanged and the shire and community bear the damage costs to local infrastructure.

The four options summarised below were based on KBR (2005) consulting engineering advice provided to the RTLAP.

4.6.2 Option A: Groundwater abstraction, desalination, water sales and evaporation ponds

Use existing production bores and pump groundwater along a pipe route to a desalination plant. This was to reduce waterlogging and salinity and generate potable water to be delivered to a tank. It was assumed that stored water would be used for irrigation of town parks, gardens and ovals. Brine to be disposed of in purpose-built evaporation ponds. Combined bore yield was expected to be 8L/s.

The meaning of water sales is the use of water by the town, valued at opportunity cost, which is the equivalent scheme water price. There were no 'sales' between two parties, but rather the town using treated pumped groundwater rather than scheme water.

4.6.3 Option B: Groundwater abstraction, desalination and evaporation ponds (no water sales)

From previous research and studies in other WA rural towns, e.g. Merredin desalination project and townsite water management plan, water sales had been observed as potentially the difference between a project being economical and not. This option was to test this argument for Wagin.

4.6.4 Option C: Groundwater abstraction, desalination and water sales (no evaporation ponds)

Evaporation ponds was by far the largest cost item. Option C was to calculate the impact of removing this cost item, with desalination brine disposed of into existing salt lakes rather than purpose build evaporation ponds.

4.6.5 Option D: Groundwater abstraction and disposal to natural salt lakes (no desalination, no water sales, no evaporation ponds)

This option was to assess whether a substantially simpler approach would have been viable, removing the top cost items of the desalination plant and purpose-built evaporation ponds. In so doing, without desalination it was assumed that there would be no water sales (given the pumped saline groundwater would not be fit for any local use). All water would be disposed of into existing salt lakes rather than purpose built evaporation ponds.

4.7 Benefits

Only costs and benefits that could be expressed in dollar terms were included. Non-market costs and benefits (environmental and social impacts not expressed in dollar terms) would need to be considered as part of further advice to decision-makers, otherwise there is a risk that unintended consequences from this project could trigger the need for future clean-up. In other words, this project that is addressing repercussions from previous decisions, could itself leave behind a legacy that would need to be fixed.

4.7.1 (Avoided) Damage Costs

For this project, economic evaluation of infrastructure damage was done using the Urban Salinity Economic Analysis Package (USEAP), designed for the RTLAP by a previous consulting project (URS, 2001). USEAP is a decision-support tool that was applied to urban areas threatened by rising groundwater, comparing the costs of alternative control strategies, taking account of the control costs and the damage costs that would be incurred if nothing were done to control the problem.

While the hydrology and hydrogeology relationships with the broader catchment are complex, this paper focuses specifically on the benefits from avoided damage to townsite infrastructure caused by salinity, due to the availability of the USEAP model. Other issues associated with rising groundwater, such as waterlogging, a legitimate focus for further attention in a separate analysis.

The assessment of salinity risk to infrastructure was based on evaluation of soil saturation levels at a given depth. The critical depth to the groundwater table applicable for infrastructure damage evaluation was taken as 1m below ground level**.** In an area where the salinity risk is 1.0 (e.g. groundwater table is at a trigger level or above, hence soil saturation is 100%), the damage cost is evaluated as 100%. In the areas where the salinity risk is <1.0, the damage cost reduced in accordance with salinity risk reduction. For a sufficiently deep groundwater table the infrastructure damage cost is close to zero.

Differences across space are dealt with by subdividing the region into zones within which the watertable is at a uniform depth and only one kind of human activity is taking place (house/ hospital/ road). Damage costs within the zone then consist of the damage done to a unit of human activity multiplied by the number of units within the zone.

The discounted present value of the damage costs for Wagin, over a 20-year horizon, were estimated to be $1.125 million. This is the base case. Simulation of pumping over this time reduced the cost of infrastructure damage to around $0.283m. The damage benefit (or avoided cost) of pumping for this case study is therefore the difference between these two figures: $0.842m.

No socio-economic survey was done as part of this thesis to assess the local community’s values and willingness to pay for various options, however social survey was done for Wagin in 2005 under the RTLA program and CSIRO Water for a Healthy Country (Johnston, Green, & Helmert, 2005).

4.7.2 Water sales

A key potential breakthrough in the economics of remediation was to include the use of abstracted water for productive purposes (URS, 2001). Rather than disposing of the water, potentially adding to the cost of the project, the aim was to find a productive use for it, creating more benefits. This was calculated by the amount of water multiplied by water price: the opportunity cost of water, taken as the Water Corp price at the time of $1.20/KL (Pluske, New water for Western Australian rural towns, 2006).

4.7.3 Other benefits

Loss of town infrastructure due to salinity was considered likely to have social ramifications as well as physical and economic damage (Department of Environment , 2003) and therefore social benefits would accrue from avoiding this damage. Other social issues such as declining terms of trade, improved communications, and the replacement of labour by technology, however, were seen as more significant to the town's wellbeing (URS, 2001). Notwithstanding this, improving general social strength was seen as a high priority to be able to deal with salinity (Department of Environment , 2003).

Additional items not included as benefits

- Values of environmental, aesthetic and recreational benefits of salinity control.
- Recreational benefits of water bodies fed by desalination brine (Poulson, 2010)
- Employment impacts.
- Residual value of project, such as pumps and pipes.

4.8 Costs

Costs of remedial action are

- The direct capital and operating and maintenance (O&M) costs.
- The opportunity cost of land or a piece of infrastructure being taken out of its current productive use and used as salinity control – note that the land being considered is already suffering damage, so its opportunity cost is falling or in some cases already zero.
- Environmental costs, such as disposal of saline water into the catchment – no data existed so these costs were not included. Salinity damage to date was a sunk cost.

The cost of piping water to an industry relocated outside the town could have been a proxy for the externality associated with the activity (e.g. intensive livestock, feedlots, abattoirs). Residents of the town live in the environment, and could consider that degradation of that environment imposes a "cost" on them, even if it is not a financial one, in the way that repairing houses is a financial cost (URS, 2001).

The costs, capital and O&M, associated with the implementation of Wagin water management were estimated by the engineering consultancy group KBR, which was engaged by the RTLAP, and are listed in Table 4-1: .

Table 4-1: Wagin capital costs

Capital Cost Item	Cost ($2006 thousand dollars)
Pipe from existing bores to desal plant	157
Pump from bores to desal plant	43
Installation and commission of desal plant	265

Pipe from desal plant to tank	17
Pump from desal plant to tank	13
Supply and install storage tank	76
Pump from desal plant to evap ponds	13
Pipe from desal plant to tank	23
Evaporation Ponds	2,125
Sub total	2,731
Location allowance	546
Sub-total capital costs	***3,278***
Additional project costs	
General contractor prelims (20%) - site set-up etc	656
Fees 10% of cost	393
Contingency (10% of cost)	393
Sub-total additional capital costs	***1,442***
TOTAL	**4,720**

4.8.1 Operational and Maintenance costs

The main O&M costs are desalination plant operation, which was removed from calculations for options that do not include desalination. Annual O&M costs of option A are shown in Table 4-2.

Table 4-2: Option A operating costs

Option	Annual operating cost ($2006, thousand dollars)
Pump operation from bores	4
Pump operation from desal plant to evaporation ponds	1
Pump operation from desal plant to tank	1
Desal plant operation	102
Maintenance personnel and repairs	9
Total Operation and Maintenance Costs	**118**

Net Benefits resulting from the introduction of one or other options were estimated as a difference between the cost of the option implementation and reduction in the infrastructure damage cost (as a result of the groundwater table lowering) plus water sales (where relevant).

While the best available data was used, much of the data were estimates and better data could produce more accurate results.

4.8.2 Discount period

Given the uncertainties in the modelling, and the impacts of discounting, a 20-year period was proposed by the Rural Towns Management Committee as a sufficient timeframe for analysis. A standard seven per cent discount rate was used. Since the analysis is done from the perspective of the decision-maker in 2006 when the data were available, this is the commencement year. An ex-post CBA was considered but sufficient data about the actual cost of the project or its benefits over the years were not available. The parameters of the CBA are shown in Table 4-3.

Table 4-3: CBA general parameters

Parameter	**Unit**	**Value**
Discount rate	%	7
Starting year	year	2006
Assessment period	years	20

5. Results

5.1 Summary

At the 7 per cent discount rate, options A and B have BCRs less than 1 and negative NPVs, while options C and D have BCRs greater than 1 and positive NPVs. These results are shown in Table 5-1.

Table 5-1: CBA results - summary table 7%

Option (7% discount rate)	BCR	NPV ($2006 million)	Comment
A) Full costs and benefits	0.68	-1.9	Not economical
B) No water sales	0.14	-5.1	Substantially less economical, as expected.
C) No evap ponds	1.76	1.7	Comfortably economical, as expected
D) no evap ponds, no desal, no water sales	1.73	0.4	Comfortably economical, although a smaller project

5.2 Sensitivity analysis, discount rate

Sensitivity analysis was conducted using 4 per cent and 10 per cent discount rates and results are shown below in Table 5-2 and Table 5-3.

Table 5-2: Sensitivity analysis results summary table 4%

Option	BCR	NPV ($2006, million)
A) Full costs and benefits	0.82	-1.1
B) No water sales	0.17	-5.2
C) No evap ponds	1.96	2.5
D) no evap ponds, no desal, no water sales	2.05	0.6

Changing the discount rate to 4 per cent does not change the original results: options A and B remain uneconomical, while options C and D remain economical.

Table 5-3: Sensitivity analysis results summary table 10%

Option	BCR	NPV ($2006, million)
A) Full costs and benefits	0.57	-2.5
B) No water sales	0.12	-5.0
C) No evap ponds	1.58	1.2

Option	BCR	NPV ($2006, million)
D) no evap ponds, no desal, no water sales	1.47	0.2

As with 4 per cent, a discount rate of 10 per cent does not change any option from a positive to a negative NPV, or vice versa.

A summary of discount rate sensitivity analysis is shown below.

Table 5-4: NPV results ($2006, million) —discount rate sensitivity analysis results for 4%, 7% and 10%

Option	Low discount rate 4%	Medium discount rate 7%	High discount rate 10%
A	-1.1	-1.9	-2.5
B	-5.2	-5.1	-5.0
C	2.5	1.7	1.2
D	0.6	0.4	0.2

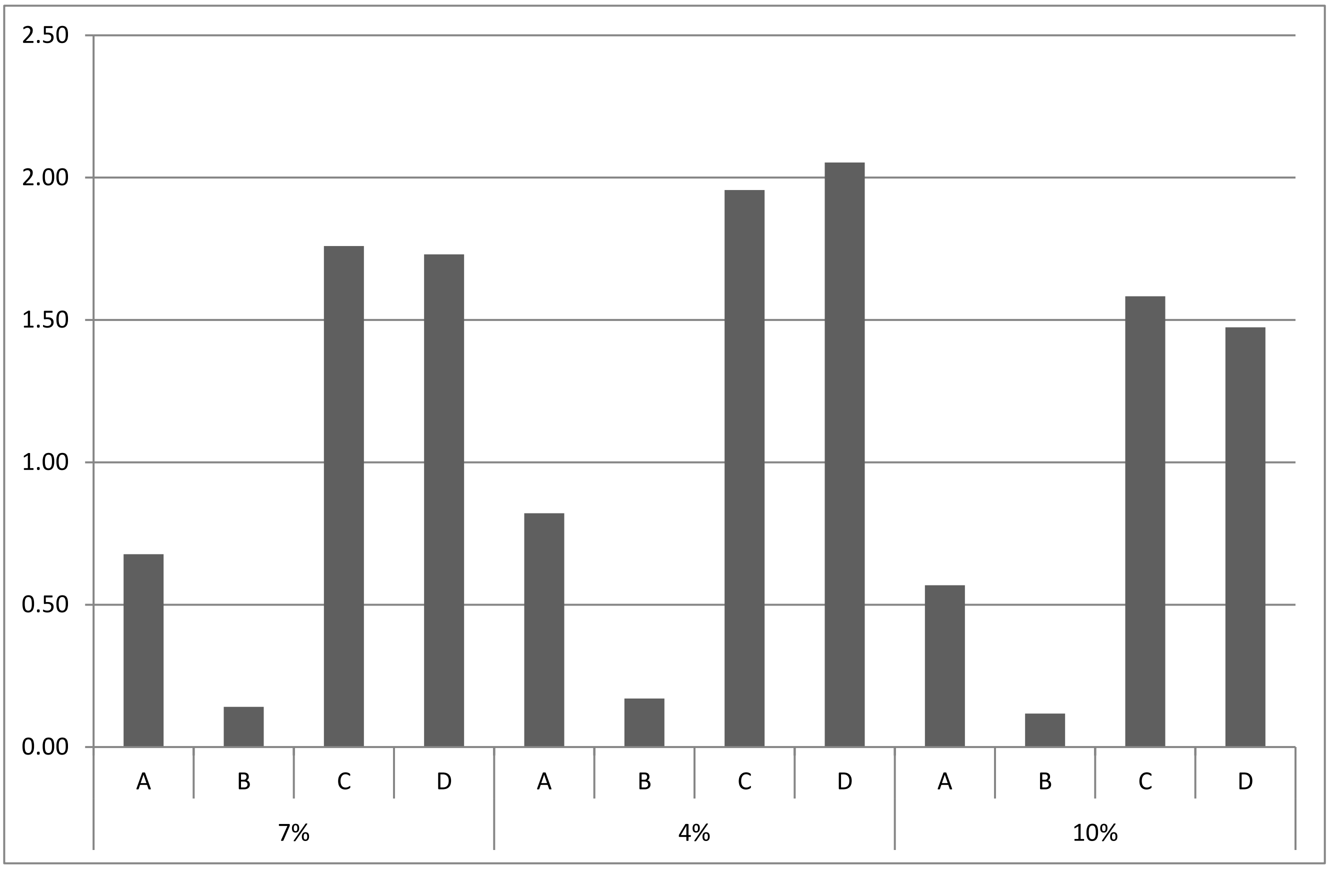
Table 5-5 summarises discount rate sensitivity analysis using BCRs.

Table 5-5: Summary of BCR results - sensitivity analysis for 4% 7% and 10%

Option	Low discount rate 4%	Medium discount rate 7%	High discount rate 10%
A	0.82	0.68	0.57
B	0.17	0.14	0.12
C	1.96	1.76	1.58
D	2.05	1.73	1.47

BCRs are shown graphically in Figure 5.1. This illustrates at a glance that options A and B have BCRs below 1 under all three discount rate scenarios, while options C and D have BCRs above 1 under all discount rates used.

Figure 5.1: BCRs at 7%, 4% and 10% discount rates



5.3 Sensitivity Analysis – plus/minus 20 percent Costs and benefits

To further investigate under what circumstances which option was economical, each option was recalculated with costs and benefits 20 per cent higher and 20 per cent lower. NPV results are shown in Table 5-6

Table 5-6: Summary of NPV results ($2006, million) – sensitivity analysis 20 per cent higher and lower costs and benefits

Option	Interest rate (%)	Original	higher costs	lower costs	higher benefits	lower benefits
A	4	-1.1	-2.4	0.1	-0.1	-2.2
	7	-1.9	-3.1	-0.7	-1.1	-2.7
	10	-2.5	-3.6	-1.3	-1.8	-3.1
B	4	-5.3	-6.5	-4.0	-5.0	-5.5
	7	-5.1	-6.3	-3.9	-5.0	-5.3
	10	-5.0	-6.2	-3.9	-4.9	-5.2
C	4	2.5	2.0	3.0	3.6	1.5
	7	1.7	1.3	2.2	2.6	0.9
	10	1.2	0.8	1.6	1.8	0.5
D	4	0.6	0.5	0.7	0.8	0.3
	7	0.4	0.3	0.5	0.5	0.2
	10	0.2	0.1	0.3	0.4	0.1

The results show that a 20% increase and decrease of costs and benefits changes almost nothing. Only option A: four per cent discount rate, 20 per cent lower costs shows a change from negative to a positive NPV.

5.4 Sensitivity Analysis – 50 per cent increased and decreased costs and benefits

Given a 20 per cent change in costs and benefits changed only one scenario from negative to positive NPV, further sensitivity analysis was conducted using 50 per cent higher and lower costs and benefits. Results are shown in Table 5-7.

Table 5-7: NPV sensitivity analysis ($2006, million) – 50 per cent increased and decreased costs and benefits

Option	Interest rate (%)	Original	higher costs	lower costs	higher benefits	lower benefits
A	4	-1.1	-4.3	2.0	1.5	-3.7
	7	-1.9	-4.9	1.1	0.1	-3.9
	10	-2.5	-5.3	0.0	-0.9	-4.1
B	4	-5.3	-8.4	-2.1	-4.7	-5.8
	7	-5.1	-8.1	-2.1	-4.7	-5.6
	10	-5.0	-7.9	-2.2	-4.7	-5.4
C	4	2.5	1.2	3.9	5.1	-0.1
	7	1.7	0.6	2.9	3.8	-0.3
	10	1.2	0.2	2.2	2.8	-0.4
D	4	0.6	0.3	0.8	1.1	0.1
	7	0.4	0.3	0.5	0.5	0.1
	10	0.2	0.1	0.3	0.4	0.1

These results show that a 50 per cent sensitivity analysis begins to change some NPVs. Decreasing costs by 50 per cent, for example, changes option A, four, seven and 10 per cent discount rates from negative to positive NPVs.

5.5 Change water price

The Wagin water price has changed since 2006 although the data for this is unavailable. Anecdotally from discussions with town officers the price changed to $1.85 and then $2.50 per KL. For the purpose of the analysis it was assumed that the water price increased in year six (from the base price of $1.20 to $1.85) and year 11 (to $2.50). Applying these water price changes resulted in annual water sales increasing to $476 thousand for the middle water price and $630 thousand for the high price. A significant change. BCRs and NPVs are shown in Table 5-8.

Table 5-8: CBA results summary table - changed water price (7% discount rate)

Option	**BCR**	**NPV ($2006 million)**	**BCR**	**NPV ($2006 million)**
	Original		Changed water price	
A) Full costs and benefit	0.68	-1.9	0.95	-0.1
C) No evap ponds	1.76	1.7	2.5	3.4

Given Options B and D involved no water sales, these options by definition will not change and have been excluded from the table and discussion.

Tables of costs and benefits for all options are included in appendices.

Having listed the results for all options above, the following chapter discusses what some of the key results mean, including the key themes and issues in the context of the scenario outlined in previous chapters and the environmental economics concepts discussed earlier.

6. Discussion

6.1 Recap key results

The findings from this study suggest that groundwater abstraction, desalination and water reuse is economical, but only in the situation where purpose-built evaporation ponds are excluded and waste water is disposed of into existing salt lakes (option C). The results also suggest that a much simpler, smaller project excluding desalination, water sales and purpose build evaporation ponds (option D) could also be economically viable.

It should be noted, however, that environmental and social impacts were not part of the calculations, the inclusion of which could change the results. Disposal of hypersaline desalination brine into the environment could have significant impacts.

The negative externalities associated with option C would need to be greater than its NPV of $1.7 million to make this option unviable when taking social and environmental values into account. That's not to say that it is impossible, however disposing of saline water into a salt lake, just logically, is likely to have minimal environmental impact. An Environmental Impact Statement would be able to provide authoritative advice on this.

6.2 Impact of removing water sales benefit

Comparing the results of options A and B at a 7 per cent discount rate shows just how big an impact removing water sales has on overall viability. As shown in Table 6-1, removing water sales drops the BCR from 0.68 to 0.14 and the NPV from -$1.9m to -$5.1m. This is consistent with previous studies (RTMC, 2001) that argue the importance of water sales to help make a project economical.

Table 6-1: Results for options A and B at 7%

Options (7% discount rate)	**BCR**	**NPV ($2006 million)**
A) Full costs and benefits	0.68	-1.9
B) No water sales	0.14	-5.1

Further complicating this trade-off could be that community values change over time. For example, as awareness increases of the environmental impact of hypersaline brine, the community could see this as overall a negative for the town, despite recreational benefits.

6.3 Original full option compared to simpler, smaller option

The results also indicate that simply abstracting and disposing of this water into existing salt lakes, with no desalination or water sales (option D) is economical, although this fails to meet the aim of productively using abstracted water. The same environmental and social arguments apply here as above, except that given there is no desalination, all abstracted water is disposed of, so there is the same amount of salt but substantially more water in this option. This may have a different environmental and social impact (higher or lower).

A further consideration is that while remote WA towns have many limitations such as sourcing economical and reliable water, one benefit they have is the existence of naturally occurring salt lakes and a climate with an extremely high potential evaporation. This makes for a potentially ideal scenario to evaporate waste water with minimal environmental impact. All of this would need appropriate examination for advice to decision-makers.

Comparing original figures of option A with the smaller and simpler option D shows BCR jumps from an uneconomical 0.68 to a strong 1.73 and original NPV of -$1.9m to a positive $0.4m. See Table 6-2.

Table 6-2: Results for options A and D at 7%

Options (7% discount rate)	BCR	NPV ($2006 million)
A) Full costs and benefits	0.68	-1.9
D) no evap ponds, no desal, no water sales	1.73	$ 0.4

While again this does not include possible environmental impacts of waste water disposal, it must be noted that option C waste water being disposed was hyper-saline desalinated brine, while option D is simply disposing water pumped from directly under the town. It would be left to hydrologists and environmental scientists to consider but one could assume that the environmental impact of the former might be larger than the latter.

6.4 Impact of removing the cost of purpose-built evaporation ponds

On the cost side, purpose-built evaporation ponds were comfortably the largest item. Removing this would be feasible, with water discharged to existing salt lakes.

Returning for comparison to the starting scenario of full costs and benefits of option A, results from option C show the significant impact of removing the cost of evaporation ponds: BCR jumps from an uneconomical 0.68 to 1.76 and NPV from -$1.9m to a positive $1.7m. See Table 6-3 below. This does not include possible environmental impacts of waste water disposal into the environment as discussed above.

Table 6-3: Results for options A and C at 7%

Options (7% discount rate)	BCR	NPV ($2006 million)
A) Full costs and benefits	0.68	-1.9
C) No evap ponds	1.76	1.7

On the other hand, however, piping waste water out to evaporate does go against the key desire of the RTLAP to find productive use for the water; turn the waste water into a resource.

6.5 Changing water price

For options A and C that involve water sales, the results show a significant change, which is as expected, given water sales revenue is around 80 per cent of total benefits for those options.

Option A changes from a BCR of 0.68 to 0.95 and a NPV of -$1.9 million to -$0.1 million. This change in water price brings the original option to the brink of being viable.

Option C on the other hand was already viable and an increase in water price makes it much more so, with BCR increasing from 1.76 to 2.5 and an NPV from $1.7 million to $3.4 million.

These calculations illustrate the large impact water price has on calculations of whether a project is viable, which in turn highlights the potential impact that subsidising water has on changing or distorting results and decisions. Water price, therefore could be having a significant impact on town decisions.

6.6 Discounting

As is typically the case in natural resource management infrastructure, in this Wagin case study the costs were mostly up-front, while the benefits were spread over many years, highlighting the impact discounting can have on calculations. Changing the discount rate can change the outcome of a CBA. Looking once again at the results from all four options in Wagin, increasing or decreasing the discount rate changed the magnitude of the results, but did not change any BCR from positive to negative, or the reverse. All BCRs for options A and B across the three discount rates used are below one and all BCRs for options C and D are above one. These results are displayed in Table 6-4.

Table 6-4: Summary of BCR results - sensitivity analysis for 4, 7 and 10 per cent - review of change

BCR	Low discount rate	Medium discount rate	High discount rate	Comment
	4%	7%	10%	
A	0.82	0.68	0.57	All below 1
B	0.17	0.14	0.12	All below 1
C	1.96	1.76	1.58	All above 1
D	2.05	1.73	1.47	All above 1

6.7 What Wagin actually implemented

As part of the RTLAP, dozens of experimental bores were sunk around Wagin in 2005. Three of these bores produced a strong water flow and groundwater pumping began in December 2005. As of February 2006, the single production bore located behind the Wagin Motel had lowered water tables below two metres for nearly half the town at risk of salinity.

Since then, the three productive bores have pumped constantly (apart from brief maintenance). These were sunk to depths of 35m, 22m, and 17m and pumped at roughly 3L/s. Water abstracted from under the town disposed of to Slippery Lake (a natural salt-lake) for evaporation. This aligns with option D above.

As an attempt to find a productive use for the abstracted water, water from two of the three pumps were piped for industrial use by a local grain processing company, with the third bore piped directly to an existing natural salt Lake for evaporation. The two pumps to the gain processor ran dry, however, before this water could be used. On one hand it is ironic that bores running dry meant that the water could not productively be used. It should be remembered, however, that pumping has a “V-shape” impact on groundwater and as such needs to be pumped a great deal lower at the pump site for the edges of the influence zone to fall, and be maintained, below the critical 2m level. Further hydrogeology study or sinking of additional bores may address this and could be seen as a limitation in the initial scope of works. Had more bores been sunk in the key regions of the town, groundwater might be able to have been maintained at a shallower level and reliable water supplied for industrial use. Having said that, according to local Council officers, dozens of bores were sunk, so every reasonable effort was made to identify the most productive bore sites.

In relation to surface water and recharge, a 2017 flood raised groundwater levels by a number of metres and took some months of pumping for groundwater levels to subside.

Wagin has not measured the reduction in salinity damage, therefore it is not possible to assess what proportion of the anticipated $842,000 in damage reduction has been achieved. Anecdotally, however, salinity damage is no longer considered a priority in the town, so it could be inferred that pumping has helped.

Further analysis is required to determine whether it is most economical to continue pumping, which seems to be the default, or further address surface water management of overwatering and flood management.

6.8 Externalities and property rights

A core focus of the RTLAP was turning a waste into a resource, or finding a productive use for the water that would otherwise have to be disposed of, at some considerable cost. The fact that it is a waste product at all is because it is an externality resulting from actions taken decades ago during the original European development of the Wheatbelt; these historical actions were allowed to be undertaken with an implicit subsidy; not covering all of the costs of development and leaving some costs for later communities to pay. Rural town salinity damage is fundamentally the result of not valuing ecosystem services (Wentworth Group, 2002). This depletes natural capital and disguises the true cost of consumption and investment decisions. It is more difficult to make a project break-even when the starting point is having to cover costs from previous projects.

If it is the case that a project does not have the property rights to impose costs on those outside the activity, projects will incorporate all of their costs into the decision-making process up-front and only those with holistic benefits greater than costs (as best we can measure and incorporate) will proceed. Recall from earlier that Young (2000) argues that there is no right to return water to the environment in a lesser quality than it was taken, and no right to use water in a way that causes waterlogging, salinity or other problems. If this rule had been applied earlier, when land clearing was occurring (and assuming there was knowledge of the consequences), then the development would:

a. not have occurred in the first place, or
b. have occurred but designed in a way to avoid salinity (either just smarter design, or more expensive if still viable), or
c. have occurred with compensation to those affected (or combination of b and c)

Property rights need to be addressed otherwise behaviour that leads to groundwater recharge could continue. The property rights that need attention in this case are those that are impacted by externality of salinity damage, which would include private residences, commercial premises, and public buildings and infrastructure. Public infrastructure could be local roads, sports grounds and shire council offices, as well as buildings of broader significance, such as heritage listed historic buildings like town halls and court houses. The property rights, therefore, rest with a combination of individuals, the local community, and broader state or even national society.

Duty of care is a central concept in land and water management (Wentworth Group, 2002). A land owner should be required to undertake a minimum of land management to avoid exactly the type of issue as salinity. Allocation and enforcement of property rights are central to sustainable and efficient water use. If consumers, companies and communities included external impacts in their decision-making, society would have a greater chance of economically optimal water use. As it stands, there remain many environmental impacts associated with extraction, through each step to disposal (Hatton MacDonald, 2004)

Economic efficiency can potentially be achieved by setting prices to recover costs, including externalities (Hatton MacDonald, 2004), as required by the 1994 Council of Australian Governments water reforms (Productivity Commission, 2003). While there is considerable agreement about the need to include externalities in pricing, examples of successfully applying this are less prevalent, with more research being required into the full cost of water use (Hatton MacDonald, 2004).

6.9 Implications of the Community Service Obligation Pricing Subsidy Policy

Just as salinity damage is an implicit subsidy - un-priced damage resulting from previous decisions - the CSO is an explicit subsidy complicating the economics of rural town water management.

A key aim of water pricing is to encourage economic efficiency, requiring that prices be set to reflect the cost of supply (Economic Regulation Authority, 2006). Set too far above the cost of supply, a price risks denying benefits to the community. A price that does not cover the cost of supply, however, is an incentive for over-consumption, and indeed a major factor in rural town salinity is overwatering of parks and ovals, contributing to recharge and generating additional waste water requiring disposal (Hatton MacDonald, 2004).

At the time Wagin was making its water and salinity management decisions covered in this paper, most rural towns did not face cost-reflective pricing. Even if water price changes it was recommending were implemented, the State Government would still have been subsidising water use by tens of millions of dollars, equating to around $3,900 annually to each customer (Economic Regulation Authority, 2006). Where Government chooses to support charities and other communities for social policy reasons, subsidising water supplies are inefficient and lack transparency (Economic Regulation Authority, 2006).

Water pricing that reflects the cost of supply allows utilities to recover the costs of supply in order to fund maintenance and infrastructure replacement. It also signals to consumers when to make investments in water-using products (such as gardens and pools), appliances that improve water use efficiency, and rainwater tanks to supply water for themselves. Cost reflective prices provide a signal to consumers to improve water use efficiency and invest in water saving devices.

The CSO subsidy also complicates the economics of rural towns local water supplies. CSOs mean that locally supplied water has to compete with subsidised imported scheme water. A project capturing and reusing local water might be economical compared to the full-cost-recovery price of water but not more competitive than the subsidised scheme water price. Cost reflective pricing therefore can mean that local water use and re-use options become more economical than imported scheme water (Radcliffe, 2004).

Further work could be done to calculate the economics of large storages required to capture and store winter rainfall through hot dry summers, and potentially over numerous years through dry times, significantly reducing rural towns' reliance on scheme water. Aquifer Storage and Recover would address the storage size and evaporation issues, with water stored below ground, except rising groundwater is exactly the problem that towns are trying to avoid. In addition, locally captured fresh surface water stored in aquifers could become saline and require treatment, with desalination working against its economic viability.

A component of the economic analysis of surface water storages could be redirecting the current scheme water CSO partly or wholly to the construction and establishment of this local water supply. Relevant to the calculation of local water storages replacing scheme water is that the CY O'Connor pipeline is a sunk cost for the purposes of this analysis and as such the historical cost of its construction would not be included in any CBA. If, on the other hand, scheme water infrastructure was to reach end of life, the cost of replacement would be included in calculations.

A component of this further analysis could be modeling the impact of re-directing the CSO subsidy to these new local town water projects. CSIRO modelling has demonstrated that increased use of locally captured water can lead to a substantial reduction in imported scheme water (Speers & Mitchell, 2000). Given extremely low groundwater transmissivity, storages could be located slightly outside towns and any groundwater recharge that did occur would not result in groundwater levels rising within towns.

Further economic analysis could also be done to determine whether it would be economical to shandy pumped saline groundwater with fresh locally captured surface water for use on local parks and gardens. The additional benefit of this option would be to avoid the surface water contributing to recharge (as long as it was not used to over-water parks and ovals).

It is important that we learn the lessons from history before we invest in new water infrastructure, or we risk repeating these mistakes (Wentworth Group, 2002).

6.9.1 Work since 2006 – Stormwater harvesting

Subsequent to the groundwater pumping decision that has been the focus of this paper, a surface water management project was in fact undertaken in Wagin. Between 2012 and 2015 Wagin constructed new surface water infrastructure, capturing much of the town catchment runoff in a new weir, and pumping up to local dams for use irrigating ovals and parks (Wheatbelt NRM, 2015). Aimed at water conservation and salinity control, the project was designed to build on the groundwater abstraction work done before. This is an example of the same goal as the RTLAP of turning a problem into a resource. It was claimed that the scheme would have economic benefits by reducing scheme water bills and community benefits by helping with town beautification. This fit-for-purpose locally captured irrigation water reduces the town's demand for imported potable scheme water.

The project was funded by a $2 million State Government grant and with scheme water prices having increased since the original groundwater project, as discussed, this could be seen as an example of CSO funding being redirected to the construction of new rural town water infrastructure to capture and use local water supplies.

7. Conclusion

The purpose of this research was to determine whether intervention to arrest worsening salinity damage of rural town infrastructure was economical. There is considerably more knowledge about the extent and causes of salinity than the effectiveness and viability of remediation options. This project aimed to be a contribution to addressing this information gap. It applied cost benefit analysis to calculate the net benefits of a range of water infrastructure options to address salinity damage in the rural WA town of Wagin. An ex-post CBA was considered but there was almost no data on what has actually happened, such as the amount of infrastructure damage actually avoided and the cost of remediation action. As a result, this study applied CBA from the perspective of the decision-makers at the time of the 2006 groundwater project.

Previous studies found that both surface water and groundwater management actions would be required to address salinity. Additionally, research had concluded that water produced from remediation projects would need to be sold in order for the project to break even. Results from the Wagin analysis however, found that under some circumstances a project that included groundwater abstraction alone (without a surface water management component) and disposal rather than sale of waste water could be economical.

Environmental and social impacts were not part of the calculations, the inclusion of which could change the results. Negative externalities associated with the options would need to be greater than its NPV to make the option unviable. In one case this was a value of $1.7 million. It is feasible that environmental and social impacts could exceed this figure, however disposing of saline water into an existing natural salt lake is likely to have minimal environmental impact. An Environmental Impact Statement would be able to provide authoritative advice on this.

Limitations included the accuracy of the cost data, which were estimates from a consulting firm and accuracy of the benefits data provided by the USEAP model and water price calculations. More accurate data could produce results with more confidence. Likewise, standard limitations of CBA existed, particularly environmental and social values not expressed in dollar terms unable to be included.

This entire project was necessary only because external costs remain from decisions taken previously. If a new project has to cover legacy costs from a previous action, in addition to all of the costs of the remediation activity, naturally that project is at a disadvantage. Policies to include externalities in project decision-making could avoid this from recurring. An example is the 1994 COAG water reforms that require prices to reflect all costs of supply, including externalities.

Since the groundwater project that is the focus of this paper was completed, Wagin has implemented a significant surface water project, capturing much of its surface water runoff, alleviating flooding and groundwater recharge. While this saves the town significantly costs of flood damage and scheme water bills, the project was funded with a $2 million State Government grant, so one could ask what the net benefit was for the whole of society (the State).

This paper has covered a range of issues related to the economics of rural town water infrastructure, in response to salinity damage. Further work could be done into:

- how much longer to continue groundwater pumping and to what depth
- viability of additional infrastructure to capture local waster to replace more scheme water; including under the scenario where scheme water infrastructure reached end-of-life, and including consideration of CSO applied to scheme water supply, no CSO, and CSO applied to subsidising local water supplies.
- techniques (in addition to or refining contingent valuation and choice modelling) to price externalities into land and water management decisions in rural towns
- accounting for irreversible environmental harm and how to incorporate ecosystem complexity into CBA viability of shandying fresh surface water with saline groundwater for irrigating parks and ovals
- productive uses of saline groundwater in industrial and commercial sectors

While these results provide advice for this specific project, a long term multi-faceted solution is required for rural towns like Wagin, given the multitude of factors influencing salinity, water and land management. Addressing recharge would be considered because that is introducing additional or new externalities onto the town but triggering future groundwater rise and salinity. Unless towns fix the cause, the symptoms will surely return.

Federal and State revenue has been allocated to the problem over many years, with mixed results. Evidence is that remedial action to date has been an order-of-magnitude too small and too slow. In 2018 the Western Australia Auditor-General found that the problem remains out of control and looks to be deteriorating for the foreseeable future. This paper outlines the importance of addressing issues of property rights and externalities in order to ensure projects cover all of their costs and not leave legacy costs for future governments and taxpayers to address. A positive outcome from this project, however, was that some remediation actions to address salinity in rural towns can be economically viable.

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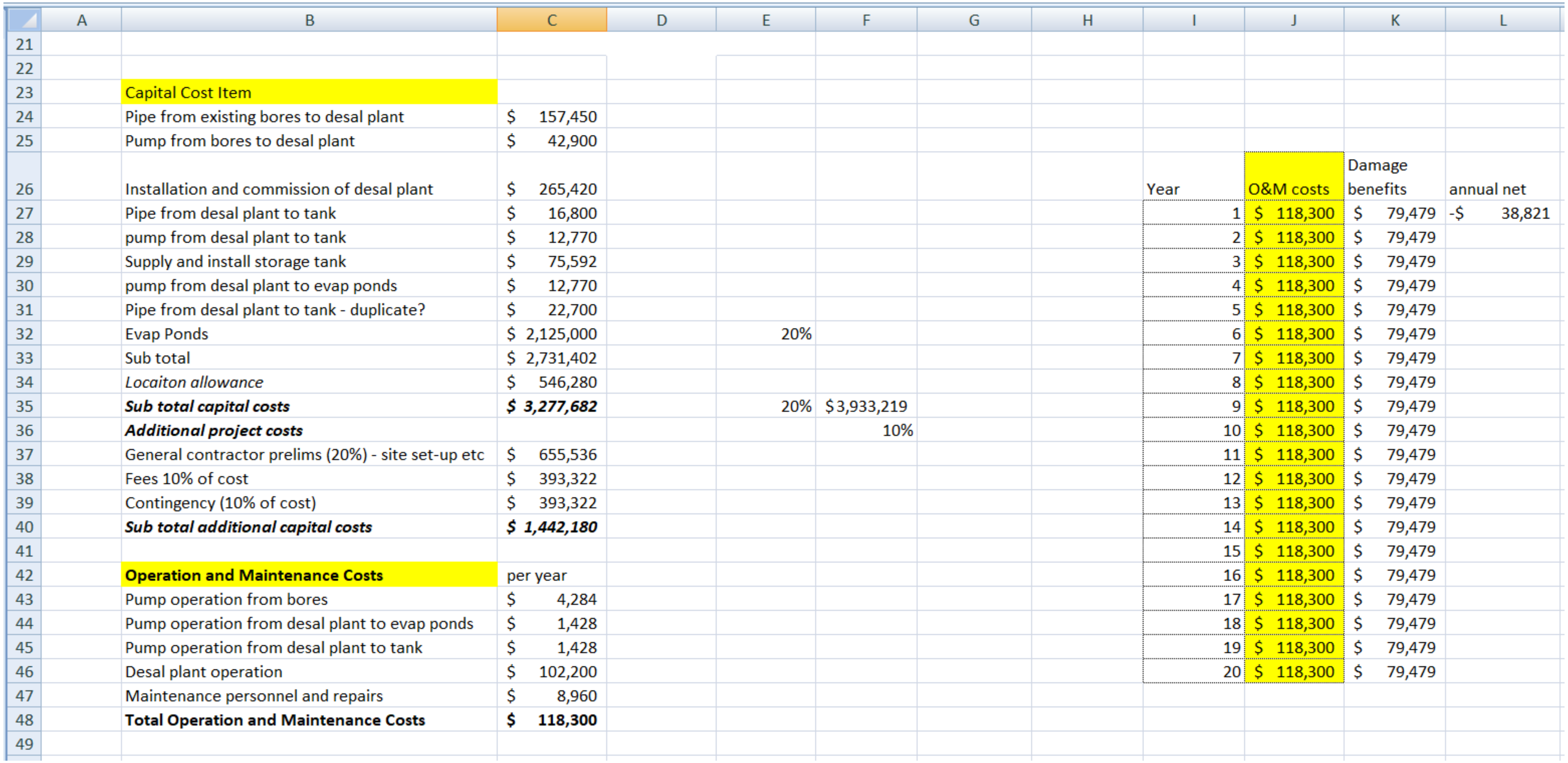
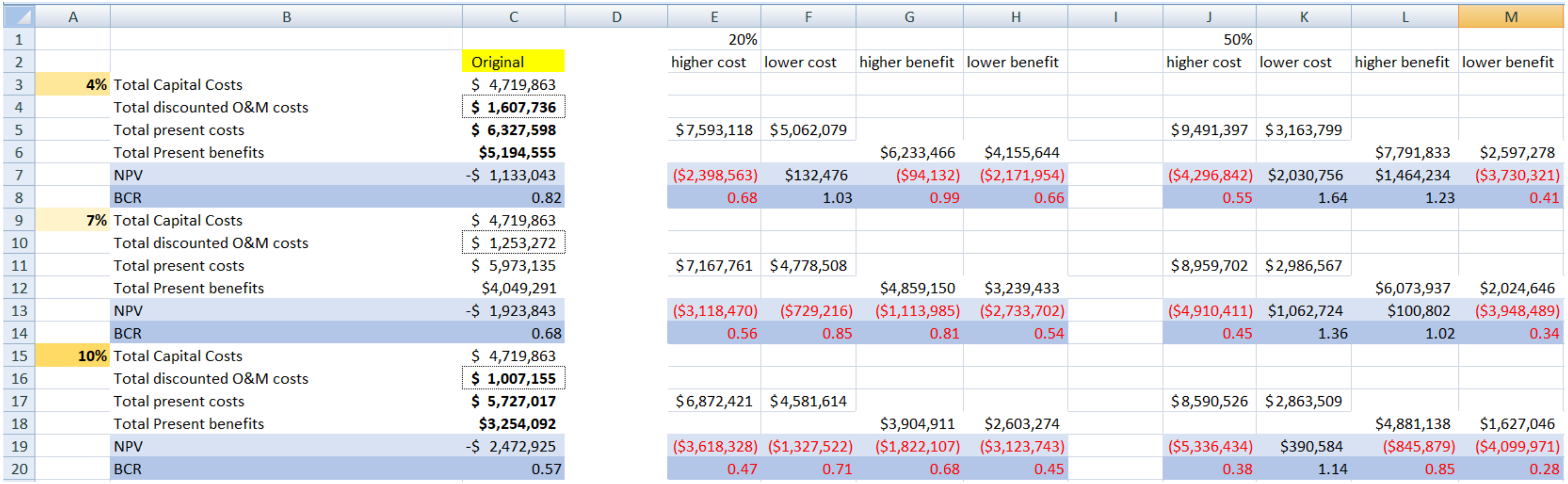
Appendix A. Option A costs and discounted benefits



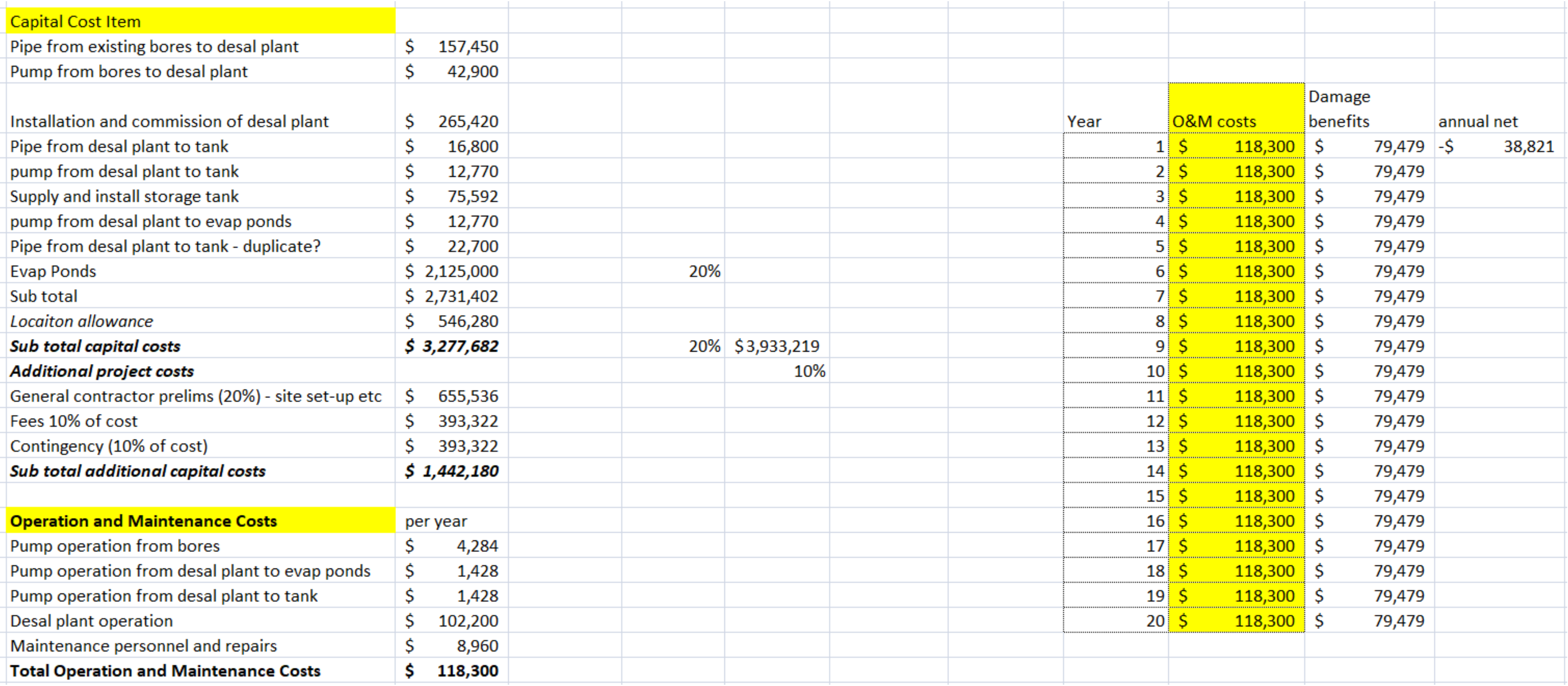
	A	B	C	D	E	F	G	H	I	J	K	L
21												
22												
23		Capital Cost Item										
24		Pipe from existing bores to desal plant	$ 157,450									
25		Pump from bores to desal plant	$ 42,900									
26		Installation and commission of desal plant	$ 265,420						Year	O&M costs	Damage benefits	annual net
27		Pipe from desal plant to tank	$ 16,800						1	$ 118,300	$ 79,479	-$ 38,821
28		pump from desal plant to tank	$ 12,770						2	$ 118,300	$ 79,479	
29		Supply and install storage tank	$ 75,592						3	$ 118,300	$ 79,479	
30		pump from desal plant to evap ponds	$ 12,770						4	$ 118,300	$ 79,479	
31		Pipe from desal plant to tank - duplicate?	$ 22,700						5	$ 118,300	$ 79,479	
32		Evap Ponds	$ 2,125,000		20%				6	$ 118,300	$ 79,479	
33		Sub total	$ 2,731,402						7	$ 118,300	$ 79,479	
34		*Locaiton allowance*	$ 546,280						8	$ 118,300	$ 79,479	
35		***Sub total capital costs***	***$ 3,277,682***		20%	$3,933,219			9	$ 118,300	$ 79,479	
36		***Additional project costs***				10%			10	$ 118,300	$ 79,479	
37		General contractor prelims (20%) - site set-up etc	$ 655,536						11	$ 118,300	$ 79,479	
38		Fees 10% of cost	$ 393,322						12	$ 118,300	$ 79,479	
39		Contingency (10% of cost)	$ 393,322						13	$ 118,300	$ 79,479	
40		***Sub total additional capital costs***	***$ 1,442,180***						14	$ 118,300	$ 79,479	
41									15	$ 118,300	$ 79,479	
42		**Operation and Maintenance Costs**	per year						16	$ 118,300	$ 79,479	
43		Pump operation from bores	$ 4,284						17	$ 118,300	$ 79,479	
44		Pump operation from desal plant to evap ponds	$ 1,428						18	$ 118,300	$ 79,479	
45		Pump operation from desal plant to tank	$ 1,428						19	$ 118,300	$ 79,479	
46		Desal plant operation	$ 102,200						20	$ 118,300	$ 79,479	
47		Maintenance personnel and repairs	$ 8,960									
48		**Total Operation and Maintenance Costs**	**$ 118,300**									
49												

Appendix B. Option A NPVs, BCRs and Sensitivity analysis



	A	B	C	D	E	F	G	H	I	J	K	L	M
1					20%					50%			
2			Original		higher cost	lower cost	higher benefit	lower benefit		higher cost	lower cost	higher benefit	lower benefit
3	**4%**	Total Capital Costs	$ 4,719,863										
4		Total discounted O&M costs	**$ 1,607,736**										
5		Total present costs	**$ 6,327,598**		$7,593,118	$5,062,079				$9,491,397	$3,163,799		
6		Total Present benefits	**$5,194,555**				$6,233,466	$4,155,644				$7,791,833	$2,597,278
7		NPV	-$ 1,133,043		($2,398,563)	$132,476	($94,132)	($2,171,954)		($4,296,842)	$2,030,756	$1,464,234	($3,730,321)
8		BCR	0.82		0.68	1.03	0.99	0.66		0.55	1.64	1.23	0.41
9	**7%**	Total Capital Costs	$ 4,719,863										
10		Total discounted O&M costs	$ 1,253,272										
11		Total present costs	$ 5,973,135		$7,167,761	$4,778,508				$8,959,702	$2,986,567		
12		Total Present benefits	$4,049,291				$4,859,150	$3,239,433				$6,073,937	$2,024,646
13		NPV	-$ 1,923,843		($3,118,470)	($729,216)	($1,113,985)	($2,733,702)		($4,910,411)	$1,062,724	$100,802	($3,948,489)
14		BCR	0.68		0.56	0.85	0.81	0.54		0.45	1.36	1.02	0.34
15	**10%**	Total Capital Costs	$ 4,719,863										
16		Total discounted O&M costs	**$ 1,007,155**										
17		Total present costs	**$ 5,727,017**		$6,872,421	$4,581,614				$8,590,526	$2,863,509		
18		Total Present benefits	**$3,254,092**				$3,904,911	$2,603,274				$4,881,138	$1,627,046
19		NPV	-$ 2,472,925		($3,618,328)	($1,327,522)	($1,822,107)	($3,123,743)		($5,336,434)	$390,584	($845,879)	($4,099,971)
20		BCR	0.57		0.47	0.71	0.68	0.45		0.38	1.14	0.85	0.28

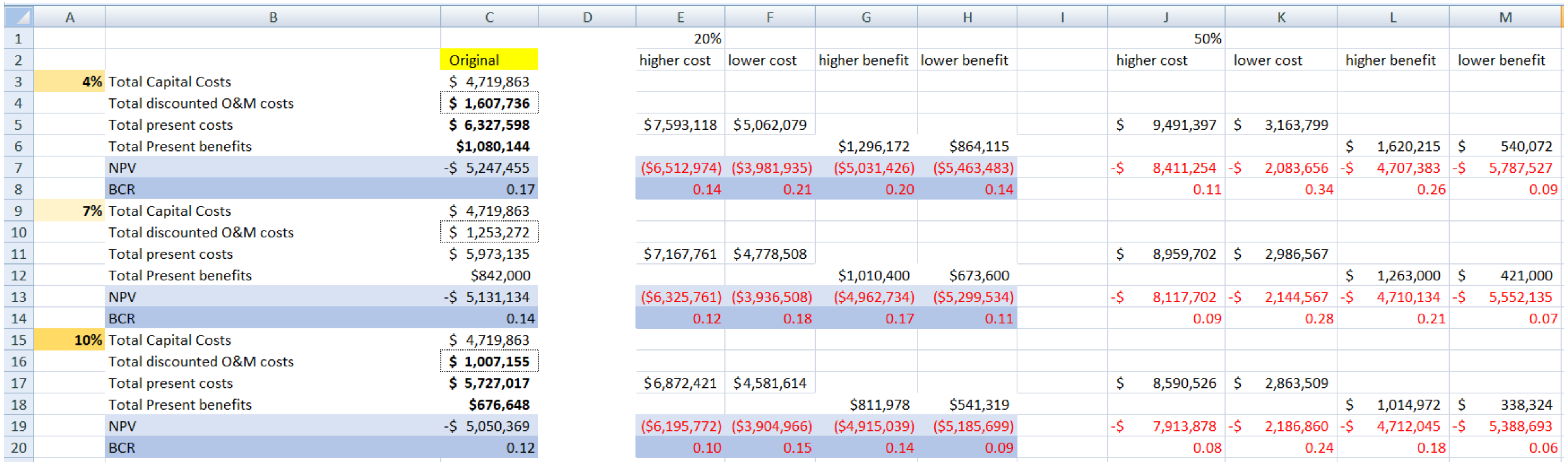
Appendix C. Option B Costs and benefits



Capital Cost Item			
Pipe from existing bores to desal plant	$ 157,450		
Pump from bores to desal plant	$ 42,900		
Installation and commission of desal plant	$ 265,420		
Pipe from desal plant to tank	$ 16,800		
pump from desal plant to tank	$ 12,770		
Supply and install storage tank	$ 75,592		
pump from desal plant to evap ponds	$ 12,770		
Pipe from desal plant to tank - duplicate?	$ 22,700		
Evap Ponds	$ 2,125,000	20%	
Sub total	$ 2,731,402		
Locaiton allowance	$ 546,280		
Sub total capital costs	***$ 3,277,682***	20%	$3,933,219
Additional project costs			10%
General contractor prelims (20%) - site set-up etc	$ 655,536		
Fees 10% of cost	$ 393,322		
Contingency (10% of cost)	$ 393,322		
Sub total additional capital costs	***$ 1,442,180***		
Operation and Maintenance Costs	per year		
Pump operation from bores	$ 4,284		
Pump operation from desal plant to evap ponds	$ 1,428		
Pump operation from desal plant to tank	$ 1,428		
Desal plant operation	$ 102,200		
Maintenance personnel and repairs	$ 8,960		
Total Operation and Maintenance Costs	**$ 118,300**		

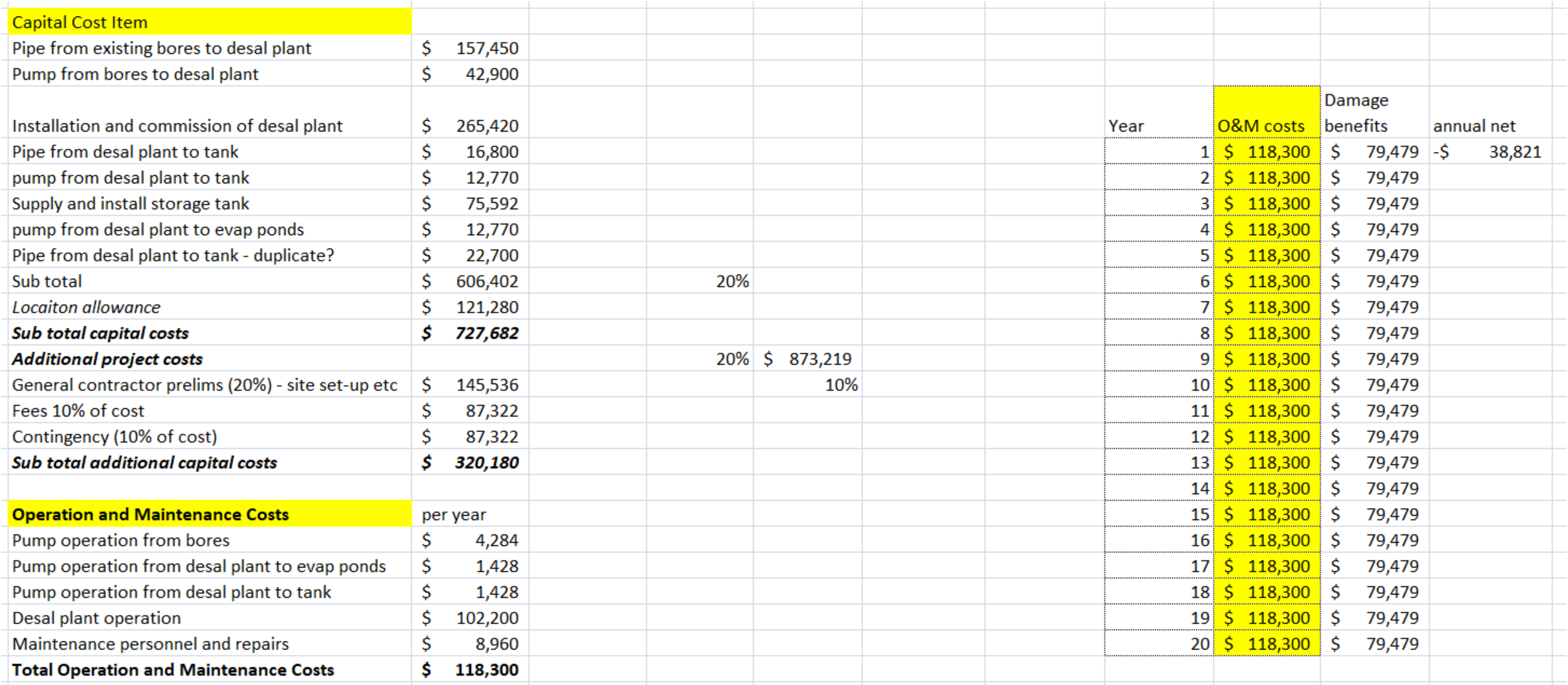
Year	O&M costs	Damage benefits	annual net
1	$ 118,300	$ 79,479	-$ 38,821
2	$ 118,300	$ 79,479	
3	$ 118,300	$ 79,479	
4	$ 118,300	$ 79,479	
5	$ 118,300	$ 79,479	
6	$ 118,300	$ 79,479	
7	$ 118,300	$ 79,479	
8	$ 118,300	$ 79,479	
9	$ 118,300	$ 79,479	
10	$ 118,300	$ 79,479	
11	$ 118,300	$ 79,479	
12	$ 118,300	$ 79,479	
13	$ 118,300	$ 79,479	
14	$ 118,300	$ 79,479	
15	$ 118,300	$ 79,479	
16	$ 118,300	$ 79,479	
17	$ 118,300	$ 79,479	
18	$ 118,300	$ 79,479	
19	$ 118,300	$ 79,479	
20	$ 118,300	$ 79,479	

Appendix D. Option B NPVs, BCRs and Sensitivity analysis



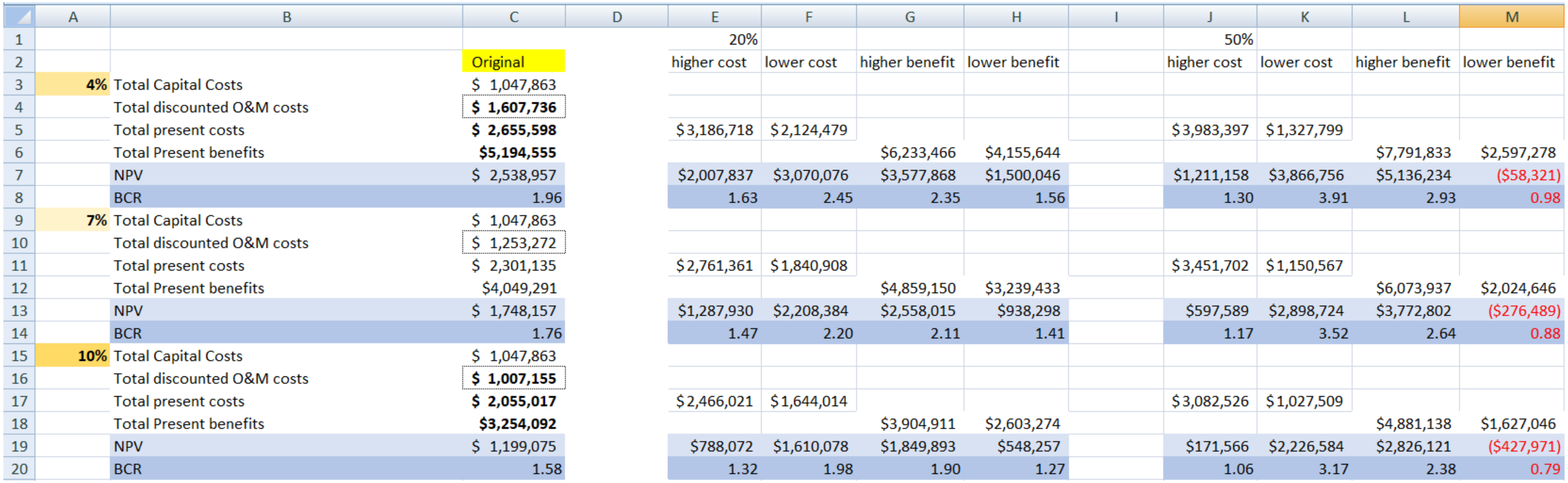
	A	B	C	D	E	F	G	H	I	J	K	L	M
1					20%					50%			
2			Original		higher cost	lower cost	higher benefit	lower benefit		higher cost	lower cost	higher benefit	lower benefit
3	**4%**	Total Capital Costs	$ 4,719,863										
4		Total discounted O&M costs	**$ 1,607,736**										
5		Total present costs	**$ 6,327,598**		$7,593,118	$5,062,079				$ 9,491,397	$ 3,163,799		
6		Total Present benefits	**$1,080,144**				$1,296,172	$864,115				$ 1,620,215	$ 540,072
7		NPV	-$ 5,247,455		($6,512,974)	($3,981,935)	($5,031,426)	($5,463,483)		-$ 8,411,254	-$ 2,083,656	-$ 4,707,383	-$ 5,787,527
8		BCR	0.17		0.14	0.21	0.20	0.14		0.11	0.34	0.26	0.09
9	**7%**	Total Capital Costs	$ 4,719,863										
10		Total discounted O&M costs	$ 1,253,272										
11		Total present costs	$ 5,973,135		$7,167,761	$4,778,508				$ 8,959,702	$ 2,986,567		
12		Total Present benefits	$842,000				$1,010,400	$673,600				$ 1,263,000	$ 421,000
13		NPV	-$ 5,131,134		($6,325,761)	($3,936,508)	($4,962,734)	($5,299,534)		-$ 8,117,702	-$ 2,144,567	-$ 4,710,134	-$ 5,552,135
14		BCR	0.14		0.12	0.18	0.17	0.11		0.09	0.28	0.21	0.07
15	**10%**	Total Capital Costs	$ 4,719,863										
16		Total discounted O&M costs	**$ 1,007,155**										
17		Total present costs	**$ 5,727,017**		$6,872,421	$4,581,614				$ 8,590,526	$ 2,863,509		
18		Total Present benefits	**$676,648**				$811,978	$541,319				$ 1,014,972	$ 338,324
19		NPV	-$ 5,050,369		($6,195,772)	($3,904,966)	($4,915,039)	($5,185,699)		-$ 7,913,878	-$ 2,186,860	-$ 4,712,045	-$ 5,388,693
20		BCR	0.12		0.10	0.15	0.14	0.09		0.08	0.24	0.18	0.06

Appendix E. Option C Costs and benefits



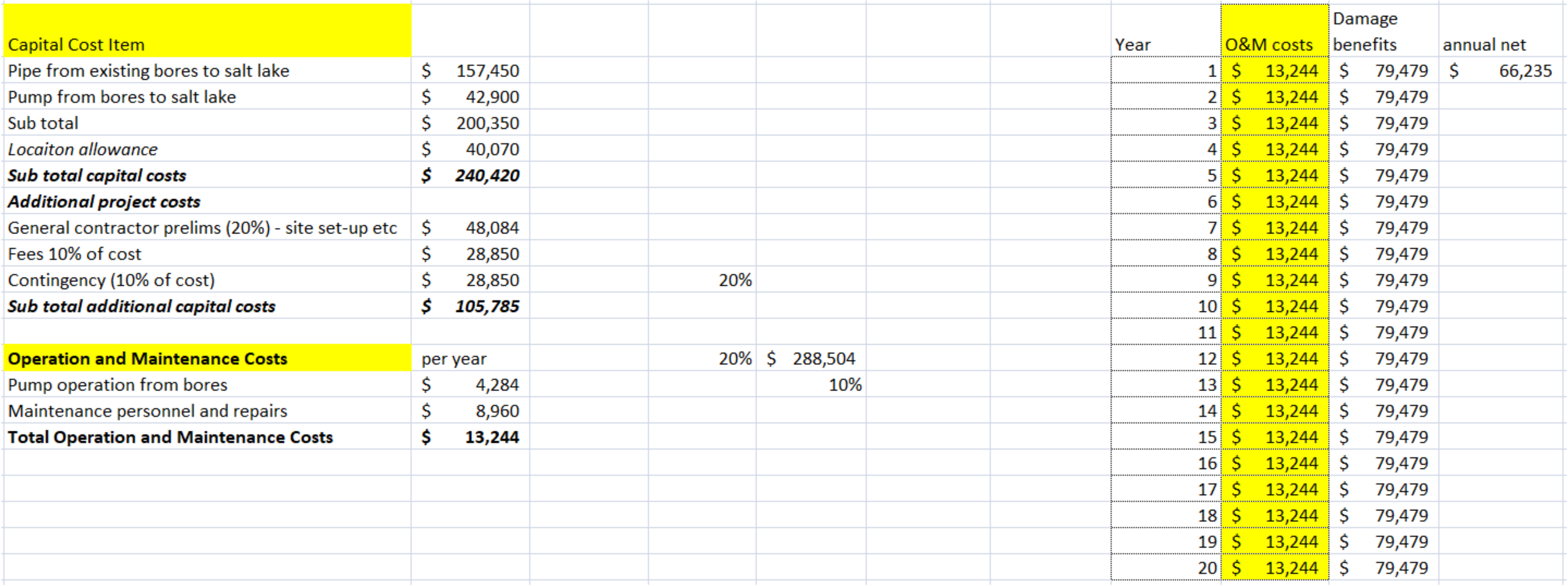
Capital Cost Item							
Pipe from existing bores to desal plant	$ 157,450						
Pump from bores to desal plant	$ 42,900						
Installation and commission of desal plant	$ 265,420			Year	O&M costs	Damage benefits	annual net
Pipe from desal plant to tank	$ 16,800			1	$ 118,300	$ 79,479	-$ 38,821
pump from desal plant to tank	$ 12,770			2	$ 118,300	$ 79,479	
Supply and install storage tank	$ 75,592			3	$ 118,300	$ 79,479	
pump from desal plant to evap ponds	$ 12,770			4	$ 118,300	$ 79,479	
Pipe from desal plant to tank - duplicate?	$ 22,700			5	$ 118,300	$ 79,479	
Sub total	$ 606,402	20%		6	$ 118,300	$ 79,479	
Locaiton allowance	$ 121,280			7	$ 118,300	$ 79,479	
Sub total capital costs	***$ 727,682***			8	$ 118,300	$ 79,479	
Additional project costs		20%	$ 873,219	9	$ 118,300	$ 79,479	
General contractor prelims (20%) - site set-up etc	$ 145,536		10%	10	$ 118,300	$ 79,479	
Fees 10% of cost	$ 87,322			11	$ 118,300	$ 79,479	
Contingency (10% of cost)	$ 87,322			12	$ 118,300	$ 79,479	
Sub total additional capital costs	***$ 320,180***			13	$ 118,300	$ 79,479	
				14	$ 118,300	$ 79,479	
Operation and Maintenance Costs	per year			15	$ 118,300	$ 79,479	
Pump operation from bores	$ 4,284			16	$ 118,300	$ 79,479	
Pump operation from desal plant to evap ponds	$ 1,428			17	$ 118,300	$ 79,479	
Pump operation from desal plant to tank	$ 1,428			18	$ 118,300	$ 79,479	
Desal plant operation	$ 102,200			19	$ 118,300	$ 79,479	
Maintenance personnel and repairs	$ 8,960			20	$ 118,300	$ 79,479	
Total Operation and Maintenance Costs	**$ 118,300**						

Appendix F. Option C NPVs, BCRs and Sensitivity analysis



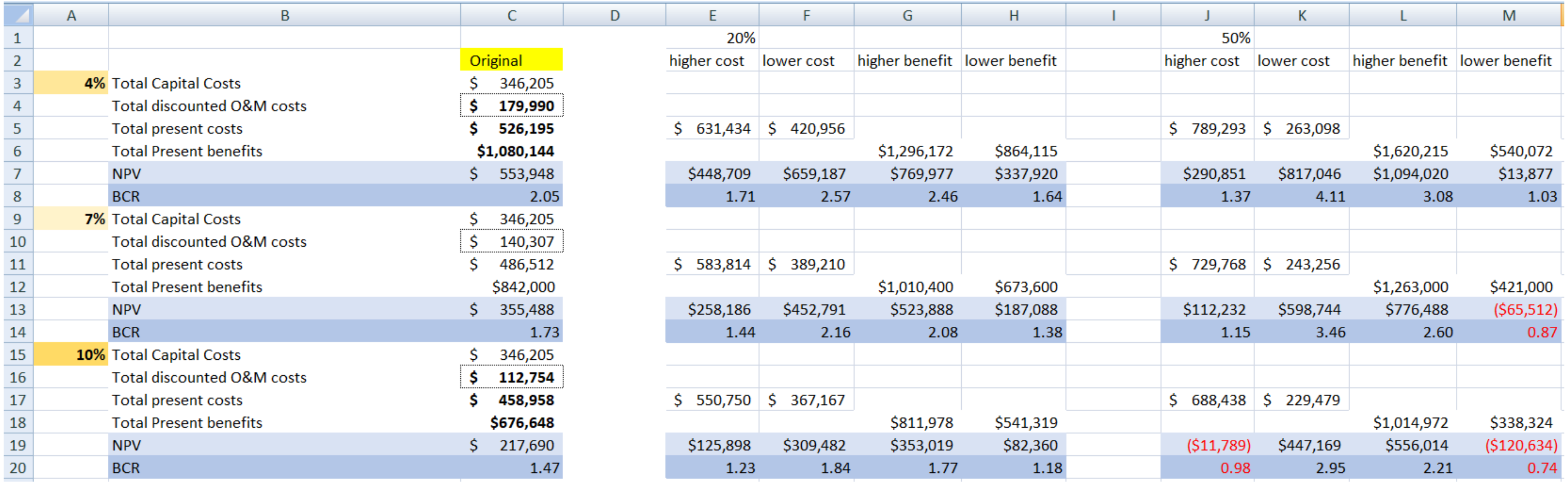
	A	B	C	D	E	F	G	H	I	J	K	L	M
1					20%					50%			
2			Original		higher cost	lower cost	higher benefit	lower benefit		higher cost	lower cost	higher benefit	lower benefit
3	**4%**	Total Capital Costs	$ 1,047,863										
4		Total discounted O&M costs	**$ 1,607,736**										
5		Total present costs	**$ 2,655,598**		$3,186,718	$2,124,479				$3,983,397	$1,327,799		
6		Total Present benefits	**$5,194,555**				$6,233,466	$4,155,644				$7,791,833	$2,597,278
7		NPV	$ 2,538,957		$2,007,837	$3,070,076	$3,577,868	$1,500,046		$1,211,158	$3,866,756	$5,136,234	($58,321)
8		BCR	1.96		1.63	2.45	2.35	1.56		1.30	3.91	2.93	0.98
9	**7%**	Total Capital Costs	$ 1,047,863										
10		Total discounted O&M costs	$ 1,253,272										
11		Total present costs	$ 2,301,135		$2,761,361	$1,840,908				$3,451,702	$1,150,567		
12		Total Present benefits	$4,049,291				$4,859,150	$3,239,433				$6,073,937	$2,024,646
13		NPV	$ 1,748,157		$1,287,930	$2,208,384	$2,558,015	$938,298		$597,589	$2,898,724	$3,772,802	($276,489)
14		BCR	1.76		1.47	2.20	2.11	1.41		1.17	3.52	2.64	0.88
15	**10%**	Total Capital Costs	$ 1,047,863										
16		Total discounted O&M costs	**$ 1,007,155**										
17		Total present costs	**$ 2,055,017**		$2,466,021	$1,644,014				$3,082,526	$1,027,509		
18		Total Present benefits	**$3,254,092**				$3,904,911	$2,603,274				$4,881,138	$1,627,046
19		NPV	$ 1,199,075		$788,072	$1,610,078	$1,849,893	$548,257		$171,566	$2,226,584	$2,826,121	($427,971)
20		BCR	1.58		1.32	1.98	1.90	1.27		1.06	3.17	2.38	0.79

Appendix G. Option D Costs and benefits



Capital Cost Item							Year	O&M costs	Damage benefits	annual net
Pipe from existing bores to salt lake	$ 157,450						1	$ 13,244	$ 79,479	$ 66,235
Pump from bores to salt lake	$ 42,900						2	$ 13,244	$ 79,479	
Sub total	$ 200,350						3	$ 13,244	$ 79,479	
Locaiton allowance	$ 40,070						4	$ 13,244	$ 79,479	
Sub total capital costs	***$ 240,420***						5	$ 13,244	$ 79,479	
Additional project costs							6	$ 13,244	$ 79,479	
General contractor prelims (20%) - site set-up etc	$ 48,084						7	$ 13,244	$ 79,479	
Fees 10% of cost	$ 28,850						8	$ 13,244	$ 79,479	
Contingency (10% of cost)	$ 28,850		20%				9	$ 13,244	$ 79,479	
Sub total additional capital costs	***$ 105,785***						10	$ 13,244	$ 79,479	
							11	$ 13,244	$ 79,479	
Operation and Maintenance Costs	per year		20%	$ 288,504			12	$ 13,244	$ 79,479	
Pump operation from bores	$ 4,284			10%			13	$ 13,244	$ 79,479	
Maintenance personnel and repairs	$ 8,960						14	$ 13,244	$ 79,479	
Total Operation and Maintenance Costs	**$ 13,244**						15	$ 13,244	$ 79,479	
							16	$ 13,244	$ 79,479	
							17	$ 13,244	$ 79,479	
							18	$ 13,244	$ 79,479	
							19	$ 13,244	$ 79,479	
							20	$ 13,244	$ 79,479	

Appendix H. Option D NPVs, BCRs and Sensitivity analysis



	A	B	C	D	E	F	G	H	I	J	K	L	M
1					20%					50%			
2			Original		higher cost	lower cost	higher benefit	lower benefit		higher cost	lower cost	higher benefit	lower benefit
3	**4%**	Total Capital Costs	$ 346,205										
4		Total discounted O&M costs	**$ 179,990**										
5		Total present costs	**$ 526,195**		$ 631,434	$ 420,956				$ 789,293	$ 263,098		
6		Total Present benefits	**$1,080,144**				$1,296,172	$864,115				$1,620,215	$540,072
7		NPV	$ 553,948		$448,709	$659,187	$769,977	$337,920		$290,851	$817,046	$1,094,020	$13,877
8		BCR	2.05		1.71	2.57	2.46	1.64		1.37	4.11	3.08	1.03
9	**7%**	Total Capital Costs	$ 346,205										
10		Total discounted O&M costs	$ 140,307										
11		Total present costs	$ 486,512		$ 583,814	$ 389,210				$ 729,768	$ 243,256		
12		Total Present benefits	$842,000				$1,010,400	$673,600				$1,263,000	$421,000
13		NPV	$ 355,488		$258,186	$452,791	$523,888	$187,088		$112,232	$598,744	$776,488	($65,512)
14		BCR	1.73		1.44	2.16	2.08	1.38		1.15	3.46	2.60	0.87
15	**10%**	Total Capital Costs	$ 346,205										
16		Total discounted O&M costs	**$ 112,754**										
17		Total present costs	**$ 458,958**		$ 550,750	$ 367,167				$ 688,438	$ 229,479		
18		Total Present benefits	**$676,648**				$811,978	$541,319				$1,014,972	$338,324
19		NPV	$ 217,690		$125,898	$309,482	$353,019	$82,360		($11,789)	$447,169	$556,014	($120,634)
20		BCR	1.47		1.23	1.84	1.77	1.18		0.98	2.95	2.21	0.74