COLLIE RIVER SALINITY RECOVERY – improving water resource outcomes in a competing environment

John Platt Wayne Tingey Tim Sparks
Department of Water
Western Australia

Abstract

Land and river salinisation in the south-west of Western Australia is a major environmental and economic problem. Land-use management for river salinity control has been practiced in the south-west of Western Australia since the early 1900s. In 1996, the Department of Water (then the Water and Rivers Commission) was nominated the lead agency in implementing the Salinity Action Plan (Government of Western Australia 1996) in five catchments, the Collie, Warren, Kent, Denmark and Helena. The mandate for the Collie was to achieve potable water in the Wellington Reservoir by 2015.

Competing for water in the Collie catchment are key industries of mining, power generation, irrigated agriculture and horticulture, public water supply, forestry and recreational tourism.

Science has been applied to a complex problem in a practical way, underpinned by extensive consultation with industry, agencies and the community, to plan the recovery of a major water resource from salinity and to develop a package of potential water resource initiatives important to the region and the state.

This paper will outline the approach taken, the recovery project, results to date, and how this project has integrated competing values into a unique water resource management opportunity potentially important to the state of WA.

1. 0 INTRODUCTION

1.1 The Collie Recovery catchment

The Collie River Water Resource Recovery Catchment (referred to as the Collie Recovery Catchment) covers that part of the Collie River catchment upstream of the Wellington Reservoir (Fig.1). It covers an area of 2827 km^2, and includes the coal mining towns of Collie (with a population of 8000) and Allanson. It is located approximately 130 km south-south east of Perth and experiences a Mediterranean climate of mild wet winters and hot dry summers. Annual rainfall varies from 1200 mm in the west of the catchment to 600 mm in the east. The catchment is mostly underlain by igneous rocks, but includes 263 km^2 of coal-bearing Permian sediments, which comprise the Collie Coal Basin.

The Collie River is the largest impounded surface water resource in the south-west region of Western Australia. With a length of 110 km, it has five main tributaries including Collie River South, Collie River East, Harris River, Bingham River and the Brunswick (which enters the Collie on the coastal plain and provides environmental flows to the estuary).

The catchment has two major reservoirs, the Wellington (186 GL storage capacity) and the Harris (79 GL), as well as the smaller Mungalup Dam, which were built to provide water to both the irrigation and domestic water supply schemes. Wellington Reservoir was completed in 1933 to supply the Collie River irrigation district on the Swan Coastal Plain. It had an original capacity of 35 GL and a salinity of about 280 mg/L. In response to irrigation demands the dam was raised in 1946 and further work was conducted from 1955 to 1960 to provide more water for irrigation and also to supply the Great Southern Towns Water Supply Scheme (GSTWSS) with potable water. This latest work increased the storage capacity to its current capacity of 186 GL, with an allocation limit.of 85 GL. Salinity levels in the Collie River at Mungalup gauging station (see Fig. 1) increased steadily over from the mid-1940's to 1992 where the average salinity stabilised at around 945 mg/L (Mauger et al*.* 2001).

The other major water resource in the catchment is groundwater contained in the Collie Coal Basin. The basin when full stored around 7000 GL of generally fresh water. During mining, excess groundwater must be removed and mining companies require allocations of groundwater for this dewatering. Dewatering operations have lowered the water table significantly in mining areas, by up to 150 metres. In recent years, the mine dewater has been used by the local power generation industry for cooling, although extra water is occasionally discharged into the river in winter as mine dewatering volume increases and cooling requirements decrease. Electricity generators also hold a groundwater allocation when there is not sufficient mine dewater available (typically during summer).

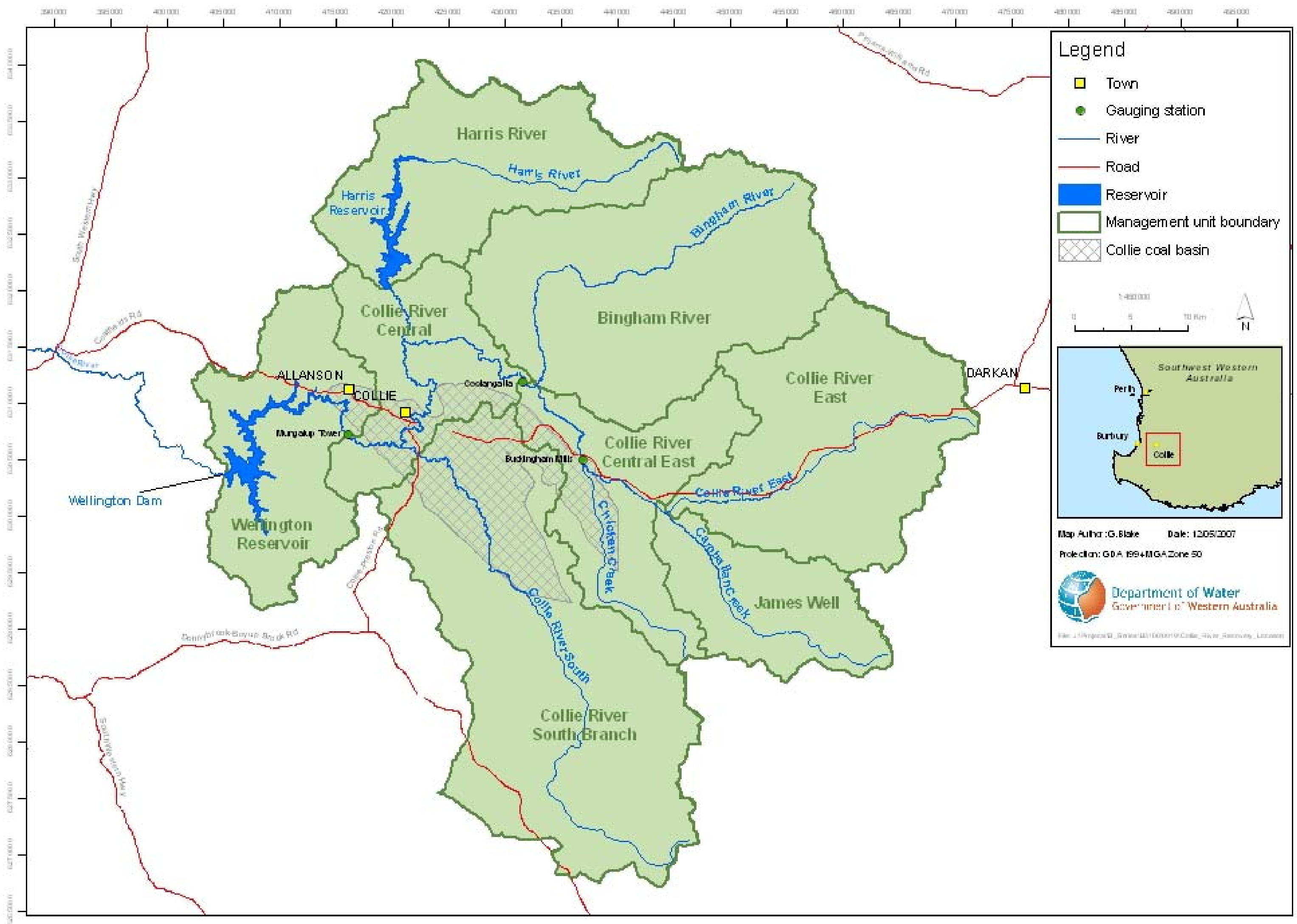

Figure 1   *Collie River Recovery Catchment*

1.2 Competing water use in the Collie catchment

In the Collie River Recovery Catchment power generation, irrigation and public water supply, amongst others, compete for the surface and groundwater resources. These uses are all of great economic and social importance to the south-west region as well as the state of Western Australia. 54% of the electricity used in the south west of WA comes from power stations at Collie.

The key water values and users in the Collie River catchment are:

- Irrigation (Harvey Water)
- Energy production (Verve Energy and in the future Griffin Energy)
- Great Southern Towns Water Supply Scheme (GSTWSS) (Water Corporation)
- Collie and Allanson towns public water supply (Water Corporation)
- Integrated Water Supply Scheme (IWSS) (Water Corporation)
- Mine dewatering (Griffin Coal and Wesfarmers Premier Coal)
- Salinity mitigation
- Environmental flows
- Recreation

Harvey Water

Harvey Water is a private water cooperative that delivers water to irrigators downstream of Wellington Reservoir. Currently it has an allocation of 68 GL/a. Salinity levels are a severe limiting factor in the productivity of the irrigators.

Verve Energy

Verve Energy has production bore licences totalling about 17 GL/a for use in its Collie and Muja power stations and in addition uses an average of 4.4 GL/a from Ewington mine dewatering. The resultant saline waste water is treated and discharged to the sea. Furthermore, Verve Energy has plans to commission another station, which may come on line between 2015 and 2020.

Water Corporation

The Water Corporation has an allocation of 10 GL from the Harris Dam for the GSTWSS, which currently supplies Collie and 32 other towns in the Upper Great Southern with high quality drinking water. It also has an allocation of 5 GL for the IWSS, which can supply potable water to Perth.

Griffin Group

The Griffin Group has two major companies operating in the Collie Coal Basin. These are Griffin Coal and Griffin Energy. Griffin Coal has a licence to dewater up to 30 GL/a of groundwater from their Ewington and Muja open-cut operations. This water has partly been used for Verve Energy's power generation needs, and in the near future 6.5 GL/a will be used by Griffin Energy at it's new Bluewaters 1 and ll power stations, the first of which is due to be commissioned in 2008.

Premier Coal Limited

Premier Coal operates two major open-cut mines at its Premier Pits 1 and 4 and has an allocation of 17 GL/a of groundwater for dewatering its proposed Pit 3 operations. The primary use for this water will likely be Verve Energy's power generation.

Salinity mitigation

During winter and spring, the Wellington Reservoir stratifies and denser saline water forms a layer at the bottom. When the difference between the top and bottom layers is greater than 400 mg/L the saline slug is released through a large gate valve at the bottom of the reservoir. Over the last 20 years between 10-40 GL/a of saline scour water has been discharged to the Collie River downstream of the Wellington Dam. Furthermore, up to 5 GL of fresh water from the Harris

Reservoir has been allocated for release at the start of the irrigation season to the Collie River to help reduce the salinity in the Wellington Reservoir.

Environmental flow
An allocation of 0.5 GL/a from the Harris Dam has been set aside for release in years of low rainfall to ensure a minimum flow in the Harris River. Environmental flows required below Wellington Reservoir are under review by the DoW but in the past have been provided by the scour operations.

1.3 The water resource recovery approach

The approach developed by the DoW is founded on the need to find solutions that have substantial effects on catchment water balances to meet salinity targets, take into account economic, social and environmental impacts and consider both engineering and vegetative approaches for salinity recovery or containment.

The department recognises that working in partnership with catchment groups, local communities, other government agencies, industry and local government is central to achieving satisfactory outcomes. A key stakeholder consultation group, the Collie Salinity Recovery Team was established in 1997; the Team has had an important role in assisting the department to develop an integrated solution which addresses the issues and expectations of stakeholders.

The approach, summarised in Figure 2, has five stages:

1. *Situation statement* — using long term data from river and stream gauging stations (continuous monitoring commenced in 1945), the situation statement is a study that identifies current and longer-term stream salinities, estimates how long before salinity returns to potable levels and salt is leached from soil profiles, and evaluates the hydrological impacts of selected salinity management or recovery options. The scale of intervention required to reach nominated hydrological targets is identified, The *Salinity Situation Statement: Collie River* was published in 2001.

2. *Evaluation of management options* — defines technical aspects of potential management options, or scenarios, and identifies the economic, social and environmental impacts of each option; in consultation with key stakeholders and using multi-criteria analysis techniques, preferred management options are identified. Trade-offs and compromises implicit to stakeholders are recognised. Benefit cost analysis (BCA) of the preferred options is then used to identify the final recommended options for implementation, which yield the strategic approach to salinity recovery.

3. *Recovery plan for salinity –* identifies and describes the major components of the option(s) selected for implementation, develops an implementation strategy, and identifies funding sources.

4. *Future options for water resource recovery* - building on the salinity recovery plan and seeking to optimise water resource management - during the evaluation of management options and in the development of an implementation plan, the issues and opportunities that exist in the context of overall water resource management are identified and the potential impacts and opportunities for key stakeholders are recognised. .

5. *Implementation –* coordinates 'on-ground' planning and implementation. This shall inevitably be followed up with ongoing monitoring and evaluation.

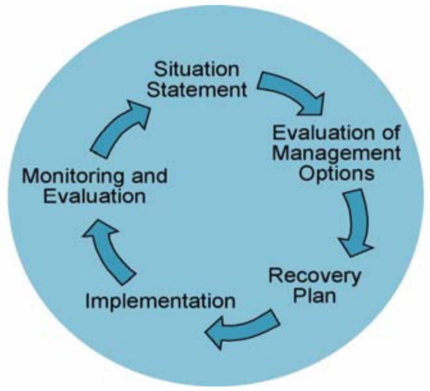

Figure 2 Stages of the water resource recovery approach

2.0 The Salinity Situation Statement

In the Collie Recovery Catchment, salinity is associated with permanent replacement of deep-rooted native vegetation by shallow-rooted annual crops and pastures on deeply weathered soil profiles of Archaean origin, which contain high concentrations of salt and relatively low rainfall. The replacement vegetation has a lower capacity for transpiration, hence it uses less groundwater. Also, the shallow-rooted vegetation does not have roots deep enough to maintain a deep “dry” soil profile compared to the previous native vegetation. This causes the recharge from rain to exceed the rate of losses and the groundwater level rises, bringing with it previously dissolved salts. In severe cases where the saline groundwater approaches the soil surface, salt scalds form, and even in less severe cases saline drainage from the area increases, as does the salinity of the streams (Mauger et al. 2001).

The clearing of native vegetation for agriculture started on the eastern boundary of the Collie catchment with a small-scale development of land around Darkan in the 1870s. Rapid expansion of agriculture between 1900 and 1930 saw the release of the more fertile swampy flats after the First World War. By 1943, 186 km^2 or about 6.5% of the catchment had been cleared. Generally the valley flats were cleared leaving the higher parts of the landscape covered by native vegetation. With the technological advancements post World War II, clearing became much easier and its extent increased markedly. Clearing continued until 1977 when the Western Australian government introduced clearing control legislation (*Country Areas Water Supply Act (CAWSA), 1947, Part IIA*). By then 660 km^2 (28%) of the catchment area had been cleared (Mauger et al. 2001) .

A state government program of reafforestation has resulted in 6740 hectares (ha) of land being purchased and planted with trees to reduce the saline groundwater discharge to the Collie river. There are also 9500 ha of private plantations, mostly *E. globulus* (Bluegum), which have been established in the last fifteen years.

The government undertook significant catchment investigations culminating in 2001 with the release of the *Salinity Situation Statement: Collie River* (Mauger et al. 2001). This report documented the history of development of surface water salinity in the catchment, its causes and consequences and the current status of stream salinity in the catchment. It showed for the first time that technically feasible engineering and vegetative options for recovering surface water resources from salinity existed.

One of the primary findings of the investigation was that 70% of the salt came from the Collie River East management unit, which occupies only 30% of the catchment area and contributes only 24% of the streamflow. It was determined that by focusing management efforts on the Collie River East the effectiveness of salinity abatement measures could be maximised.

Projections prepared for the Salinity Situation Statement indicated that::

- without clearing controls the median salinity of inflow would have risen to around 1700 mg/L.
- with 25% of the recovery catchment still cleared inflow salinity would have increased to ~1100 mg/L.
- with the reafforestation that has already taken place but no additional action, average inflow salinity would level at 760 mg/L.

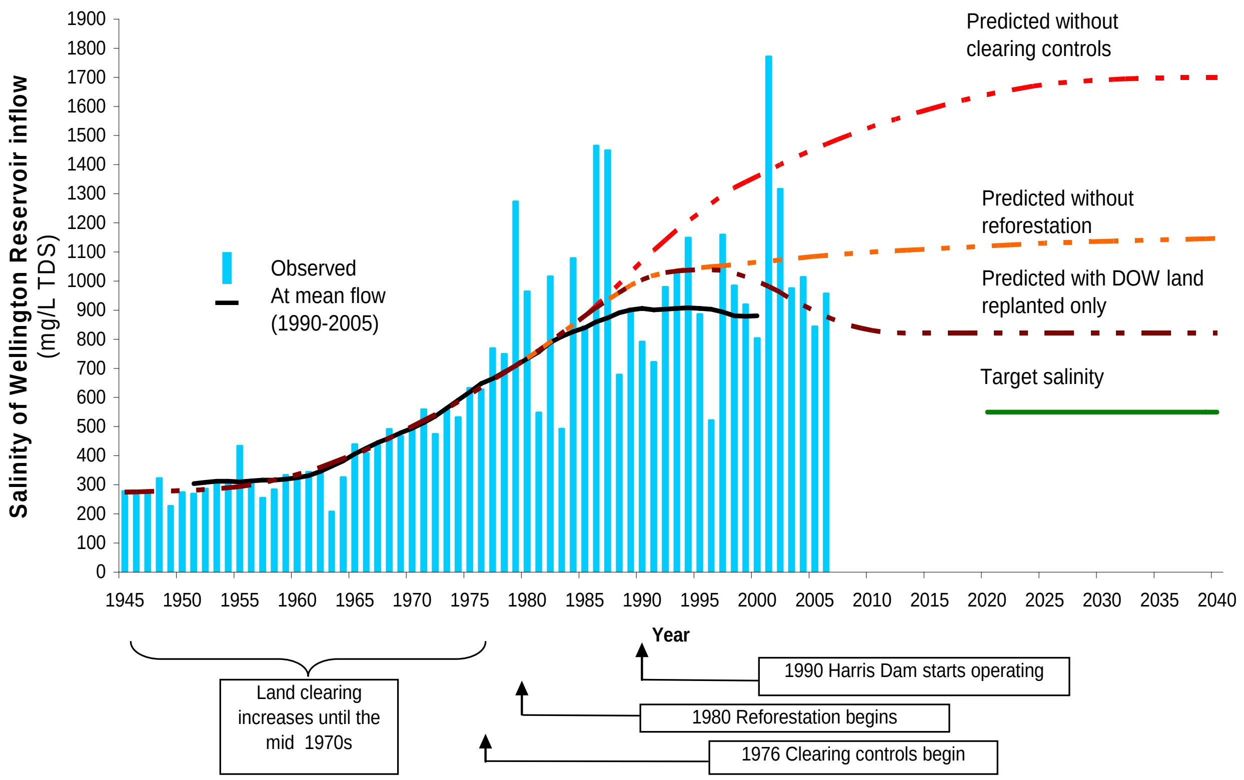

Figure 3 Wellington Reservoir inflow salinity-observations and scenario predictions

3.0 Evaluation of management options

The development and evaluation of potential management options, and the involvement of key stakeholders, was conducted in accordance with DoW's Water Resource Recovery approach (Fig. 4).

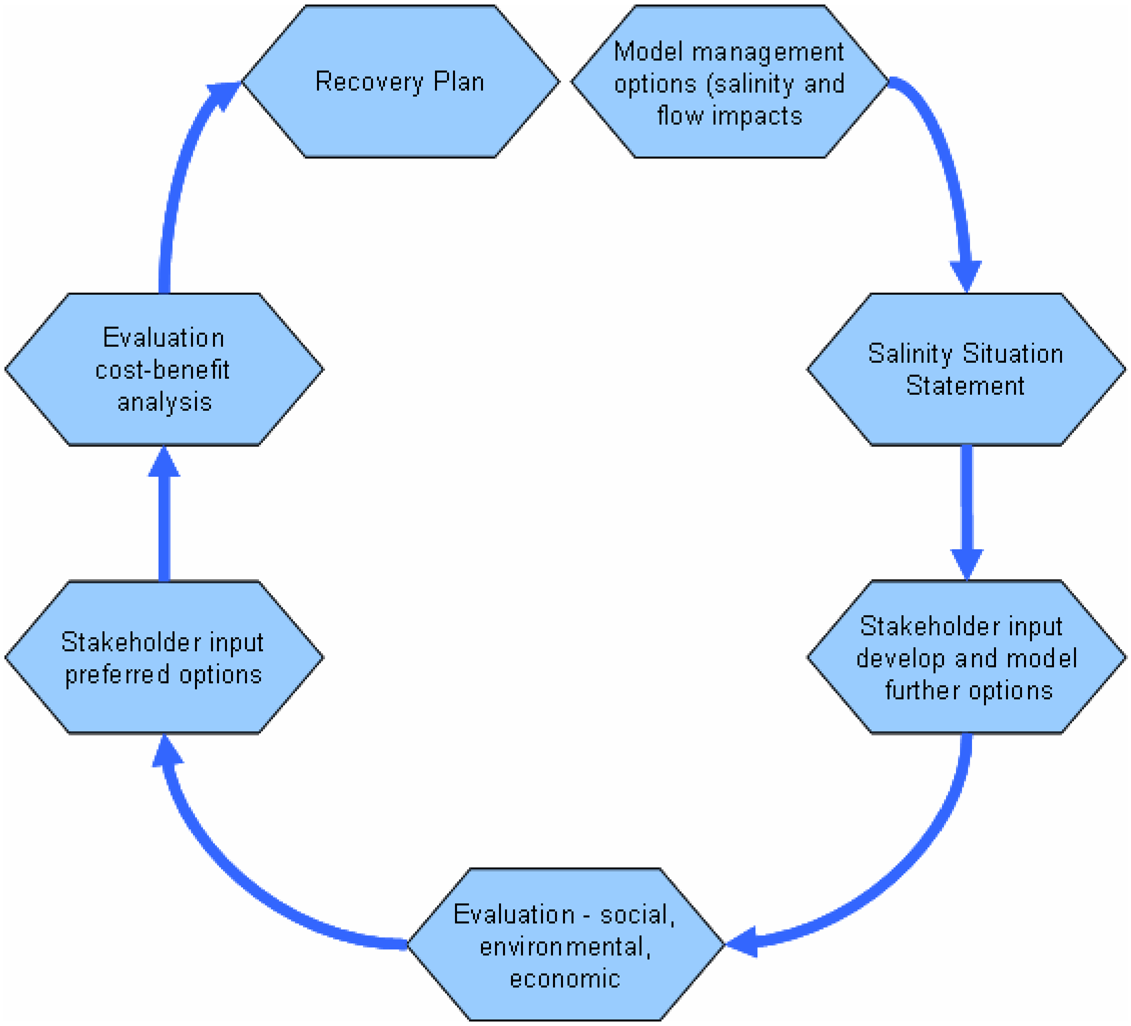

Figure 4 The development of management options.

3.1 Conceptual Scenarios

The *Salinity Situation Statement: Collie River* (Mauger et al. 2001) considered a range of six management options for the Collie River. Use of MAGIC modelling software allowed for the first time estimation of the hydrological effectiveness of the different options. These were:

- *Upland commercial trees:* This involved plantings of various configurations and densities of chipwood or saw-log quality trees (depending on rainfall) on all land with deep well-drained soils suitable for growing 'commercial' trees. Trees intercept groundwater recharge, especially in upland areas.
- *Lowland trees:* This option involved land not suitable for commercial chipwood or sawlog trees, but rather suitable for planting with other varieties. This land is usually situated lower in the landscape and can be subject to waterlogging and salinity.
- *Lucerne:* Deep-rooted perennial pastures such as lucerne on all suitable land can significantly reduce groundwater recharge.

- *Shallow drainage:* Shallow drains in discharge areas reduce soil erosion, inundation and waterlogging. The drains do not affect the rate of discharge of salt from the ground.
- *Groundwater pumping:* Lower groundwater levels using a series of groundwater extraction bores constructed where deep groundwater discharge otherwise occurs. Pipelines and associated pumping stations would be required to move the saline water outside the catchment or, if possible, to a site for treatment.
- *Diversion:* Streamflow from the most saline tributaries could be intercepted by a dam and transported out of the catchment or to a site for treatment by pipeline and pumps.

The modeling indicated that along with reducing stream salinity, decreases in streamflows were also an outcome of all the options. Reduction in streamflows, which means a reduction in the amount of water potentially available to Wellington Reservoir, is therefore important to consider when comparing salinity reduction options.

3.2 Development of further options

During stakeholder consultation following the release of the *Salinity Situation Statement*, a further 26 options or mixes of options were suggested. Subsequent modelling indicated that these options yielded reservoir inflow salinities ranging from 550 mg/L to 700 mg/L. Salinity levels of 700 mg/L and above severely affect productivity of common pasture plants and it was decided to discard those options from further consideration.

This left 13 management options which were projected to yield salinities of either 550 mg/L or 600 mg/L for further consideration (Table 1). Although none of these options achieved the 500 mg/L target, taking these options forward for evaluation was considered justified on the basis that (i) they may be easier to justify on the basis of economic or social issues and (ii) the salinity of current potable water supplies in Western Australia can be as high as 600 mg/L.

3.3 Option evaluation – MCA stakeholder workshop

A workshop held in November 2002 used a multi-criteria analysis (MCA) technique to enable representatives of all major stakeholders in the catchment to contribute to a formal evaluation of the management options. Forty-six people attended, representing 27 major stakeholder organisations. The aim of the workshop was to select a number of preferred options for more detailed evaluation and potential development. The economic, environmental and social impacts were estimated at a conceptual or pre-feasibility level for each of the 13 options and used to inform the decision-making process. In addition, issues concerning implementation for each option were considered.

Detailed information packs were supplied to workshop participants prior to the workshop. Table 1 presents a summary of the triple bottom line impact assessment for each scenario.

The five top ranked options by participants were (URS 2002; URS 2003):

- Option 12 – 50% diversion of Collie River East into Muja void (600 mg/L).

- Option 9 – 100% diversion of Collie River East 9km downstream from James Crossing into Muja mine void (600 mg/L).

- Option 10 – 30% diversion at James crossing and partial groundwater extraction at Collie River South, full groundwater extraction (227 bores) at Collie River Central East (600 mg/L).

- Option 2 – 16 000 ha of upland trees and 700 ha of lowland trees (550 mg/L).

- Option 4 – Groundwater extraction (225 bores) and 3000 ha of lowland trees (550 mg/L).

A further two options were raised that had not been previously analysed. Both options were designed to achieve an outcome of 550 mg/L and reflected elements of the management options that were put forward as being highly desirable during the community consultation process. The additional options have the capacity to achieve a rapid response in salinity reduction as well as a longer term solution to address the fundamental causes of dryland salinity. The options were a combination of Option 12 (50% diversion at Buckingham) combined with another salinity reduction strategy (URS 2002; URS 2003):

- 'Buckingham diversion' option combined with 4200 ha of upland plantations and 3000 ha of lowland revegetation (Option 12a).

- 'Buckingham Diversion' option combined with groundwater pumping (Option 12b).

The most preferred option by a large margin was for a 50% diversion at Buckingham into available mining voids followed by a full diversion (9 km downstream from James Crossing). Both of the preferred options were estimated to reduce salinity to 600 mg/L. Fundamentally, the results of the stakeholder workshop showed that the community valued social outcomes above environmental and economic outcomes. Furthermore, participants were keen to see long-term sustainable outcomes for the catchment and its industries, including water production. These preferences were carefully considered during the further development of the management options.

Option	Cost ($ M)	Cost ($m /GL)	Social Impact	Environmental Impact	Implementation	Possible water available (GL / year)
550 mg/L Target						
Groundwater pumping	122	6.7	Minor	Low	Staged, complex	18.3
Upland trees	27	1.7	Significant - locally	Low	Staged	15.9
Lowland trees	40	2.3	Moderate – locally	Low	Staged	17.6
Trees + Pumps	65	3.6	Low	Low	Staged	18.2
Desalination	142	7.7	Minor	Low	Non-staged, complex	18.4
600 mg/L Target						
Part pumping	107	5.8	Minor	Low	Staged, complex	18.5
Upland trees	23	1.4	Significant - locally	Low	Staged	16.5
Lowland trees	32	1.8	Moderate - locally	Low	Staged	17.5
Full diversion	162	9.2	Low	Low	Non-staged	17.6
30% Diversion + pumping	128	7.0	Low	Low	Non-staged	18.3
Pumping + trees	45	2.5	Low	Low	Staged	17.7
50% Void diversion	17	1.0	Low	Possible	Non-staged	17.8

Level of impact key –Significant, Moderate, Low, Minor (in descending order of impact)

Table 1 MCA Scenario summary

3.4 Benefit – cost analysis

The above seven options were recommended by the Collie Recovery Team in 2002 for more detailed assessment and benefit-cost analysis (Table 4) (URS 2004). The analysis was developed to incorporate the following major effects, activities and values:

a. water values;
b. irrigation and dryland agriculture values;
c. environmental and social values; and
d. cost of options to address salinity in the Collie River Recovery Catchment.

The net present value (NPV) shown in Table 4 reflects the combined value of the above estimates. NPV refers to the value of a project's benefits in relation to the value of a project's cost. A positive NPV value indicates that the project's benefits outweigh its costs and should therefore be considered to go ahead. Benefit cost ratio (BCR) is derived by dividing the present value benefits by the present value costs. A BCR value of greater than one indicates that the value of an option's benefits is greater than the option's costs (URS 2003).

Table 2 Benefit-cost analyses of the preferred options

Option	Resultant salinity at Wellington Reservoir (mg/L)	Maximum cost ($ million)	Benefit cost ratio (BCR)	Net present value (NPV) ($ million)
(12) 50% diversion of Collie River East into Muja void	600	10	2.4	28
(9) 100% diversion of Collie River East 9km downstream from James Crossing	600	138	0.3	–115
(10) 30% Diversion at James Well and groundwater extraction with 127 bores	600	83	0.4	–62
(2) 16 000 ha upland trees and 7000 ha lowland trees	550	85	1.2	7
(4) Groundwater extraction with 225 bores in Collie River East and Central East and 3000 ha lowland trees	550	75	0.8	-13
(12a) 50% Buckingham diversion with 4200 ha of upland trees and 3000 ha of lowland trees	550	44	1.7	28
(12b) 50% Buckingham diversion and groundwater extraction with 177 bores in Collie River South	550	58	1.0	3

Of the original five preferred options, only Option 12 and Option 2 returned positive NPV values and BCR values of greater than one. However, Option 2 was eventually discarded as it was identified as having significant negative social impacts as well as costing significantly more.

Several options (9, 10 and 4) were shown to have significant environmental costs as well as returning negative NPV values. This is predominantly a result of impacts on urban and industrial users from using water with elevated salinity levels (URS 2003). Furthermore, these options were considered unfeasible as the costs are greater then the benefits.

Options 12, 12/a and 12/b all returned positive NPV values as well as BCR values above one, indicating positive returns on investment are likely. They were also identified as being most preferred by the stakeholder consultation group.

3.5 The recovery strategy and final management options

3.5.1 Recovery strategy

An important outcome of the stakeholder workshop and the triple bottom line analysis was identifying that an integrated solution to salinity mitigation in the Collie Recovery Catchment would be the most appropriate strategic approach. The recovery strategy is to use engineering options in the short-term combined with higher water use farming systems and trees in the long term. This is comprised of two major components, Buckingham diversion and disposal, and higher water use farming systems and trees.

3.5.2 Final management options

Buckingham diversion and disposal

The original diversion option (Option 12) consisted of a diversion at Buckingham Weir, with permanent storage in Muja void. Further consultation with other stakeholders indicated concerns that the stored water would affect local groundwater quality. Later still, the owners indicated that the void would after all be required by them for other purposes, and offered instead the use of Chicken Creek 4 mine void, a much smaller void. The diversion option was then re-designed to use temporary storage of diverted water in Chicken Creek 4 mine void (CC4) and disposal via a purpose-built pipeline to the sea. Conceptual design costings which included a pipeline to the sea resulted in a cost of $28m, so this option remained preferable in the short term. Hence the option of combining a partial diversion at Buckingham with tree plantations and higher water use farming systems was taken forward (pending funding) for more detailed assessment. This would be comprised of feasibility analysis, preliminary design and then final design and construction plans.

However in the early engineering design phase, it became apparent that the cost of building a designated pipeline to the sea would be prohibitively expensive. During this phase (which included a trial diversion into CC4) the CC4 void was also earmarked for mining purposes and needed to be emptied by 2012. However, the trial diversion phase was important as it provided for “proof of concept” operations and allowed studies to be conducted relating to the effects of a river diversion on salinity levels flowing to the Wellington Reservoir.

An alternative storage and water disposal option was sought. The possibility of diverting salty river water into the Western 5H (W5H) void and desalinating the diverted water was investigated. The W5H void had available storage capacity and the existing Verve Energy ocean disposal pipeline had sufficient spare capacity to take the concentrated brine from a desalination plant, thereby alleviating the need for a purpose-built disposal pipeline. Desalination technology had progressed significantly since the original consideration of the diversion options, with the introduction of smaller, cheaper, compartmentalised reverse-osmosis plants. These plants now fit in with the scope of the indicated budget as well as producing fit-for-purpose fresh water for use in the region, a result that was not originally considered in the development of previous management options.

Improved farming systems

To ensure stakeholder involvement, members of the Collie Recovery Team were involved in the development of this component of the plan. The approach used was:

1. The Collie Recovery Team (CRT) nominated a comprehensive list of tactical farming system options.
2. A Technical Advisory Group (TAG) reviewed the proposed options and prepared recommendations.

The list of tactical options was grouped into seven categories by the TAG:

- Improving the water use of annual pastures
- Perennial pastures
- Interception earthworks
- Deep drains
- Siphons/bores
- Trees in blocks or plantations
- Trees in alleys

For each category the TAG estimated the implementation costs, stream salinity benefit, technical assumptions or constraints, likelihood of adoption and effectiveness over time .

Commonly suggested options, such as replacing annual pastures and crops with perennial pastures and trees, present particular challenges because:

- Farming systems based on perennials are largely unproven in this district.
- Their adoption can sometimes incur substantial set-up costs and requires a transformational change in management approach from ‘set’ to ‘rotational’ stocking, and involves a perceived fundamental change in traditional farming lifestyles.
- There is considerable local resistance to further reforestation, stemming largely from anticipated negative social and economic impacts (depopulation and rural decline).

The TAG reached the following conclusions:

- Farm scale engineering options (shallow and deep drains, siphons and bores) have issues of economics regarding disposal and/or uncertain actual salinity benefit to the reservoir and they also need to be implemented at full scale. Therefore these are not recommended without additional study.
- Annual pastures have low salinity benefit, with limited potential to significantly increase pasture growth on local farms, and are therefore not recommended as a preferred measure for salinity mitigation.
- Trees and perennials are justified, on the basis of reduced infiltration to groundwater and resultant reduction in stream salt load and reduced risk. There are incremental benefits and the mix could be decided by auction (trees) and a specific call (perennials).
- The project design needs to include identification of landholder collaborators and needs to develop a marketing package and provide expert agronomy advice.
- Trees and perennials should be established in Collie River East and Collie River South management units.

3.5.3 Funding Options

Given that the conceptual design costing was around $30m, it was clear that significant funding would be required. At the time, the National Action Plan for Salinity and Water Quality was developed by the Federal and State governments, and a project proposal was submitted. This proposal was accepted for funding.

Subsequently, as more detailed studies of engineering costs, farming system costs and stakeholder issues have been carried out, the original proposal has been modified and redesigned within the budget while still attaining satisfactory water quality outcomes.

4.0 The Recovery Plan

Based on the results of all the studies carried out, stakeholder consultation, and funding available the DoW developed a draft Collie River Salinity Recovery Plan.

The draft Recovery Plan proposes a staged implementation of four major projects that, fully executed, should result in salinity in the Wellington Reservoir being reduced from 900 mg/L to 615 mg/L by 2015 (Table 4) and improved amenity of the Collie River, its tributaries and surrounding landscapes. The four projects are:

1. **Diversion at Collie River East**

   Stage 1: Trial Diversion of 1.5–3 GL/a of saline flows from Collie River East at Buckingham with temporary storage in CC4 mining void.

   Stage 2: Diversion of 4.5 GL/a from Collie River East at Buckingham Weir with temporary storage in W5H mine void. The water will then be treated at proposed desalination plant and at Muja power station's existing desalination facilities. Brine disposal is to the ocean via Verve Energy's existing, upgraded ocean discharge pipeline.

2. **Diversion of Collie River South Branch**

   Diversion of up to 0.8 GL/a of saline flows from the Collie River South into Lake Kepwari.

3. **Improved farming systems and tree planting**

   An incentive scheme and other measures aimed at encouraging wider adoption of trees and other high water-use farming systems such as perennial pastures.

4. **River rehabilitation and marron recovery**

   The area around the diversion site will be rehabilitated for water quality and to encourage natural fauna recovery.

Table 3 Predicted salinity reductions of inflows to the Wellington Reservoir

Component	**Improvement**[i] (mg/L)	**Cumulative improvement** (mg/L)	**Resultant Salinity** (1995 average flow year mg/L)
Landuse as at 1996	0	0	900[ii]
Landuse as at 2007	115	115	785[iii]
Collie River East — Stage 2 (4.5 GL)	130[iv]	245	655
Collie River South (Lake Kepwari)	10	255	645
Farming systems	30[v]	285	615

i The salinity improvement is highly variable and is dependant on annual rainfall
ii Mauger et al. 2001, pp. 81.
iii URS 2004, pp. 2-3. Figure from Mauger et al. 2001, pp. 83 not used as 1800 ha of plantations assumed to be planted in James Well was not planted.

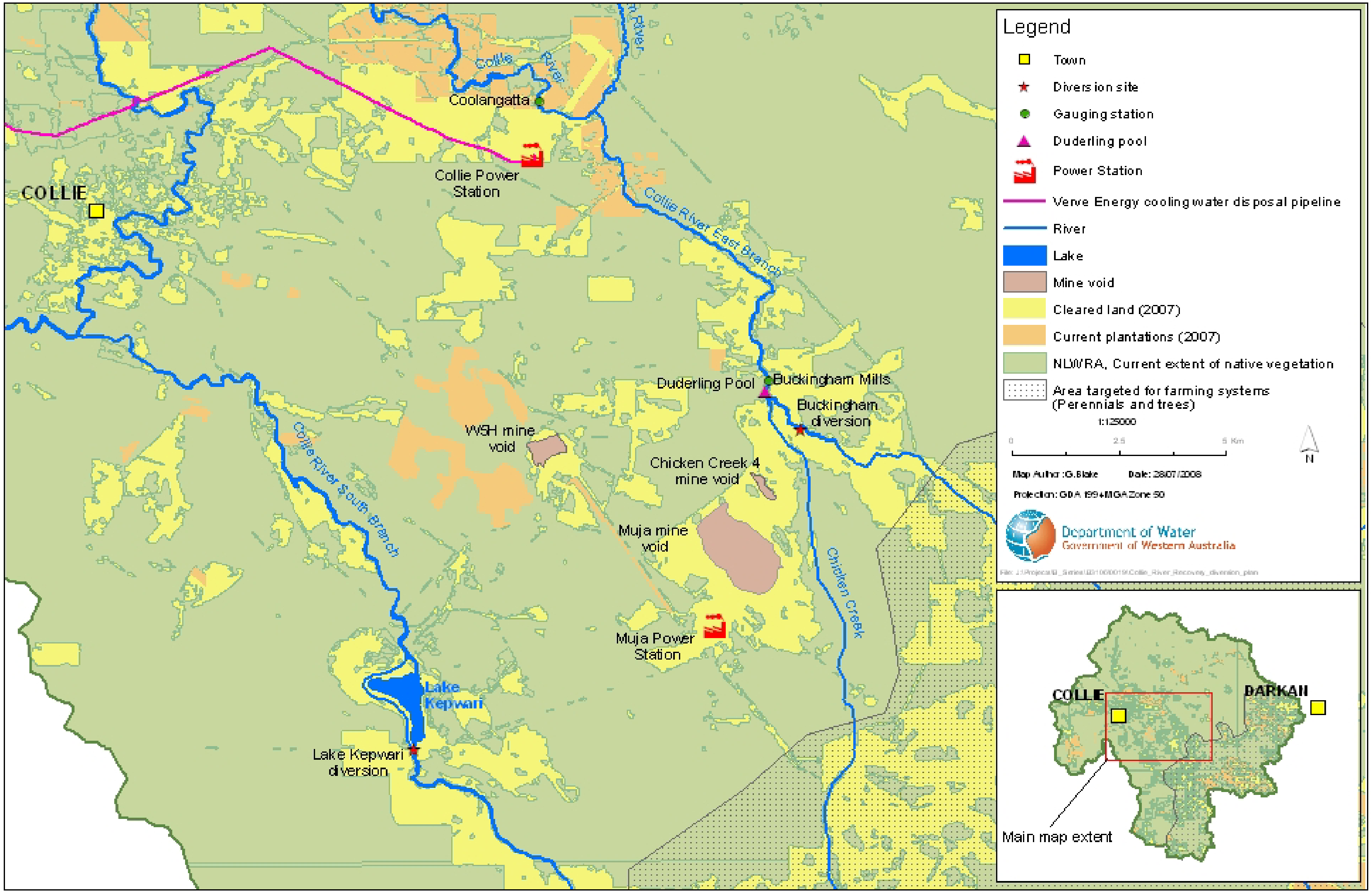

Figure 5 Key components of the Collie River salinity recovery

4.1 Stage 1 Trial Diversion – "proof of concept"

A temporary pumping station and weir were installed at the diversion site at Buckingham to divert the 'first flush' winter saline flows. The pumping station used diesel pumps on a bunded temporary hard standing adjacent to the diversion site. A small pool behind the temporary weir was also excavated to provide the necessary operating storage in the river. Actual pumping from Buckingham Weir commenced on 8 August 2005 and was repeated in the winters of 2006 and 2007 (Table 5). Due to the late start in 2005 only 1.0 GL of water with 3 kt of salt was diverted.

Table 4 Diversion from Buckingham Weir to Chicken Creek 4 void

Year	Pumping duration	Volume diverted (GL)	Salt diverted (kt)	Reduced salinity at Mungalup GS (mg/L)
2005	3 months (Aug-Oct)	1	3	30
2006	6 months (May-Oct)	2.1	13.4	418
2007	6 months (May-Oct)	3	14.5	151

In the second year of the trial the pumping started earlier in order to catch the saltiest water after the first winter rains. 2.1 GL of water containing 13.4 kt of salt was diverted to CC4. Effectively, the diversion removed around 8.5% of the water and around 30% of the salt that would have flowed past the Mungalup gauging station. This equated to an improvement of 418 mg/L to water entering the reservoir during the diversion period. In the third year, 3 GL of water containing 14.5 kt of salt was diverted. This equated to removing approximately 4.14% of the total water and 15% of the total possible salt flowing through Mungalup gauging station.

The salinity at the Reservoir wall is measured by Water Corporation at the top, middle and bottom of the water column. During the main trial diversion years of 2006 and 2007 the bottom salinities peaked at around 1250 mg/L, compared to around 1700 mg/L for the years in 2002 – 2005 and 2008. This indicates that the effect of diverting the saltiest river flows from the river at Buckingham had a measurable effect in the Reservoir.

4.2 Stage 2 Diversion – 4.5 GL/a from Collie River East

The infrastructure and layout for the Stage 2 diversion is represented schematically in Figure 7.

The pump station and pipeline from Chicken Creek 4 void is a temporary arrangement to enable the 6.1 GL of diverted river water in the void to be pumped out.

The summer operating mode will operate for approximately 270 days per year. There will be no diversion during the summer as the river dries up.

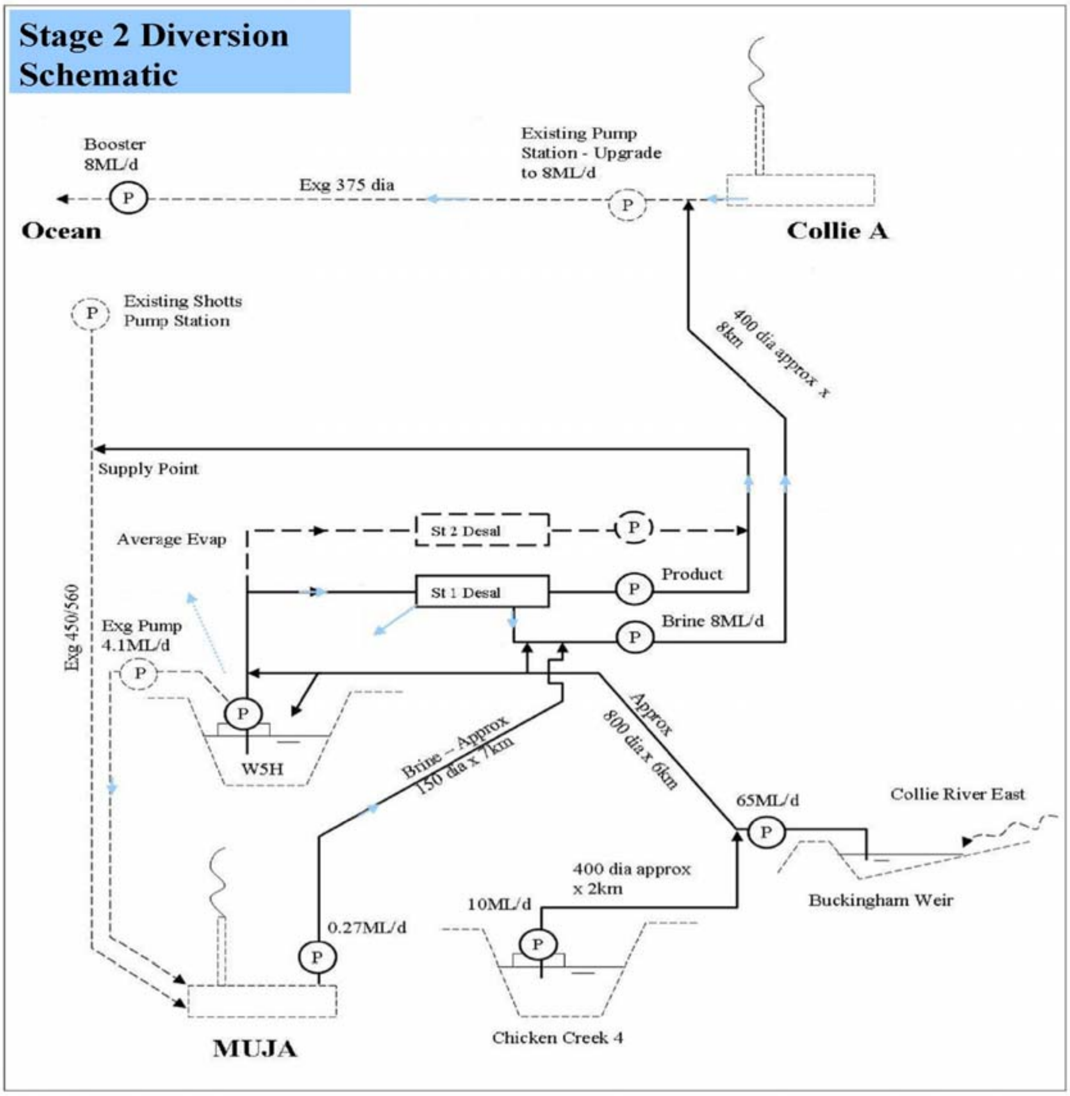

Figure 6 Schematic of Stage 2 Diversion Infrastructure

During this period, 3 ML/d will continue to be removed from W5H to Muja via the existing system and 10 ML/d will be removed and treated by the new desalination plant. This gives an overall water balance, allowing for evaporation and backwash flows, of 4.45 GL removed from W5H. Therefore, at the end of the summer period, when Collie River East starts to flow, there is sufficient space within the void for storing part of the winter diversion of 4.5 GL.

The winter mode will operate for 90 days per year during the high-flow months of July to September.

It is intended that 65 ML/d will be diverted from the weir to both W5H (60.77 ML/d) and to the brine outlet (4.23 ML/d) via the bypass. The flow rate in the bypass is limited by the capacity of Verve Energy's ocean disposal pipeline. Environmental flows in the river will be provided by the weir design. The existing system will continue to extract 3 ML/d from W5H to Muja and the new desalination plant will cease to operate, as the demand for cooling water by industry during winter is reduced. This mode gives an overall water balance of 4.2 GL added to W5H and a river diversion of 4.58 GL.

To ensure that as close as possible to 4.58 GL of the river's saltiest water is removed every year, salinity gauges at the Buckingham Weir diversion will monitor salinity levels continuously, and only when a threshold of salinity of 2000 mg/L is detected will the pumps be activated to remove water from the weir at this point. The threshold salinity is exceeded on most days.

4.3 Diversion of Collie River South

Lake Kepwari was formed by the filling of the former Wesfarmers Coal Collie WO5B void. The lake is 70 m deep, covers an area of about 100 hectares and has a volume of approximately 30 GL (Brendan Kelly *pers. comm* 2008). The void is located in the former course of Collie River South, which was realigned to the west to allow for mining operations.

Filling commenced in 1999 under a licence from the Water and Rivers Commission on the condition that all river pools downstream of the void were filled before water was diverted into the void and the volume of water diverted was limited to 5 GL/a at a maximum flow rate of 100 ML/d. The pit was progressively filled over succeeding years. The salinity of the water in the pit is around 1400 mg/L (average 1999-2005) and in the course of a year, pH ranges from 4.5 to 4.9. The water body stratifies in summer and mixes during autumn and winter.

Under the current operating regime, with no further water being diverted into the void, there is a deficit in the lake-water balance with losses from evaporation and seepage exceeding direct rainfall recharge to the lake by up to approximately 0.8 ML/a. This suggests that ongoing diversions from Collie River South will be required to maintain current water levels.

It is proposed that future diversions into Lake Kepwari are undertaken during the months of April and May which would capture the saltiest winter flows in Collie River South. Salinities average 2500 mg/L during this time near Lake Kepwari. This will maximise the salinity improvement in the Wellington Reservoir. Diversions from 0.5 to 0.8 GL/a would replace losses due to evaporation and seepage while preventing overflow. This would deliver a salinity benefit of approximately 10mg/L to the Wellington Reservoir.

4.4 Perennial pastures and trees

Measures to encourage wider adoption of high water-use farming systems are proposed with the aim of reducing recharge from cleared land in the James Well, upper Collie East and upper Collie South Branch management units. If fully implemented, these measures are expected to contribute a salinity improvement in the Wellington Reservoir of around 30 mg/L .

It is recommended that farmers interested in perennials be offered up to $500/ha to cover establishment costs which may include lime, fertiliser, fencing or water reticulation (recognising that paddock subdivision is usually required to facilitate rotational grazing). It is estimated that about 500 ha of perennials may be established through this offer.

Furthermore, it is recommended that the remainder of the funding available is used to complement current commercial packages offered by the Forest Products Commission for the establishment of eucalyptus sawlog, pine sawlog or sandalwood plantations integrated with current farming systems. An incentive of $1000/ha to landholders will enable the establishment of up to 1700 ha of trees.

4.5 Waterway rehabilitation

It is proposed that the area of the Collie River East around the Buckingham Diversion site will be rehabilitated. In addition salinity, pH and sediment load issues are also proposed to be addressed in order to aid the recovery of native fish and marron populations which were once common along the entire length of Collie River East. This will involve direct seeding of tree, understorey and sedge plant species as well as stock exclusion from river banks. Furthermore, mine dewater used by the mining companies to supplement local river pools at Buckingham affected by nearby mining operations will be treated to raise the pH to close to neutral (neither acidic nor alkaline).

5.0 Future options – from salinity recovery to water resource recovery

This salinity recovery project created a renewed interest in the Wellington Reservoir as a potable water source. This attention created issues including local versus state water needs (including metropolitan Perth), competing interests for new water licences, water-quality protection requirements for a reservoir used for drinking water rather than recreation and the need for the source to meet the standards set in Australian Drinking Water Guidelines. However, this will not be considered in the immediate future with the proposed 45 GL desalination at Binningup being the state's next new source of water. A comprehensive 'big picture' approach to the Wellington Reservoir has been outlined in part by *Water Source Options in the Collie-Wellington Basin* report (WSOSC 2007). The report suggested that, at total water cost of $1.64/kL for a 57 GL option and $1.73/kL for a 45 GL option, the Wellington Reservoir is a realistic source of water for the IWSS, but more work needs to be done on salinity recovery, water treatment and water sharing.

Long-term management options

The 'Kelly Report' (WSOSC 2007) builds on the strategies to be implemented as part of the *Collie River Salinity Recovery Plan* to reduce salinity. This provides a basis to make improvements in irrigation, provide water to industry and to develop a drinking water source by working collaboratively with stakeholders in the Collie Basin.

By providing power stations with additional water, the groundwater they traditionally use could be pumped to the Stirling Reservoir for use in the IWSS. It is anticipated that this could yield between 5 and 10 GL/a.

As a consequence of the diversion, water in the Wellington Reservoir will become progressively fresher. This will benefit irrigators who currently use water with salinity levels that limit productivity. Additionally, the reservoir water will become attractive to industry as 'fit for purpose' water. 'Fit for purpose' water has a salinity between 600–750 mg/L and can be used by the power and alumina industries as part of their industrial processes. It is anticipated that there could be 17–34 GL/a of Wellington Dam water available.

Private-Public Partnerships

The Collie Salinity Recovery Plan provides a basis to make improvements in irrigation, provide water to industry or to develop a drinking-water source, by working collaboratively with stakeholders in the Collie Basin. Private Public Partnerships could be used to create a water utility in the region. However, before this can be progressed, a planning study is needed to explore the relationships between the supply and demand of water and implications of the varying water qualities. This study is currently being commissioned and is the next step in determining the long-term management of the water resources of the Collie River basin.

6.0 Conclusions

Results

The Department of Water's water resource recovery approach has resulted in the following:

- A salinity recovery project which attracted $30m of funds from the National Action Plan for Salinity and Water Quality.
- Trial diversion operations have confirmed a reduction in salinity in water entering the Reservoir due to the diversion i.e. the scale is such that it can make a difference.
- Signs of behaviour change among some landholders observed – expressions of interest in trialling perennial pastures received recently where previously there was no interest.
- Key stakeholders are attempting to work together for the benefit of the whole.
- Salinity recovery has led to water resource recovery with potentially a significant quantity of water made available.

Conclusions

For a capital expenditure of $30m, salinity of water in Wellington Reservoir will be lowered tp less than 650 mg/L.

The recovery plan forms a building block for a major water supply of "fit for purpose" industrial water and a in addition a potable water supply.

Science has been applied to a complex problem in a practical way, underpinned by extensive consultation with industry, agencies and the community, to plan the recovery of a major water resource from salinity and to develop a package of potential water resource initiatives important to the region and the state.

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