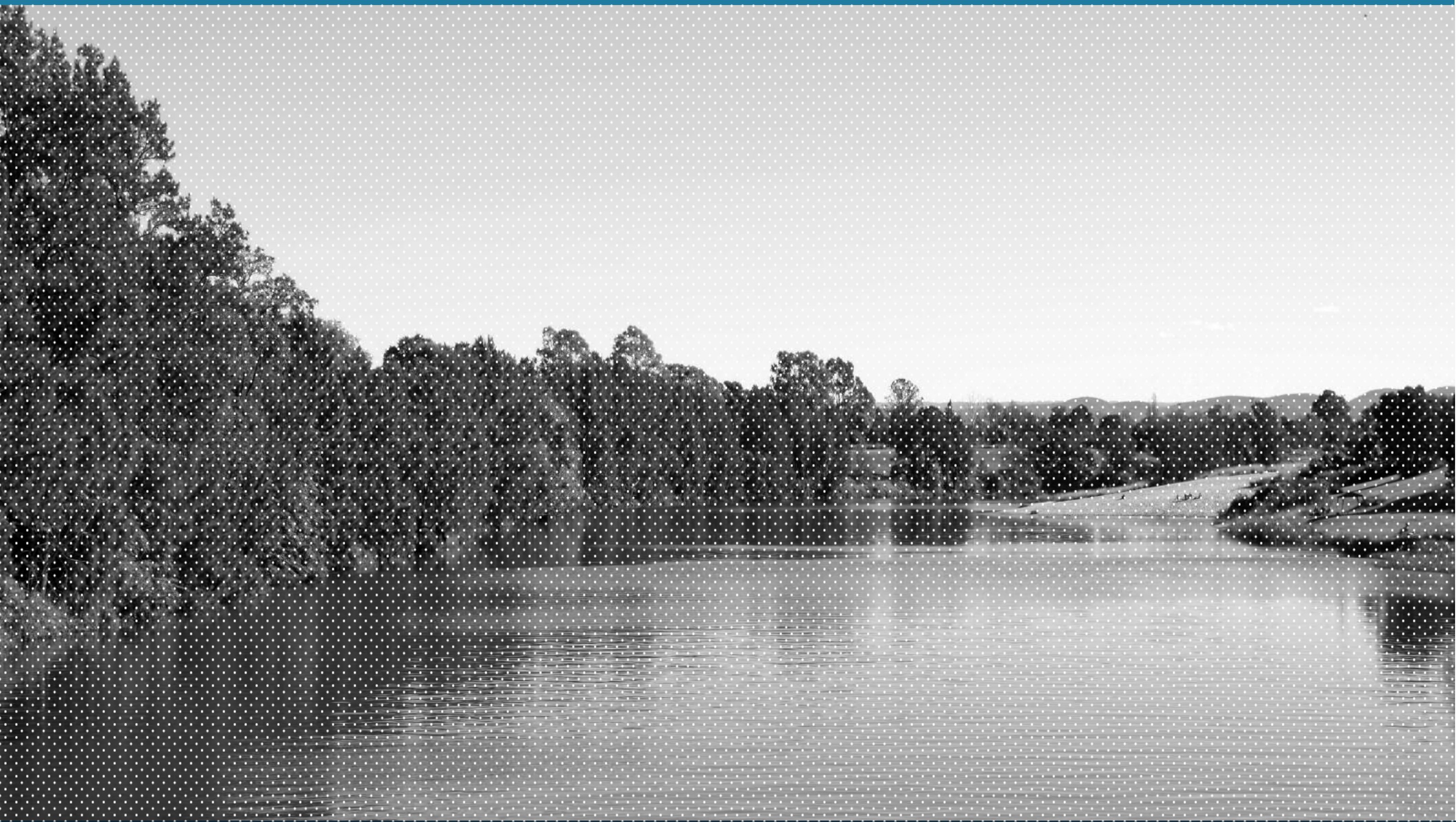


frontier economics

Salinity cost function review

Final Report | 22 June 2023

Contents

Tables

Figures

Boxes

Executive Summary

Purpose and scope of this review

High salt concentrations in land and water hinders the use of these resources for development and natural environment purposes. Excessive salinity has implications for water quality, plant growth, biodiversity, land productivity, industry, infrastructure, and supply of water. Salinity affects all jurisdictions within the Basin, with the aggregate impact most evident in the mid and lower parts of the Murray River.

All landscapes in the Basin contribute to salinity in the shared water resources. For over 35 years, the jurisdictions have committed to shared and individual responsibilities and actions to manage basin river salinity. As a result, in-river salinity has been successfully managed by reducing the net amount of salt entering the river through both individual State and joint salinity management actions, including salt interception schemes. However, salinity is an ongoing risk, and management and resources are required to maintain the program's success.

A key part of the salinity management framework was the establishment of a Basin Salinity Target and a 'cap and trade' arrangement which requires each jurisdiction to ensure their actions have no net negative impacts on salinity in the river. Registers were established to monitor and record salinity actions which require jurisdictions to offset any salinity impacts associated with new developments by accredited salinity management works and measures. This could include salt interception schemes, irrigation development works, catchment strategies, bore decommissioning works.

Estimated salinity impacts are converted into estimated credits and debits using a Salinity cost function and recorded on the Register. The salinity cost function is a modelling tool that relates levels of river salinity to the economic impact of salinity (or its removal) on the various river water users. The current urban and commercial elements of the salinity cost function provide the economic basis for calculating the salinity cost effect (the average dollar cost per year) from salinity on agricultural, household, commercial and industrial water consumers.

While the Salinity Cost Function has been an integral part of salinity management in the southern MDB for several decades, given the current assumptions have been unchanged since 2005, the 2020 Independent Audit Group for salinity recommended a review of the salinity cost function be undertaken leading up to the 2026 review of the BSM2030. Salinity management today requires both an accountability framework for the jurisdictions to comply with their salinity management obligations, and the ability for the MDBA and States to demonstrate the benefits of salinity management to Governments, Treasuries and other parties.

This review of the salinity cost function was split into two stages:

- Stage 1: high-level review of the purpose of the cost functions and investigation of different options for determining the impacts from river salinity, including consideration of whether the cost functions are still required
- Stage 2: assuming there is still a legitimate role for the cost functions (from Stage 1 assessment), undertake a more detailed review of cost functions encompassing:
    - document and assess the assumptions underpinning the cost functions

- o examine the scope to simplify or broaden the cost functions to incorporate other economic, community/social, cultural and environmental factors
- o determine if there are approaches that can assist alignment with Basin Plan evaluation requirements
- o recommend the most appropriate cost functions to be adopted for future use by the Murray-Darling Basin Authority, and
- o identify knowledge gaps, major areas of uncertainty/risk and prepare recommendations for further work.

Engaging with the MDBA, and Basin Jurisdictions has been a key part of our review — involving individual jurisdiction engagement and joint workshops with Basin Jurisdictions and the MDBA.

Key findings

The key findings from our review are as follows.

1. **The agreed salinity cost function continues to play a critical role for managing State accountability for salinity management obligations under the Basin Salinity Management 2030 strategy.**
2. **The current salinity cost function does not reflect the benefits attributable to contemporary salinity management and therefore does not meet the needs of the States and the MDBA for a measure of the benefits of salinity management and associated investments for the purposes of contemporary investment evaluation.**

The main role of the salinity cost function is to provide a 'common currency' for understanding the relative costs and benefits of various actions to manage salinity. Importantly it accounts for the locational and seasonal impacts of salinity. Our high-level review of the purpose of the salinity cost function found that it remains an agreed measure to manage State accountability under the Basin Salinity Management 2030 strategy.

Given this agreement, the register offset process underpinned by the cost function provides a means by which States (and their water users) may undertake actions that increase river salinity (such as development and expansion of horticultural industries) as long as other offsetting actions are taken to ensure that no net negative salinity impact occurs. All parties are currently in surplus with credits exceeding debits.

One historical purpose for the salinity cost function was to direct investments in Salt Interception Schemes (SIS). However it is not expected that further SIS investment is required in the short-to-medium term, but rather that other salinity responses (such as catchment strategies, and land and water management plans) would be used.

There are, however, a number of factors that limit the extent to which the salinity cost function reflects the *current* expected economic benefit to water users (a significant portion of the demonstrable benefits of salinity management):

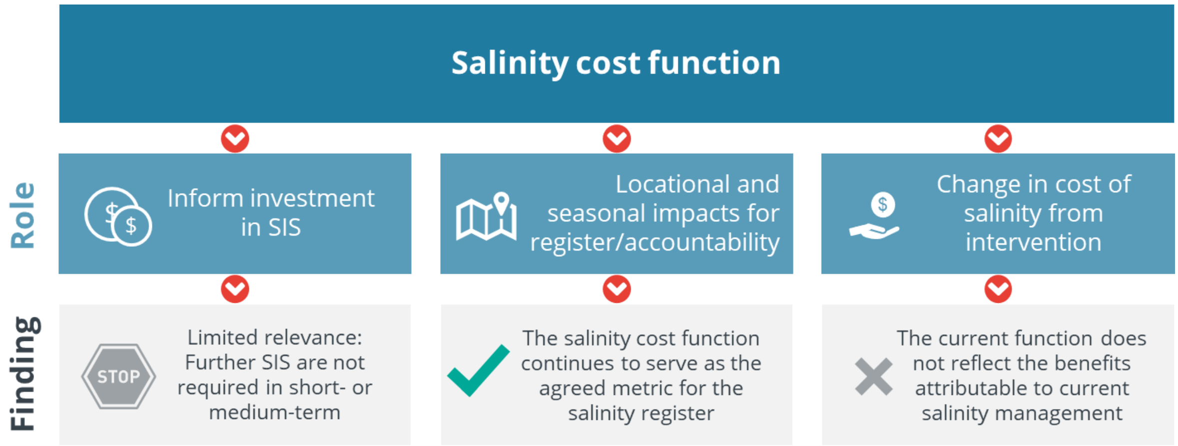
- the salinity cost function is measured in nominal dollars for the year 2005 (2005 dollars).
- the assumptions underlying the economic impacts of salinity are out of date (by more than 20 years) and there have been significant changes in agricultural development and urban/commercial water use since 2005.

- the salinity cost function is calculated over the benchmark period of 1975–2000, and the seasonal conditions which occurred in this period may not reflect current and expected future conditions.

Further, the current salinity cost function does not include aspects of social, cultural and environmental impacts of salinity — which would be increasingly important to a contemporary evaluation of the benefits of salinity management.

The outcomes of the examination of the purpose of the salinity cost function and finding of current performance are summarised in **Figure 1**.

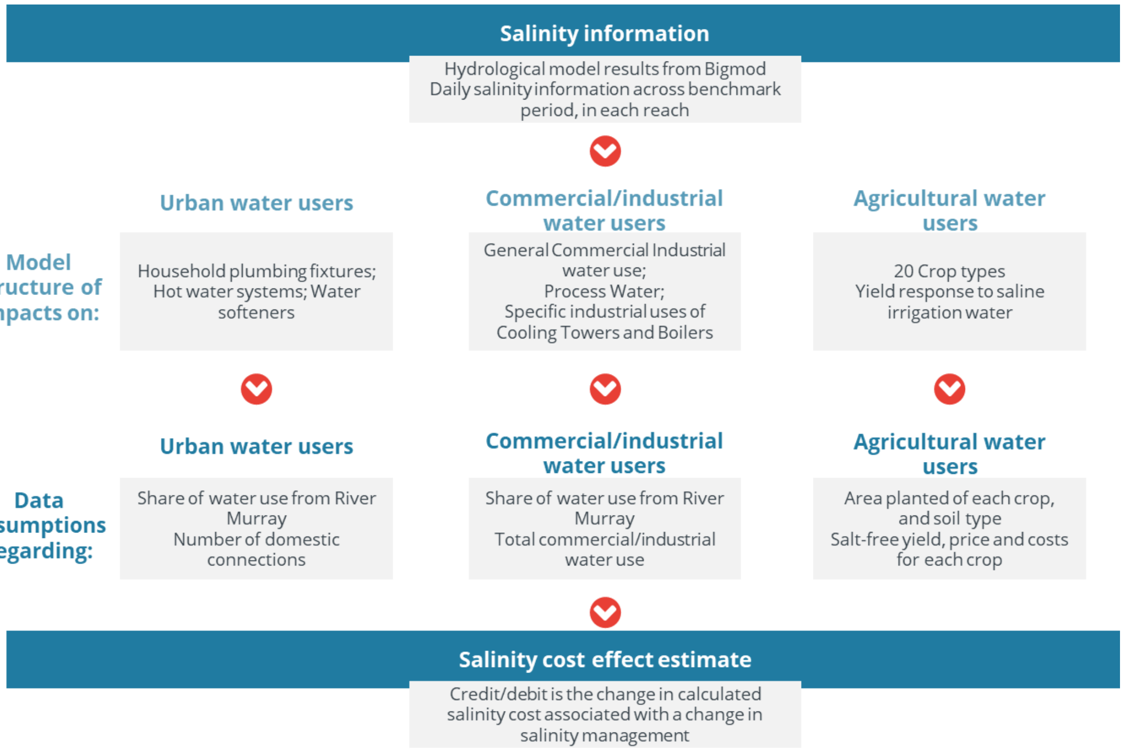
Figure 1: Purpose of the salinity cost function and current performance



3. **Although the salinity cost function incorporates many direct salinity impacts on water users, the underlying assumptions are not based on the best available knowledge.**

The review also entailed a more detailed assessment and systematic documentation of the components and underlying assumptions of the salinity cost function. The model structure is set out in **Figure 2**.

Figure 2: Salinity cost function model structure and assumptions



The detailed urban and agricultural components of the salinity cost function estimate the impact of the many ways salinity impacts water users, but the data assumptions used in the function are not based on the best available knowledge. For example,

- Agricultural water users
  - Crop prices have significantly changed since 2005, due to inflation and commodity price movements.
  - Crop areas have also significantly changed since 2005, notably the significant horticultural development and expansion that has occurred in the lower Murray region (of Victoria, NSW and South Australia) — including an increase in almond crop area from 4,033 ha pre 2005 to 46,260 ha in 2021.
- Urban water users
  - Salinity cost impacts on households are expected to have increased from the values established in 2005 dollars.
  - The number of domestic water connections has increased, significantly so in the Adelaide region. Total water use has not increased, due to a decline in 'per connection' water use, although declines in some uses such as in household outdoor water use is not expected to be associated with a change in salinity costs.
  - The reliance on River Murray water for Adelaide households (and hence the degree to which urban water quality is affected by Murray salinity) may have changed with the completion of the Adelaide Desalination Plant, although water from the Murray is still a lower cost source of water in most years and has recently formed 50% of supply (5-year average).
- Commercial/Industrial water users

- o Salinity cost impacts on commercial/industrial water users are expected to have increased from the values established in 2005 dollars.
- o The volume of commercial/industrial water uses has significantly decreased in the Adelaide region since 2005. For example, manufacturing water use has declined 69% between 2000 and 2020, and it is estimated commercial/industrial water use more broadly has declined by 45%.

The current salinity cost function is applied over a Benchmark period (1975-2000) for hydrological modelling of salinity impacts. This period includes two years in which salinity peaks were observed and in which salinity management was particularly beneficial. The period 2000-2020 involves six years in which salinity management led to large reductions in salinity (>240EC difference). This suggests that there may be value in extending the modelling period (such as, to use 1975-current) in order to capture the full knowledge/experience with salinity management impacts.

4. **Although the salinity cost function incorporates many salinity impacts on water users, it does not consider social, cultural and environmental impacts. However, the incorporation of these types of impacts into a monetised and formula-based model would be challenging, and evidence suggests that the magnitude of these impacts may be small because of ongoing actions to manage salinity.**

Increasingly, demonstrating the economic, social, cultural and environmental value of investments is important to justify funding from State Governments. While the cost function demonstrates many of the economic impacts of salinity management, it does not capture the social, cultural and environmental impacts.

Reviews to date have found that while social, cultural and environmental impacts from salinity exist, they are unlikely to be significant enough to include in the cost function framework. These impacts are often caused by significant peaks in salinity which can damage fish and riverbed fauna. This means it is difficult to robustly establish each impact in a formula to embed in the cost function.

Due to effective salinity management it is widely agreed the threat of salinity to social, cultural and environmental values has been reduced and without salinity management the impacts would be worse. Quantitatively estimating these avoided impacts using economic appraisal methods is likely to be challenging and would require agreement amongst the MDBA and States on the counterfactual and estimation timeframe.

A qualitative description of the social, cultural and environmental impacts is likely to be more compelling and representative. This qualitative analysis can be supported by quantitative information on economic impacts as indicated by the cost function.

5. **The salinity cost function is an established and accepted tool to manage the salinity register and State accountability for salinity management actions. There is no urgent need to change the cost function and its assumptions for this purpose given that State agreement is not in jeopardy and that updated assumptions are unlikely to significantly change State register balances. Rather, updates could be made at a time aligned to other processes — such as shift in the hydrological modelling approach, the 2026 review of BSM2030, or in establishing the cooperative salinity management approach for the period 2031-2045.**

States resoundingly agreed that the State accountability framework was integral to cooperative salinity management, and that the current salinity cost function was fulfilling this role. By estimating the relative impact of actions, the salinity cost function enables States to acceptably offset these actions.

In collaboration with the MDBA, we undertook an analysis of how register entries calculated by the salinity cost function would change if horticultural crop areas were updated to the best available knowledge and found:

- the locational signal did change, sometimes significantly.
- However, the overall State balance did not change significantly.

Based on this analysis, the review found that there is not an urgent need to change the function and its assumptions for the purposes of the State salinity accountability framework. When it does become appropriate to update the cost function, the data assumption update could build on the existing agreed and accepted model structure.

In the short and medium term, there are a number of processes that will have significant implications for the salinity cost function and salinity management, that may provide a suitable opportunity to update the cost function itself. These include the shift in the hydrological modelling approach from Bigmod to SOURCE, the 2026 review of BSM2030, or in establishing the cooperative salinity management approach for the period 2031-2045.

6. **An alternative to updating the salinity cost model is to adopt a simplified approach that focuses on the locational impacts in the calculation of the salinity cost effect, but this may not be sufficient to capture the extent of salinity changes and associated benefits since 2005.**

The critical role of the salinity cost function is that it has enabled States and water users to 'internalise' the externality of salinity impacts and serves as the measure of 'no net negative impacts' for the purposes of the agreed Basin salinity management framework. A significant part of this potential externality is the locational element where salt entering higher up the river will negatively impact more water users (compared to if the salt entered further down the river).

This suggests that a simple locational measure of 'equivalent EC' could underpin State accountability for Basin salinity management. In the modelling undertaken for this review, a strong link between "dollar benefit" and "EC at Morgan" (i.e. $/EC) of SIS and the location where salt entered (or was prevented from entering) the river was observed — with the benefit increasing as the intervention occurred further upstream and thus affected more water users.

However, there are other accountable actions that do not demonstrate the same link in $/EC. This is where other factors such as the seasonality of salinity changes, or the case of dilution flows (rather than the increase or decrease in salt load) are significant.

For actions that have comparable seasonality and other factors, but different salt loads, this suggests that simplifying the calculation of the salinity cost effect using a simple locational measure may be sufficient. The simple measure may not acceptably capture the relative impact on water users for actions that have different seasonal characteristics or which relate to dilution benefits.

Further, it could be hard to reach agreement between States on a new locational function, as compared to updating the currently agreed function.

The salinity cost model would no longer be required if the basis for State accountability was changed, away from the salinity cost effect and to a measure of EC at Morgan. This would represent a significant change to State salinity management — it would mean that locational impacts along the shared NSW/Victorian length of the Murray are no longer recognised, while the impact of these upstream states on downstream South Australia is recognised (as per the impact on EC at Morgan).

7. **Another approach to simplifying the current salinity accountability framework is to reduce modelling complexity. This could aggregate sets of historical accountable actions that have similar characteristics and timing, or 'roll up' legacy actions to a new current baseline, in order to reduce the resources required for salinity register modelling.**

Currently each register item is modelled individually and in sequence. This means that over 300 hydrological model runs are required (each with post processing via the salinity cost function) to calculate the salinity register entries. This represents a very significant demand on modelling resources. For example, to undertake the modelling for this review it required reprocessing the salinity cost function on more than 140 hydrological model runs (to implement one set of changed assumptions for twenty accountable actions).

An alternative modelling approach is to aggregate sets of register entries such as historical accountable actions that have similar characteristics and timing, in order to reduce the resources required for managing salinity register modelling.

Another simplification approach is to 'roll up' legacy actions into a new current baseline, so that only new accountable actions need to be modelled as separate hydrological runs (this includes the 'action' to discontinue a previous action).

8. **A significant gap in current arrangements is that the current salinity cost function does not reflect the benefits attributable to current salinity management. It is recommended that the MDBA and States undertake further work to demonstrate benefits of current salinity management.**

The salinity cost function that underpins the salinity register does not adequately represent the benefits of current salinity management. In our view, demonstrating these benefits could be best achieved by an assessment which documents the scope of quantitative and qualitative benefits from salinity management. This should consider the range of annual outcomes in these benefits, and not just the average over a given time period. Where possible, the evaluation of expected benefits also needs to relate to current/recent and plausible expected future conditions.

There are several options for how such an assessment could be delivered, all of which could build on the existing knowledge accumulated in the current salinity cost function, but aligning the analysis to be more representative of current requirements:

- Inferred: a limited adjustment to the quantitative information from the current salinity cost function and existing modelling, such as to update to current dollars, as well as including descriptive analysis of qualitative benefits of in-river salinity management.
- High-level: a high-level adjustment to the quantitative information from the current salinity cost function, such as an update to data assumptions that have significantly changed. This could be supplemented by additional disaggregation of results, and application to an agreed timeframe (e.g. current/recent/future) condition. This option would include a descriptive analysis of qualitative benefits of salinity management based on available literature, including social, cultural and environmental and salinity impacts beyond those in-river, such as in the landscape and affecting roads and infrastructure.
- Detailed: a detailed recalibration of model structures in the cost function, relying on significant consultation with water users in the various sectors, as well as updating data assumptions. The analysis of other benefits could build on the high-level approach by seeking to modify and adapt information in available literature and draw assumptions around scale and magnitude of key benefits.

A robust demonstration of the benefits of current salinity management would increase the understanding and communication of the value of these cooperative efforts. This in turn would assist in making the case for continued funding and inform the goal of BSM2030 to deliver cost-effective and efficient salinity intervention.

9. Work to demonstrate the benefits of current salinity management would also be able to assist the Basin Plan evaluation.

Under the Water Act 2007 (s13.05), the Basin Plan must be evaluated every 5 years, and the 2025 evaluation will inform the 10-yearly review of the Basin Plan in 2026.

The socio-economic work for the evaluation is commencing, although no detailed framework for the evaluation was yet available.

It should also be noted that the salinity register entries for actions that occurred prior to the commencement of the Basin Plan in 2012 contribute 83-85% of the change to date (as measured in EC and dollars of salinity cost effect). Further, entries since the Basin Plan have built on the existing cooperative relationship between the MDBA and the States (evident for at least the past 40 years).

This means that attributing socio-economic benefits of salinity management to the Basin Plan would be problematic. However, an assessment (such as recommended above) for the evaluation of the demonstrable benefits of current salinity management would provide a useful basis for the socio-economic evaluation of Basin Plan salinity management.

Pathway forward

Subject to a decision by Jurisdictions to continue to use Salinity Cost Effect rather than Salinity Effect as the measure of accountability for the Salinity Registers, our key recommendations are that:

1. The use of the salinity cost function be retained to enable the registers to continue to operate as a key accountability mechanism for the States' salinity management.
2. The MDBA undertakes further work to provide a narrative that demonstrates the benefits of current salinity management. This would include a quantitative assessment based on updating the data assumptions of the salinity cost function and applying the function to historical, recent and (where possible) expected future conditions, to describe the average/expected economic benefits as well as the risk management benefits of avoiding spikes in salinity. This would also include a qualitative assessment of other impacts of salinity management, including social, cultural and environmental.
3. The salinity cost function be updated as part of future processes, i.e. either as part of the shift in hydrological modelling approach from Bigmod to SOURCE, the 2026 review of BSM2030, or in establishing the cooperative salinity management approach for the period 2031-2045. The updated assumptions would be consistent with (or build on) the above demonstration of the benefits of current salinity management.

The report includes Attachment 1 that outlines the scope of work recommended in point 2 above. In our view, demonstrating these benefits could be best achieved by an assessment which documents the scope of quantitative and qualitative benefits from salinity management.

1 Introduction

1.1 Introduction

Cooperative salinity management since the 1980s has largely been successful, allowing for a more effectively managed natural resource. The management framework has allowed for large developments along the river especially in the lower Murray.

The salinity cost functions have been a part of this successful management. They were introduced to serve three purposes – informing the investment of Salt Inception Schemes, understanding the locational impacts of salt, and accountability.

There is concern that the current cost functions are out of date. Key concerns include that the cost functions no longer demonstrate the economic impacts of salinity due to the use of 2005 nominal dollars and the benchmark period, and a number of changes since 2005 has resulted in the modelled and actual worlds diverging.

Salinity management today requires both an accountability framework for the States' salinity management obligations and the ability for states to demonstrate the benefits of salinity management to Governments, Treasuries and other parties. The cost functions underpin the accountability framework, yet in their current form, the cost functions are unable to demonstrate the benefits of salinity management.

1.2 Scope of this project

The review was split into two stages:

Stage 1:

- review the purpose of the cost functions
- investigate different options for determining the impacts from river salinity, including consideration of whether the cost functions are still required.

Stage 2:

- evaluate the current assumptions underpinning the costs functions given the contemporary knowledge and the need to consider a broader range of economic costs and benefits
- investigate simplifying or broadening the cost functions framework to consider all the benefits of salinity management, including identifying other economic, community/social, cultural and environmental factors that may be considered for inclusion in the cost functions framework
- determine if there are approaches that can be included to assist alignment with Basin Plan evaluation requirements
- provide a high-level expert opinion on the most appropriate cost functions to be adopted for future use by the Murray-Darling Basin Authority

- identify knowledge gaps, major areas of uncertainty/risk and prepare recommendations for further work.

1.3 Engagement was a key part of our analysis

Engaging with the MDBA, and Basin Jurisdictions was a key part of our analysis.

As part of Stage 1 we engaged with the MDBA, Commonwealth and State governments individually to understand their views on the cost function and registers, establish common strengths and weaknesses for the current system, and understand a consensus prior to the group consultation stage.

We also held a joint workshop with Basin Jurisdictions and the MDBA to reach a common understanding of issues of strengths and weaknesses of the current salinity cost functions. The workshop also consisted of a robust discussion of alternative ways forward, and it resulted in an agreed approach for the scope of Stage 2.

This agreed approach was reflected in a scoping memo and is actioned by this report.

We also engaged with key stakeholders as required during Stage 2. This included engagement with SA Water and SA Government to assist the understanding of changing urban and industrial water use.

We also undertook extensive desktop analysis and reviewed key strategies and papers on salinity management in the Basin across the project.

1.4 Structure of this report

This draft report sets out our approach to the salinity cost functions review, and our recommendations for a pathway forward. The remainder of this report is set out as follows:

- Section 2 discusses the background of cooperative management of river salinity
- Section 3 sets out the key assumptions underpinning the salinity cost function
- Section 4 provides an assessment of the model structure and assumptions
- Section 5 considers the gaps in the scope of the cost functions
- Section 6 sets out a pathway forward
- Section 7 makes the case for benefit estimation for the salinity program.

2 Murray Darling Basin cooperative management of river salinity

Key findings:

- Cooperative salinity management in the Murray Darling Basin has been very successful to date
- State accountability for salinity management actions is a key driver of this success and continues to remain important moving forward
- The Registers have been central to the successful salinity management accountability framework
- The cost functions play a key role in operationalising the Registers
- Performance against the Basin Salinity Target has been successful, but the modelled world and the actual world are diverging, with current modelled salinity at 798EC at Morgan.

2.1 Managing river salinity is a policy problem

There is a long history of salinity management in the Murray Darling Basin. Salinity affects all jurisdictions within the Basin, with the aggregate impact most evident in the mid and lower parts of the River Murray. High salt concentrations in land and water hinders use of these resources for development and natural environment purposes. Excessive salinity has implications for water quality, plant growth, biodiversity, land productivity, industry and supply of water. Salinity levels are a function of salt load and flow regime.

All landscapes in the Basin contribute to salinity in the shared water resources. Both peak events and ongoing average salinity levels have impacts in the Basin. Salinity is a 'tragedy of the commons' issue where without intervention it will not be managed and get worse with time. As such, jurisdictional co-operation is required for effective salinity management in the Basin and maximise the net benefits from salinity control.

For over 35 years, the jurisdictions have partnered to manage basin river salinity and there is a current collective agreement out to 2030. The Murray–Darling Basin (MDB) Agreement, the current Basin Salinity Management 2030 strategy and its predecessors the Basin Salinity Management Strategy 2000-2015 (BSMS) and the Salinity and Drainage Strategy have provided the policy framework under which jurisdictions have committed to shared and individual responsibilities and actions to address salinity impacts on the river. As a result, in-river salinity has been successfully managed by reducing the net amount of salt entering the river through both individual State and joint salinity management actions, including salt interception schemes.

To date, the management of salinity in the MDB is widely considered a success. The Independent Audit Group in 2019 found the Basin salinity management program to date to be “one of the best examples of a successful long- term natural resources management program in the world”[1]. However, they noted that salinity is an ongoing risk, and management and resources are required to maintain the program’s success.

The core concepts for the state agreement are summarised in **Figure 3**.

Figure 3: Core concept for State’s agreement

Source: Frontier Economics

Box 1: Basin Salinity Management 2030

The current guiding framework for salinity management in the Basin is the Basin Salinity Management 2030 Strategy (BSM2030 Strategy). This strategy takes a lighter hand to regulation than its predecessors and accounts for the changing landscape of Basin water management.

Key elements of the BSM2030 strategy include:

- Maintaining the cap and trade approach to Basin Salinity management
- Supporting the new Basin Plan including incorporating changes from increased environmental flows
- Exploring ways to better manage Salinity Interception Schemes (SISs) to adapt to different levels of river salinity
- Reducing the frequency of audit, reporting and reviews
- Investing in improving knowledge of future salinity risks
- Including a review point.

Source: Murray Darling Basin Ministerial Council (2015), Basin Salinity Management 2030 BSM2030, November 2015, https://www.mdba.gov.au/sites/default/files/pubs/D16-34851-basin_salinity_management_strategy_BSM2030.pdf

1 Wickes, R., Smith. G., Walker, G. (2020), Report of the Independent Audit Group for Salinity, July 2017-June 2019, p. 3

2.1.1 Basin salinity target

Schedule B of the Murray Darling Basin Agreement specifies the Basin Salinity Target to maintain the average daily salinity at Morgan at a simulated level of less than 800 EC for at least 95% of the time, modelled over the Benchmark Period[2] using current year levels of development.

The '95% of the time' element of the target recognises that at times river salinity will be high due to climatic conditions or other factors. That is, the target is to reduce duration of the peaks to just 5% of the time.[3]

The Basin Salinity Target was first met in 2010 due to a combination of management practices since 1988..[4]

At the time of setting the target, Morgan was used as the reference site as this matched the existing hydrological and salinity modelling. Morgan was chosen as the measurement site for the modelling as it was downstream of the large Woolpunda and Waikerie salt inflows and was the offtake for the Morgan-Whyalla pipeline. However, this site is upstream of the offtakes for Adelaide water supply at Mannum and Murray Bridge.[5]

The Benchmark Period is from May 1975 - April 2000. Use of a benchmark period allows for a consistent assessment of river salinity outcomes in a climatic scenario that has both wet and dry seasons.

To achieve the target and assess the feasibility of salinity management investments, the Basin Salinity Management Strategy introduced a cost function to underpin both the agreed salinity accounting framework and cost-benefit analyses of potential investments in salinity management.

2 The reference period covers the years 1975 to 2000.

3 Managing salinity in the MDB fact sheet

4 Hart et al (2020), Salinity Management in the Murray-Darling Basin

5 Close, A. (2014), Salinity Cost Functions, 26 November 2014, a presentation for the Murray Darling Basin Authority

Box 2: Salt interception schemes

Salt interception schemes (SISs) are critical to managing salinity impacts by diverting saline groundwater and drainage water before it enters the river. Following the high river salinity experienced during the 1970s and 1980s, the 1989 Salinity and Drainage Strategy introduced SISs to reduce river salinity by up to 80 EC. Schemes were introduced at Woolpunda, Waikerie and Mallee Cliffs, with improvements completed at Buronga and Mildura/Merbein.

The MDBA has cost sharing arrangements to allow for joint funding of SISs by four governments. For schemes with a shared salinity impact benefit the relevant state meets a share of all costs in proportion to the salinity benefit accruing to the state. The remaining Investigation and Construction costs are shared by the Commonwealth paying 25%, then the balance shared equally between NSW, Victoria and South Australia ,, and NSW Victoria and South Australia equally sharing operating and maintenance costs.

Source: Salinity and Drainage Strategy 1989 and Cost Shares Principles, MDBA July 2019.

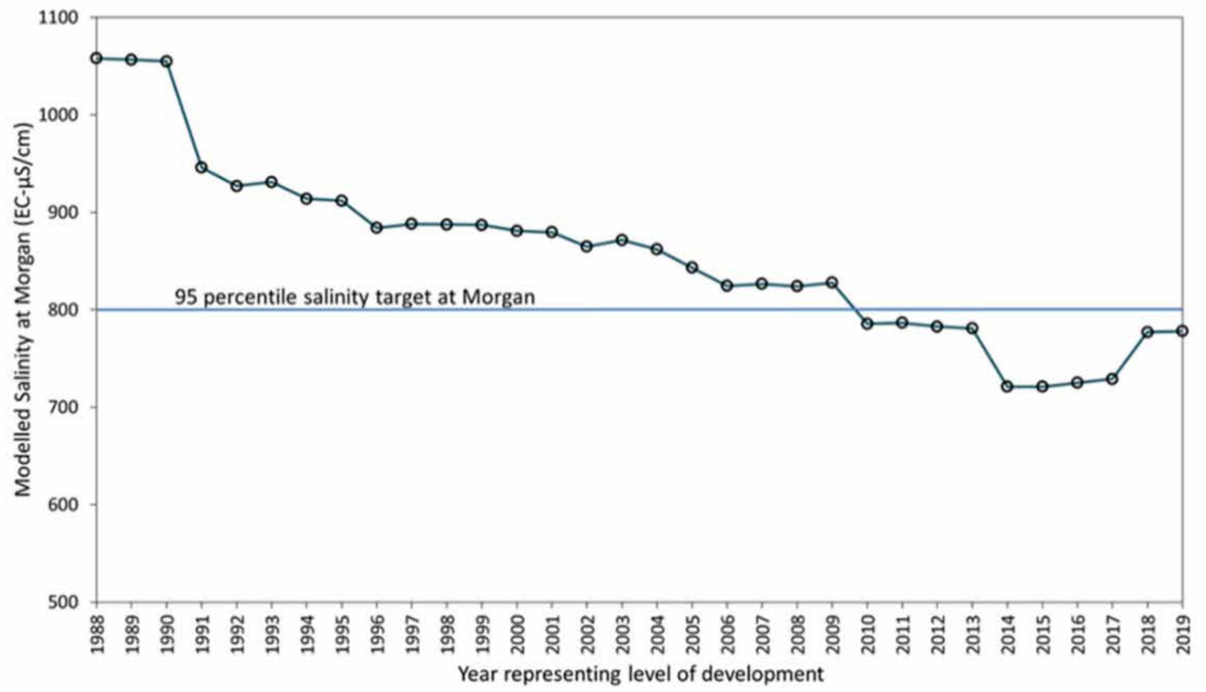
Performance against the target

Long-term salinity management has been successful in maintaining salinity levels at Morgan well below the 800 EC target. In 2018-19, it was modelled that with salinity management, 96% of the time, salinity levels were below 800EC at Morgan based on the benchmark period, compared to only 72% of the time in the absence of salinity management.[6]

On the basis of the modelling over the benchmark period, modelled EC over recent years has risen to 798 EC signalling an imminent breach of the target. However, this may not be accurate reflection of actual EC in the river as environmental water volumes recovered under both The Living Murray initiative and for Bridging the Gap under the Basin Plan are not able to be modelled by the version of the Bigmod model currently used to prepare the salinity registers and therefore the significant associated dilution benefits of these flows are not included. This is being addressed under the current transition to using the Source. Murray model for preparing the salinity registers. Recent register reviews are revising EC impacts down, not up.

6 MDBA (2020), Basin Salinity Management 2030 | 2018-19 Comprehensive report, Murray-Darling Basin Authority, Canberra, March 2020, p. 9

Figure 4: Modelled 95th percentile salinity over the 1975-2000 Benchmark Period at Morgan, given level of development



Source: Hart et al 2020.

2.2 Establishment of the Registers

As part of the long-term management of salinity and setting the salinity target, Registers were established to monitor and record salinity actions. The Registers underpin the management of river salinity. The BSM2030 strategy outlined that “one of the key elements for the success of salinity management in the Basin is the commitment of all jurisdictions to a strong salinity accountability framework implemented through the salinity registers”.[7]

Under Schedule B of the Murray-Darling Basin Agreement, each State maintains a Salinity Register, which together constitute the agreed salinity accounting framework. Actions that change river salinity are recorded as credits or debits on the registers. There are two registers – Register A and Register B:

- Register A records the impacts of each accountable action that occurred after the baseline date[8] (i.e. when states agreed to take action) and includes jointly funded works and measures

7 MDBA (2020), Basin Salinity Management 2030 | 2018-19 Comprehensive report, Murray-Darling Basin Authority, Canberra, March 2020

8 1988 for New South Wales, Victoria and South Australia, 2000 for Queensland and the Australian Capital Territory

- Register B accounts for delayed salinity impacts, which have an effect on salinity levels after 2000 but which are the result of actions taken before the respective baseline dates.[9]

Accountable actions[10] and delayed salinity impacts are recorded on the Registers as either a credit or a debit:

- A salinity credit is a reduction in average salinity costs as estimated by the MDBA, and
- A salinity debit is an increase in average salinity costs as estimated by the MDBA.

For example, actions such as irrigation development, which increase river salinity, result in a debit on the Salinity Register, whereas actions such as salt interception and improved irrigation efficiency, which decrease salinity impacts, result in credits on the Salinity Register.

The cost functions currently provide the basis for estimating salinity credits or debits ($millions/year) generated by the various actions of Basin governments and to record the credit/debits in the Salinity Registers. That is, the units of account for the registers reflect the 'economic cost' of salinity.

The Registers, as at February 2022, are included in Appendix 1.

2.2.1 Register requirements

The Registers are legislated under Schedule B and as such are subject to a number of requirements. These requirements centre around ensuring ongoing register stability and no net negative impacts on salinity in the river.

For example, Clause 16 (1) places strong obligations on State Contracting Governments to maintain non-negative impacts:

> *cl.16(1) A State Contracting Government* ***must take whatever action may be necessary****:*
>
> *(a) to keep the total of any salinity credits in excess of, or equal to, the total of any salinity debits, attributed to it in Register A; and*
>
> *(b) to keep the cumulative total of all salinity credits in excess of, or equal to, the cumulative total of all salinity debits, attributed to it in both Register A and Register B.*

Registers A and B balances are summed for an overall net credit balance for each state. States must maintain a summed net register (summing registers A and B) that is non-negative and also a register A balance that is non-negative.

This system is designed to incentivise future developments to be offset by necessary accredited measures such that the net impact is not negative[11]

Estimated salinity impacts are converted into estimated credits and debits using the Salinity cost functions (see further discussion below) and recorded on the Register.

9 MDBA (2020), Basin Salinity Management 2030 | 2018-19 Comprehensive report, Murray-Darling Basin Authority, Canberra, March 2020

10 Accountable actions are defined as those that cause a change in average daily salinity at Morgan of 0.1 EC or more by 2100

11 Basin Salinity Management 2030

Once recorded on the register, there is scope for the impact to be recalculated, if:

- The accountable action is reviewed or there is a delayed salinity impact
- The calculations are altered and the attribution of either or both salinity credits and debits changes
- The salinity cost effect is not reliable, then it must remove the salinity credit or debit and replace it with a provisional entry, and must use best efforts to make a reliable estimate as soon as practicable and amend the register.

Current register positions

Currently, the balance of Registers A and B shows NSW, Victoria and South Australia in a net credit position (see **Table 1**).

These positions are not taken for granted, with Victorian modelling showing that the state is nearing a debit soon. The salinity credits are expected to run out by 2080 for most jurisdictions.[12]

Table 1: Current register balances

Current	NSW	VIC	SA	Total
Register A	5.34	4.94	3.45	19.37
Register A+B	5.74	4.85	7.25	23.48

Source: MDBA

2.3 Salinity cost functions

Salinity cost functions are modelling tools that relate levels of river salinity to the economic impact of salinity (or its removal) on various river water users. The cost functions calculate the economic salinity cost effect ($ millions/year) of salinity on agricultural, household, commercial and industrial consumers and government instrumentalities.[13] Their main role today is to provide a ‘common currency’ or the basis for understanding the relative costs and benefits of various actions to manage salinity for the purpose of the register.

The current cost functions were adopted in 2005. They were developed based on studies conducted by GHD in 1999 and Allen Consulting Group in 2004 and were applied under the Basin Salinity Management Strategy.

When introduced, the salinity cost functions served three purposes:

- To inform decisions to invest in salt interception measures
- To enable the effects of locations of actions to be taken into account for the purpose of calculating no net negative impacts on the registers
- To enable salinity cost effects in the registers to be calculated.

[12] Independent audit review for salinity in MDB (2019)

[13] Murray-Darling Basin Authority (2014) General Review of Salinity Management in the Murray-Darling Basin, p 56.

The objective of the cost functions was to provide an economic measure of the changes to river salinity that would result from any particular action, work or measure, such as:

- salinity increases resulting from drainage works or development activities proposed somewhere along the river
- salinity reductions to be obtained by the implementation of a salt interception scheme
- adoption of best practice irrigation methods in a given area.

Under the BSMS, the cost functions were also applied to assess the economic viability of various works and measures (salt interception schemes) that were proposed to reduce river salinity.

The cost functions have proven most useful in providing a basis for understanding the relative cost-benefit impacts of accountable actions, particularly in the salt interception program to all water users throughout the River Murray system. The location of an action which causes an increase or decrease in river salinity is a key determinant of its economic impact. The further upstream an action occurs, depending on the base salinity level of the river at various river reaches, the greater the economic cost (from an increase) or benefit (from a decrease) per unit change in salinity.[14]

According to the 2014 general review:

> *"To date, the cost functions have been useful in providing the basis for understanding the relative cost benefit analysis of accountable actions, particularly in the salt interception program, enabling the costs and benefits to all water users to be assessed along the whole of the River Murray, rather than just the biophysical salinity effects as expressed in the salinity levels at Morgan (Newman and Sakadevan 2006). If only the modelled biophysical salinity impacts on Basin Salinity Target at Morgan were used for comparing between different options to manage river salinity, it would have put a greater emphasis on actions that prevent salt inflows closer to Morgan without considering the overall economic benefits of using better quality water by all users throughout the River Murray System. The location of the use is important relative to actions that cause an increase or decrease in river salinity. The further upstream an action occurs, depending on the base salinity level of the river at various river reaches, the greater the economic cost (from an increase) or benefit (from a decrease) per unit change in salinity."*

In summary, the salinity cost functions:

- Are an agreed metric for the salinity register.
- Are measured in 2005 dollars, and cost estimate based on Pre 2005 land areas and crop prices

[14] Murray-Darling Basin Authority (2014) General Review of Salinity Management in the Murray-Darling Basin, p 56.

- Produce average cost estimates for conditions observed in the 1975-2000 Benchmark period
- Calculate incremental costs from given actions based on context of previous actions (changing salt loads and rivers flows).

The Benchmark Period

As noted above, the salinity cost functions and Basin Salinity Target are based on the Benchmark Period – an agreed climatic period for hydraulic modelling. This period was chosen due to the high variability in water availability and good salinity data for that period, and not because it was expected to be representative of future conditions.

> *"As the Benchmark Period is the fundamental hydrological dataset underlying the modelling framework, progress against the Basin Salinity Target is highly sensitive to the selected period. Any investment plan aimed at delivering on the existing Basin Salinity Target needs to recognise that achievements against the target are only relevant for the corresponding Benchmark Period"*[15]

There is a difference between costs incurred to meet the Basin Salinity Target and State obligations under Schedule B[16], as compared to the benefits of changing salinity in the river (affecting water users, etc). This reflects the difference between modelled and observed salinity.

While actual in-river salinities have remained low in the last year or two, progress against the Basin Salinity Target is monitored through a modelling approach rather than through actual salinity measurement. The modelled value indicates the current and expected salinity impacts of Accountable Actions recorded on the Salinity Registers, utilising the existing Benchmark Period.

2.4 Concerns with the cost functions

There has been a long history of reviews of the cost function and salinity management (see **Figure 5**). The cost functions were reviewed in 2009 under the Basin Salinity Management Strategy 2001-2015. The reviewers proposed a range of methods to reassess salinity costs but found that in many cases the functions derived in 1983 were still the best available.

The 2014 General review of salinity management in the MDB found: "An important consideration for BSM2030 [Basin salinity management for the period 2015-2030] is to develop clear direction on the future role of the salinity cost effect ($ million per year) in managing accountabilities under the salinity registers."[17] This direction has yet to be established. The 2020 Report of the Independent Audit Group for Salinity 2017-2019 found: "The register framework including the cost functions needs to be reviewed. The cost functions are based on an economic assessment in

15 Mid-term review of BSMS

16 The Basin Plan also sets out a salt export objective — to ensure adequate flushing of salt from the River Murray System into the Southern Ocean — as well as salinity targets at five reporting sites.

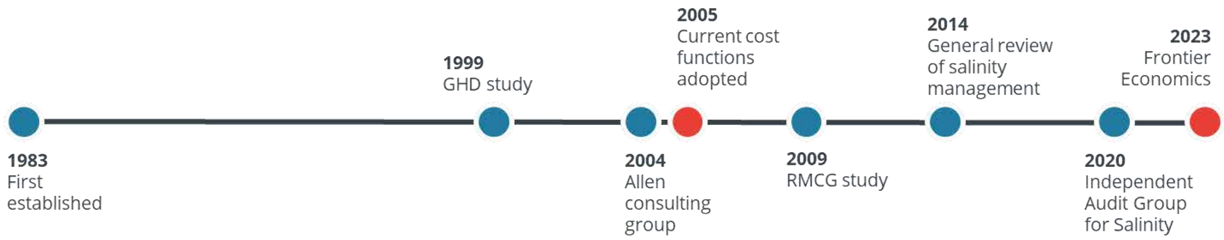
17 MDBA (2014), General review of salinity management in the Murray-Darling Basin, p. 57

2005, are out-of-date and do not provide a sense of the value of ensuring water is managed to below 800EC at Morgan."[18]

Recommendation 6: In the lead up to the 2026 review of the BSM2030 the following knowledge gaps be explored:
2) The economic impacts and opportunities provided to the basin industries and communities from salinity mitigation
3) Revisit the cost function framework of the salinity registers[19]

Further, the 2020 report stated, "The only economic information available is in the cost functions of the salinity registers and this is based on the economic modelling undertaken in 2004 and has not been updated. Consequently, the cost functions are not used anymore in promoting the program because they are 15 years old and industries and communities have changed significantly since then as has the value of a dollar."[20]

Figure 5: Previous reviews of the cost functions and salinity management



Source: Frontier Economics

Reviewing the cost functions against their original three purposes provides insights into the key concerns with the cost functions:

1. **Informing decisions to invest in salt interception measures:** while useful in the past, SISs are unlikely to be built in the future. Attention has focused on continuing expenditure on operating and maintaining existing SISs and communicating the benefits of ongoing salinity management.
2. **Enabling the effects of locations of actions to be taken into account:** the locational relativity is intuitive through the cost functions. The relative impact of salt going into and out of the river depends on the location of the action. All else equal, the relative impact increases the further upstream salt would have entered the river. However, the current cost functions have not been updated to account for the growth in horticulture in the lower Murray which may change the relative impacts.
3. **Enabling salinity cost effects in the registers to be calculated:** the registers have been essential to cooperative salinity management and accountability. There is a question as to whether calculating the monetised 'cost' effect of salinity rather than the quantitative EC

[18] Wickes, R., et al (2020), Report of the Independent Audit Group for Salinity, July 2017-June 2019, p. 3

[19] Wickes, R., et al (2020), Report of the Independent Audit Group for Salinity, July 2017-June 2019, Recommendation 6, p. 20

[20] Wickes, R., et al (2020), Report of the Independent Audit Group for Salinity, July 2017-June 2019, p. 20

impact is required for this accountability. Additionally, the current economic cost of salinity is no longer represented by the cost functions.

Salinity management has changed significantly since 2005, meaning that some of the original purposes of the cost functions are less important, and there are new or revised purposes that should be addressed – namely, accountability between states and communicating the benefits of ongoing salinity management.

3 Key assumptions underpinning cost functions

Key findings:

- The salinity cost function is evaluated over modelled hydrological conditions over the period 1975-2000. This provides the daily/monthly/annual estimated salinity level (EC) in each of the 22 river reaches.
- The salinity cost effect on agricultural water users is based on a 'bent stick' model of crop response to salinity, and applied using data assumptions such as irrigated crop areas, crop yields, crop prices, and crop harvesting costs. The salinity level affecting crops is based on the modelled salinity in the months in which they are irrigated, as a weighted average based on the irrigation requirement in each month.
- The salinity cost on urban household/domestic water use is based on the assumed cost of salinity impacts on Household plumbing fixtures, Hot water systems and the use of Water softeners. For commercial and industrial water users the salinity cost is based on the assumed cost of salinity impacts on General Commercial Industrial water use, Process Water, Cooling Towers and Boilers. For these types of uses the salinity level affecting use types depends on the resultant salinity level from mixing Murray water and other sources. Outside of reach 20 (which has offtakes to Adelaide), water use is assumed to be 100% Murray water. For reach 20, water use is a mix of Murray water and other sources (with an assumed level of 610EC), and the proportion depends on seasonal conditions.

The salinity management framework is regarded as having a "strong technical underpinning, including modelling river salinity and modelling the impacts of all actions on the register".[21]

The Workshop in Stage 1 with the MDBA and States identified a need to systematically document the inputs and assumptions underpinning the cost functions. This section of our report performs this role.

The model structure is set out in **Figure 6**, and identifies:

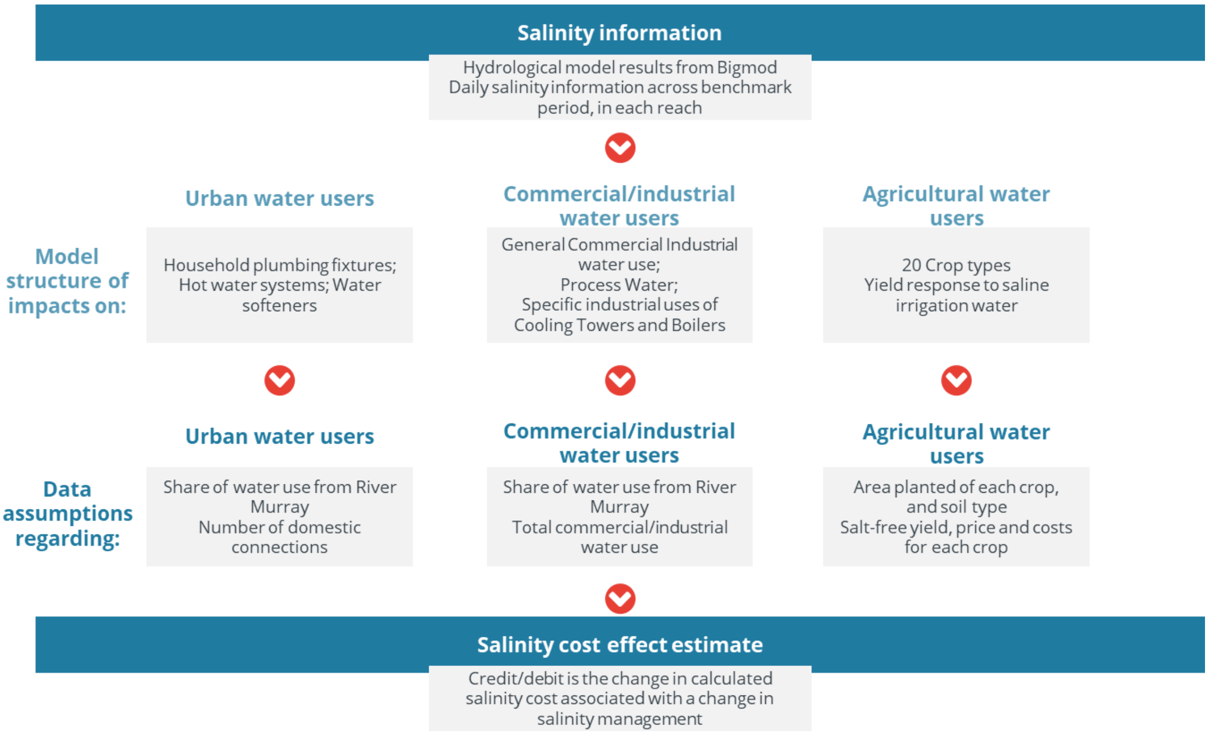
- the reliance on salinity information that comes into the salinity cost model.
- the model structure that identifies types of salinity impacts on water uses and uses formula from the literature to calculate impact relationships (such as reductions to agricultural yield).

[21] Hart et al (2020), Salinity Management in the Murray-Darling Basin

- the data assumptions in the model that determine how much water use is affected under each type of impact (such as through number of households, areas of irrigated crops and volumes of water use) and the data on the costs of these impacts (such as prices of forgone yield).
- The culmination of these calculations to generate the salinity cost effect, which serves as the measure of salinity impacts, and the change in salinity cost effect associated with an accountable action that is recorded as a credit or debit on the salinity register.

The elements are discussed in the sections below.

Figure 6: Salinity cost function model structure and assumptions



Source: Frontier Economics

3.1 Salinity information

The salinity cost function is evaluated over modelled hydrological conditions over the period 1975-2000, using the hydrological model Bigmod.[22] The hydrological model is run by incrementally adding each of the accountable actions, providing the consequent salinity estimates.

Bigmod provides the daily/monthly/annual estimated salinity level (EC) in each of the 22 river reaches (**Table 2**). The modelled salinity level at Morgan (in reach 19, between Lock 2 and Lock 1) is reported as a headline indicator of Murray river salinity.

22 Close, A. 1996, A new daily model of flow and solute transport in the River Murray, In *proceedings of the 23rd Hydrology and water resources symposium*, Hobart, Australia, 21-24 May, 173-178.

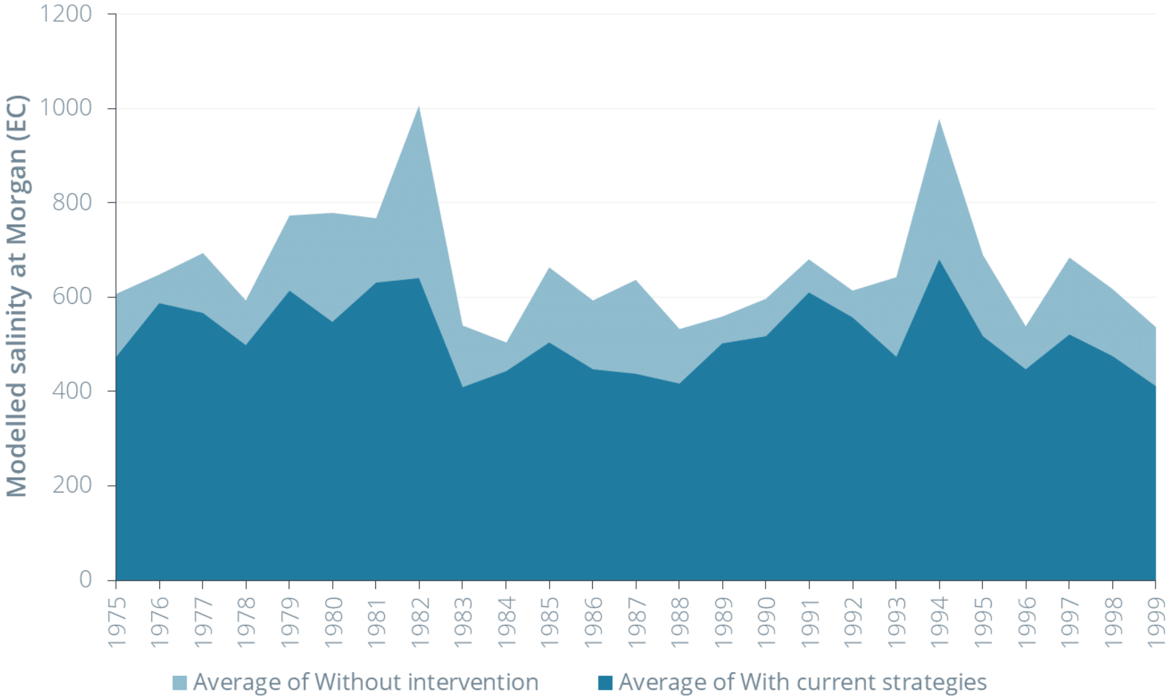
Table 2: River reaches

Reach no.	River Reach description
1	Albury – Yarrawonga
2	Yarrawonga – Torrumbarry
3	Yarrawonga Main Channel
4	Edward – Wakool System (excluding Wakool Channel)
5	Mulwala Canal
6	Wakool Canal
7	Torrumbarry – Wakool
8	National Channel
9	Wakool to Wentworth (excluding Merbein, Red Cliffs, FMID, Coomealla and Curlwaa)
10	FMID, Merbein and Red Cliffs
11	Wentworth – Rufus River
12	Coomealla and Curlwaa
13	Menindee – Wentworth
14	Darling Anabranch
15	Rufus – Lock 5
16	Lock 5 – Lock 4
17	Lock 4 – Lock 3
18	Lock 3 – Lock 2
19	Lock 2 – Lock 1
20	Lock 1 – Murray Bridge
21	Murray Bridge – Wellington
22	Wellington – Barrages

Source: MDBA

Figure 7 presents the annual average salinity at Morgan as estimated with and without the full set of accountable actions. The base level of salinity, without salinity management interventions, varies from year to year in the benchmark period (shown in light blue in **Figure 7**). The salinity management actions reduce the modelled level of salinity in all years, by differing amounts (shown in dark blue in **Figure 7**).

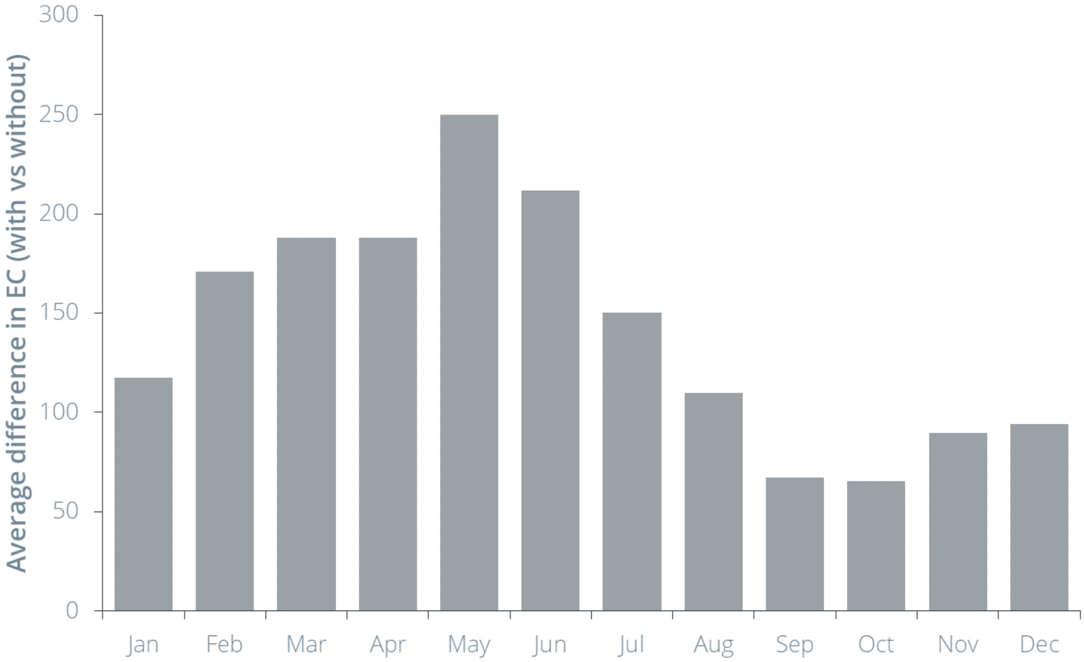
Figure 7: Modelled salinity levels during the Benchmark Period, with/without 2022 strategies



Source: Frontier Economics analysis of data provided by the MDBA.

The modelled differences in salinity not only changes between years but also changes by time of year (**Figure 8**).

Figure 8: With/without difference in salinity levels during the Benchmark Period, monthly



Source: Frontier Economics analysis of data provided by the MDBA

The disaggregated data for the change in salinity by reach was not available at the time of writing. However, it would be expected that the difference in modelled salinity levels (with and without current salinity actions) generally increases in downstream reaches because an increasing number of salinity actions affect the lower reaches. It should also be noted that the level of salinity can also vary significantly between reaches, based on local groundwater conditions.

The salinity cost function relies on salinity estimates in each of the reaches, as they are relevant to the water users drawing from those sources.

3.2 Agricultural water users

3.2.1 Origin of the salinity cost quantification

In 1999, GHD conducted a Salinity Impact Study for the (then) Murray-Darling Basin Commission. This proposed the use of agricultural salinity/loss relationships, developed by the Institute of Sustainable Irrigated Agriculture and the Loxton Centre.

The basic form adopted for the relationship between salinity and yield was the 'bent stick' model developed by the United States Department of Agriculture (USDA) Salinity Laboratory (Maas and Hoffman 1977).[23] This relationship assumes no yield reduction up to a threshold level of soil water salinity, and a straight line reduction in yield with increasing salinity above the threshold. Assumptions were also required to convert soil salinity to river salinity, which involved selecting a leaching fraction which in turn is dependent on soil type.

The recommendations from the GHD report for agriculture have remained part of the salinity cost function since 2005.

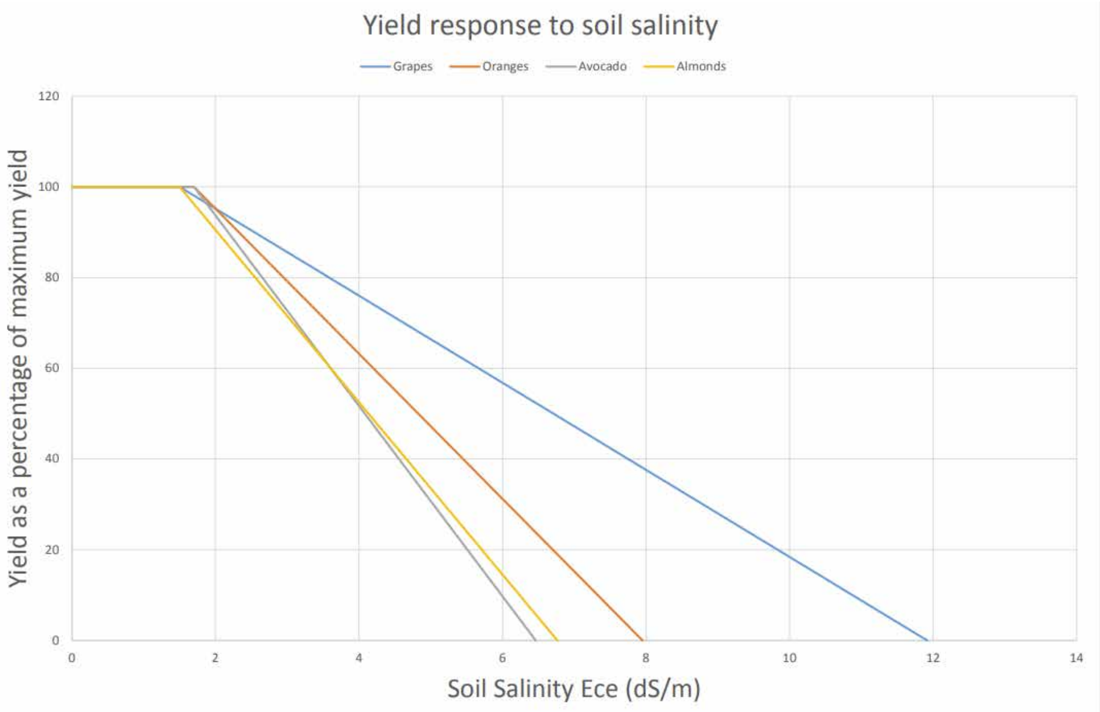
3.2.2 Model structure

The model structure is underpinned by the 'bent stick' relationships for crop yield response, as shown in **Figure 9**. The relationship between salinity and yield differs between crops based on their relative salt tolerance.

To determine the average salinity of water diverted to each crop, in each of 22 reaches, assumptions are made on the monthly diversions required for each crop (**Figure 10**) and these are applied to the reach salinity outputs of the hydrological model. The monthly diversions are assumed to be same for the same crops in various reaches. Average annual salinities are assumed to be appropriate given buffering of salt in the soil.

23 Maas, E. V., and Hoffman, G. J. 1977, 'Crop salt tolerance - current assessment'. *A.S.C.E. J. Irrig. Drain. Div.* 103:115-134.

Figure 9: Agricultural Yields – Bent Stick plots



Source: GHD 2009, based on Maas and Hoffman 1977.

Figure 10: Water use – profile across the months

Source: GHD 2009, based on: Crop factors from Water Requirements for Horticultural Crops, Technical Report No. 263, 1998, Primary Industries and Resources, SA and 2. Crop Factors from FAO irrigation and drainage paper no. 24 - Doorenbos, J. and W.O Pruitt (1977) Crop water requirements.

In addition to the annual salinity model from the USDA, GHD proposed that there were long-term salinity costs associated with the build-up of salinity in woody crops that would not have been measured by USDA (who only tested seedlings). To address this omission, GHD increases the slope of the 'bent stick' to allow for these long-term effects — using a scaling factor of 2 for grapes and 4 for fruit trees. These long-term effects are included in the current salinity cost function.

These crop responses are applied to assumptions regarding average yield and an average value of the crop at the farm gate, and marginal harvest costs.

3.2.3 Current assumptions

The current crop assumptions in the salinity cost function are based on crop land use data collated by GHD (1999). The data were sourced on the basis of five broad geographical areas which encompass the 22 river reaches. These areas are Riverina (Hume Dam to Wakool Junction, NSW), Northern Victoria (Hume Dam to Wakool Junction, Victoria), Lower Murray (Wakool Junction to SA border, NSW), Sunraysia (Wakool Junction to SA border, Victoria), and South Australia (SA border to the barrages).

GHD could not identify data sources that closely mapped to the 22 reaches. Of the data that were available, they were not available for a common time period, but generally ranged over the period 1994 to 1999. Sources included:

- Grower surveys in 1995/96 and 1996/97
- Land and Water Management Plans (LWMPs)
- Goulburn-Murray Water crop census
- Agricultural Resources Study (January 1998) (survey based) of crop type/irrigation system/soils data for Lower Murray NSW
- Sunraysia Irrigated Culture Survey, 1991/92
- Extensive discussions with State departments and regional experts.

GHD derived assumptions for crop prices and farm costs based on the following sources:

- NSW Agriculture's Farm Budget Handbooks.
- Department of Natural Resources and Environment, Victoria.
- Department of Primary Industries, Queensland Farm Note for Avocados

The values used are presented in following tables in Appendix 2:

- Areas and yield— **Table 16**
- Price and costs — **Table 17**
- Soil responses — **Table 18**
- Foliar responses when overhead spray is the irrigation method — **Table 19**.

3.3 Urban and commercial/industrial water users

The current model calculates salinity costs and identifies that excessive salinity would impose large costs on urban and commercial/industrial water users who rely on water drawn from the Murray, including offtakes to the Adelaide water supply at Mannum and Murray Bridge.

3.3.1 Origin of the salinity cost quantification

The origin of the cost functions are from work by Dwyer Leslie (1983)[24] and prior reports. With respect to Adelaide, major identified salinity-related costs were:

- **Urban** (Corrosion, water heaters, soap use and water softening) and
- **Industrial** (Water treatment, scaling of plant, more frequent replacement of treatment water).

The estimated salinity costs for Adelaide took into account the percentage of the supply that came from the local catchment. This implied a higher weighting for those years when 80% of the supply came from the Murray and lower weightings for years when the percentage was much less.

In 1999, GHD found that in many cases the salinity cost functions derived in 1983 were still the best available (GHD's suggested changes related mostly to agricultural water use). One exception was that a survey of soap use in Adelaide, Melbourne and Sydney which revealed that soap use was no higher in Adelaide than other cities. As a consequence the function for soap costs was removed.

In 2004, the Allen Consulting Group were engaged to review the municipal and industrial costs, making a number of recommendations for modifying these cost functions. The recommendations from the GHD report, as amended by the Allen Consulting Group were adopted for use in the Basin Salinity Management Strategy — and have remained since 2005.

3.3.2 Model structure

The model structure comprises of sets of salinity impact equations for domestic water users (**Table 3**), general industrial water users (**Table 4**), and specific industrial water users (**Table 5**). In the salinity cost equations below, T = measure of salinity in mg/L TDS (Total Dissolved Solids). TDS is calculated at 0.6 times the measured salinity in EC. Also note that the cost estimates are in 2005 dollars.

[24] Dwyer Leslie Pty Ltd (1983). 'The economic impacts of salinised water supply'. Saltcost. River Murray Water Quality Management Group. Revision A, Aug. 1983.

Table 3: Salinity costs to domestic water users

Domestic costs Item	Salinity cost ($/household/year)
Household plumbing fixtures	0.9160 T - 2
Hot water	0.0544 T + 136
Domestic filters and rain water tanks	0
Water softeners	0.0998 T + 0.8
Total Domestic costs	0.02458 T + 135

Source: Allen 2004

Table 4: Salinity costs to general industrial water users

General Industrial	Salinity cost ($/kL/year)
General Commercial Industrial water use	0.00063 T + 35
Process Water	0.00320 T

Note: Volume of each type of water use is an assumed proportion of total industrial water use.
Source: Allen 2004

Table 5: Salinity costs to specific industrial water users

Specific Industrial	Salinity cost ($/year)
Cooling Towers	3,983,000 $e^{0.0011 \cdot T}$
Boilers	3,198,300 ln T + 1,110,600

Source: Allen 2004

3.3.3 Current assumptions for key parameters

The current assumptions in the salinity cost function relating to key parameters such as the proportion of water sourced from the Murray, and volumes and types of water uses differ between those for Adelaide water supply drawing from reach 20, and other reaches (**Table 6**).

Table 6: Urban/Commercial assumptions

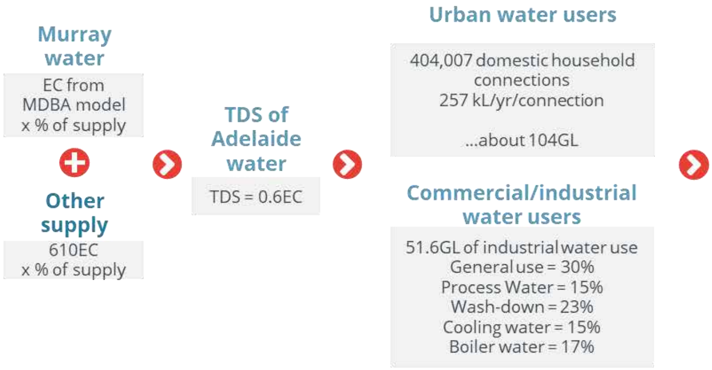
Assumption	Adelaide water supply drawing from reach 20	All other reaches
Percentage of total water from River Murray	Ranges from 26.77% to 85.41% depending on the year in the benchmark period (1975-2000) EC for non-Murray supplies is 610EC	100% of water is assumed to be from the Murray source
Domestic Connections	404,007 connections	Specified by reach, totalling 97,291 connections
Industrial Water Use	51,620 ML/year	Specified by reach, totalling 9,608 ML/year
Mix of industrial water use types	General use: 30% Wash-down: 23% Cooling water: 15% Boiler water: 17% Process water: 15%	General use: 40% Wash-down: 45% Cooling water: 3% Boiler water: 2% Process water: 10%

Source: GHD 1999 (Gutteridge Haskins and Davey Pty Ltd (1999). Salinity Impact Study. Report to Murray Darling Basin Commission, Tables 7.1 and 8.6.) as presented in Allen Consulting 2004.

The application of assumptions to Adelaide (urban/commercial water use in reach 20) is set out in **Figure 11**. This shows that the estimated benefit of salinity mitigation varies from year to year based primarily on the change in salinity level and the proportion of water sourced from the Murray. For example,

- under 1975 conditions the share of Murray water use was 28% of Adelaide's supply and salinity management was modelled to have led to a reduction in salinity from 606EC to 471EC. This provides an estimated benefit to urban/commercial water users of $5.6 million in a year.
- Under 1982 conditions the share of Murray water use was larger (at 81%) and the salinity change attributable to salinity management was larger (from 1006EC to 641EC). This provides an estimated benefit to urban/commercial water users of $43.1 million in a year.

Figure 11: Estimated benefits to urban/commercial water users



Difference in salinity costs ($m/yr) adjusted for inflation		
	1975	1982
Household plumbing fixtures	1.4	10.5
Hot water	0.8	6.2
Domestic filters and rain water tanks	-	-
Water softeners	1.5	11.4
General Comm/Industrial water use	0.4	2.8
Process Water	1.1	8.3
Cooling Towers	0.2	2.1
Boilers	0.3	1.9
Total	**5.6**	**43.1**

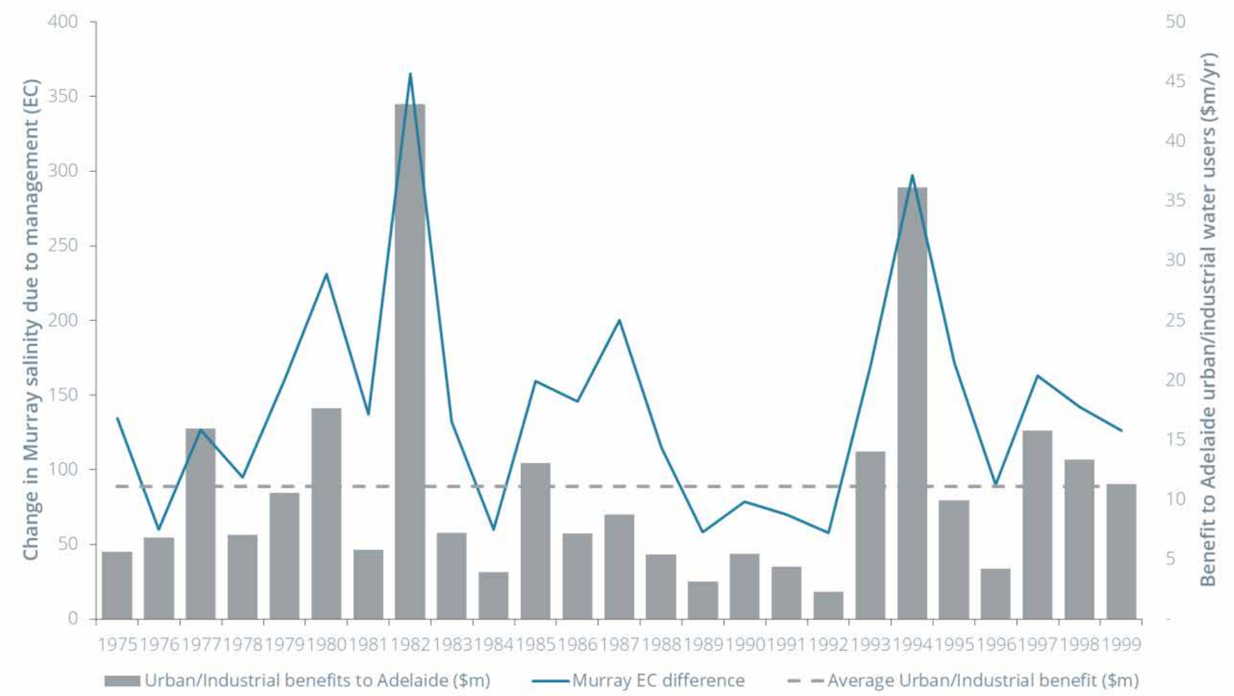
606→471EC
28% of supply

1006→641EC
81% of supply

Source: Frontier Economics analysis.

Over the benchmark period of 1975-2000, **Figure 12** evaluates the estimated benefits of salinity management for each year for Adelaide. The benefits are highly variable (as are the salinity differences from intervention, recall **Figure 7**), and average $11 million/year.

Figure 12: Salinity management benefits to Adelaide urban/commercial water users, 1975-2000 conditions



Source: Frontier Economics analysis.

4 Assessment of model structure and assumptions

Key findings:

- The use of the benchmark period 1975-2000 is accepted for the purposes of salinity accountability. However these conditions are not representative of current or future conditions, and this limits the use of salinity cost function results for benefit assessment. For example, the benchmark period has two years in which the salinity difference attributable to salinity management is greater than 240EC, while the period 2000-2020 has six such years.
- The 'bent stick' model of crop response remains suitable, but the assumptions for crop areas, prices, etc that the response function is applied to are not up-to-date. Changing the crop areas to account for observed horticultural development since 2005 does not significantly change the salinity register balances of the States. This means that while the salinity cost function may remain acceptable for the purposes of salinity accountability, updated data would need to be used to provide values which were appropriate for the purposes of benefit assessment.
- The urban /commercial model structure remain suitable if the inputs are updated for inflation, but the assumptions regarding number of connections and water use — particularly for the Adelaide region — are not up-to-date. Again, while the salinity cost function may remain acceptable for the purposes of salinity accountability, updated data would need to be used to provide values which were appropriate for the purposes of benefit assessment.
- Although the salinity cost function incorporates many direct salinity impacts on water users, the underlying assumptions are not based on the best available knowledge.
- Overall, the current salinity cost function does not reflect the benefits attributable to current salinity management and therefore does not meet the needs of the States and the MDBA for a measure of the current benefits of salinity management and associated investments for the purposes of contemporary investment evaluation.

This section provides an assessment of model structure and assumptions for the salinity cost function framework. This builds on the documentation of the assumptions/inputs in the previous section, and considers how/if each input should be changed and what is needed to change the input. The intent is to identify what the *significant* changes may be, as part of updating the cost function (when it is agreed to do so) and therefore assist in understanding how achievable they are.

On this basis, this section provides an assessment of the suitability of the model structure and assumptions of the salinity cost function framework for two contemporary purposes:

- for salinity management register function, and

- for demonstrating (quantitatively or otherwise) the benefits of salinity management.

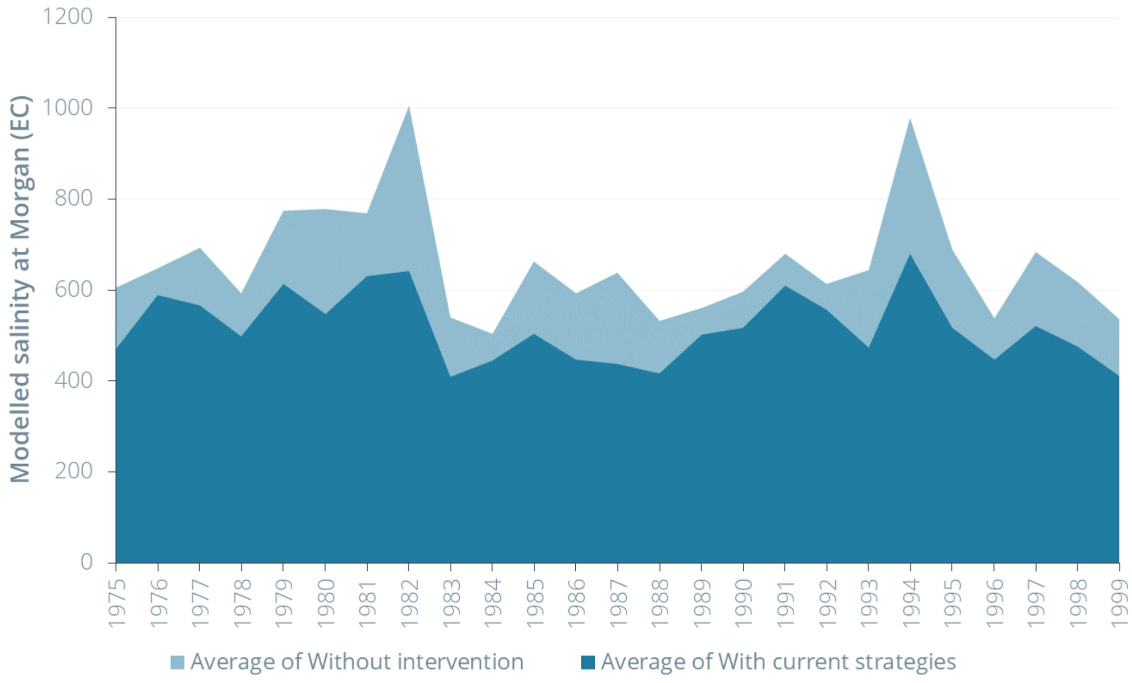
The sections follow the structure from above, namely consideration of salinity modelling, agriculture, and urban/commercial. It also considers other potential inclusions and gaps to be considered in more detail in the following section.

4.1 Salinity modelling

The current salinity cost function is applied over a Benchmark period (1975-2000) for hydrological modelling of salinity impacts, which involves two years in which salinity peaks were observed and in which salinity management is particularly beneficial.

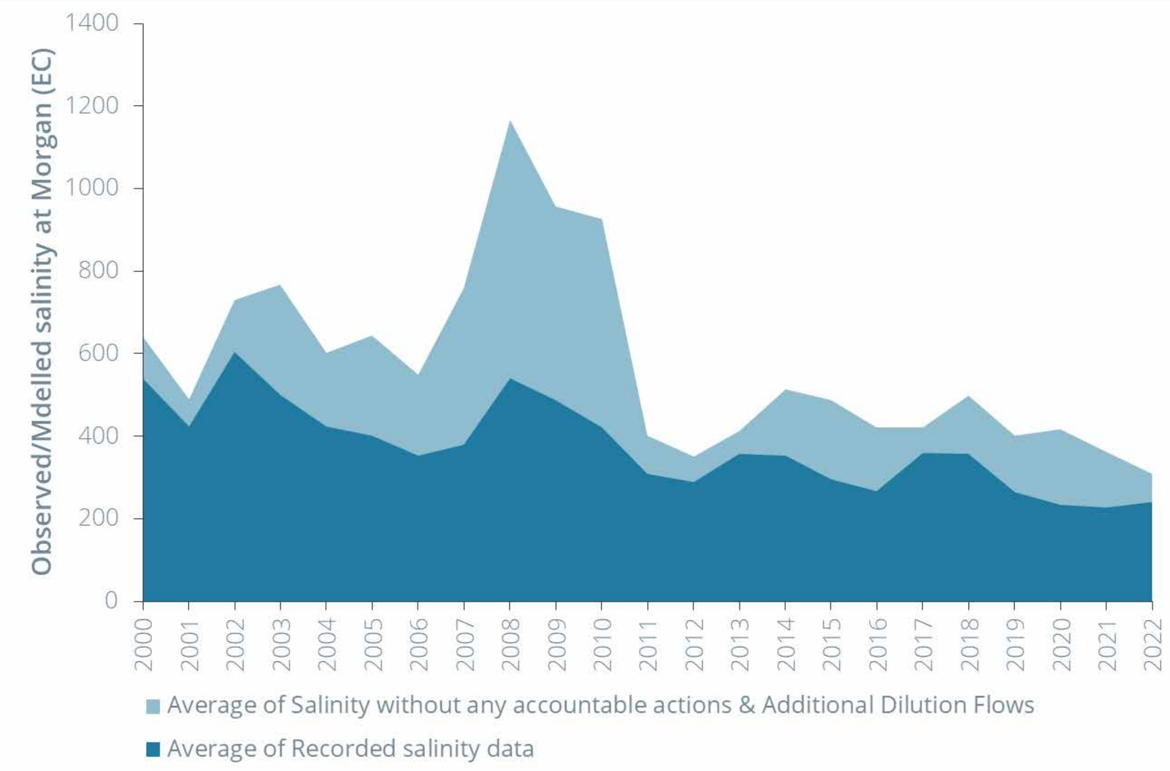
However, these conditions are not representative of current or future conditions, for example the period 2000-2022 involves six years in which salinity management led to large reductions in salinity (>240EC difference). **Figure 13** and **Figure 14** show salinity differences in 1975-2000 and 2000-2022 respectively, and **Figure 15** compares then in an ordered manner — it should be noted that the difference in 2000-2022 would be larger if the modelled salinity given current strategies was considered, rather than observed salinity (this data was not available within the timelines of this review).

Figure 13: Salinity differences 1975-2000



Source: Frontier Economics analysis of MDBA data

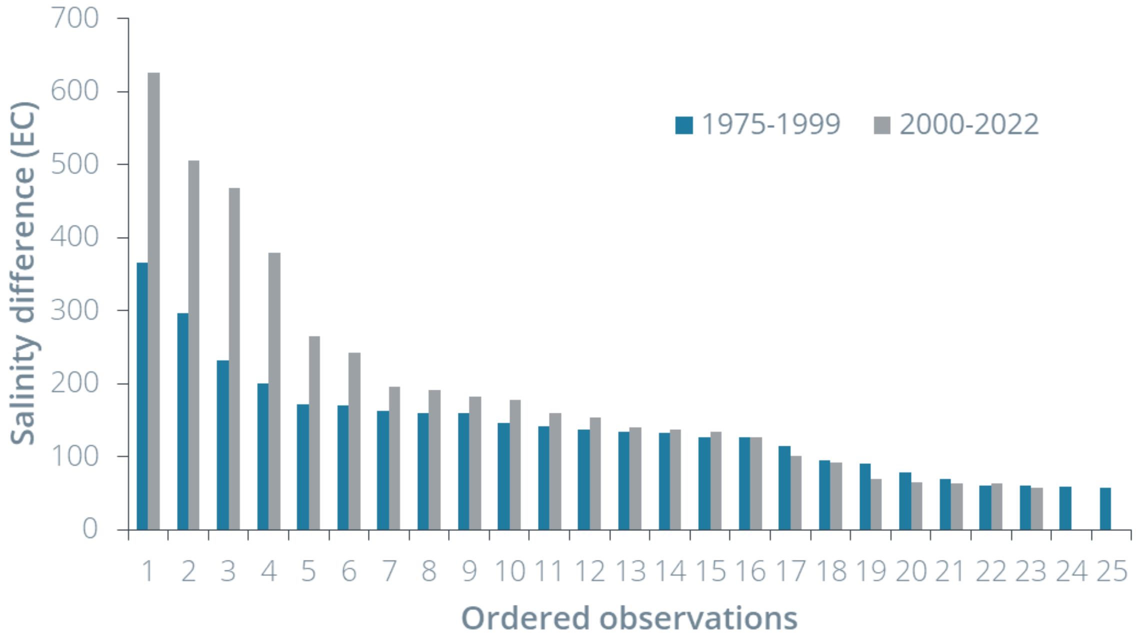
Figure 14: Salinity differences 2000-2022*



*Note: * 2000-2022 data is 'observed' rather than 'modelled with current strategies'.*

Source: Frontier Economics analysis of MDBA data

Figure 15: Ordered series of salinity differences 1975-2000 and 2000-2022



Source: Frontier Economics analysis of MDBA data

Differences in the modelled salinity outcomes between the benchmark and actual time period does not limit the use of the salinity cost function for managing State accountability for salinity management under the BSM2030 — if all parties continue to agree on the use of the benchmark period.

The use of the benchmark period 1975-2000 does however limit the use of salinity cost function results for robust benefit assessment — and may underestimate the benefits of salinity intervention given that 'high benefit' years have occurred more often in the most recent period as compared to the benchmark period.

This suggests that there is value in extending the modelling period to the current time in order to capture the full knowledge of and experience with salinity management impacts. We would also expect that, given the longer time series, the results would not be overly volatile to the incorporation of additional years of data. This is a question for MDBA modellers, as to the viability of a change to the modelling period. We note that the use of a 1975-current time period is consistent with contemporary approaches to resource assessment, such as Victorian guidelines for assessing water availability[25], which use a post-1975 historic climate reference period.

4.2 Agricultural water users

The source of the original 'bent-stick' model structure for agricultural impacts (Maas and Hoffman 1977) is a seminal paper which is still regularly cited (at the time of writing, nearly 5500 citations). As Zorb et al explain, the 'bent-stick' relationship, whereby crop yield is reduced if soil salinity surpasses crop-specific thresholds, is still considered sound:

> The inhibition of biochemical or physiological processes cause imbalance in metabolism and cell signalling and enhance the production of reactive oxygen species interfering with cell redox and energy state. Plant development and root patterning is disturbed, and this response depends on redox and reactive oxygen species signalling, calcium and plant hormones.[26]

This suggests the suitability of using the bent-stick model structure going forward. Further, in 2009, RMCG undertook a review of the salinity function and recommended to keep using the Maas and Hoffman relationship in the model.

RMCG did, however, note that there were opportunities to update and simplify the model by:

- Regular updating estimates of crop area, yield and return data.
- Simplifying crop and soil types and make more use of FAO standards (such as aggregate the four citrus crops to a single line item).
- Removing the long-term salinity impact factors.

The recent release by SunRise (in August 2022) provides the most recent data on crop areas in regions most affected by Murray salinity. It presents irrigated crop area data for the Lower

[25] DELWP 2020, Guidelines for Assessing the Impact of Climate Change on Water Availability in Victoria, November.

[26] Zörb, C. , Geilfus, C.-M. and Dietz K.-J. 2019, 'Salinity and crop yield', *Plant Biology*, Volume21, IssueS1, p.31-38, January.

Murray-Darling 2003 to 2021 and includes analysis of the Edward/Kolety and Wakool river system.

SunRise (2022) also quantifies the significant horticultural development that has occurred in the lower Murray (across NSW, Victorian and SA) in the past twenty years. The differences between this data and the cost function assumptions (in the relevant reaches) are presented in **Table 7**. The distribution of the increased crops areas of grapes, almonds and olives, by State, are set out in **Table 8**. It is also noteworthy that olives is a crop that is not represented in the current cost function.

Table 7: Most recent available data on crop areas (ha)

	Cost Function (<2005)	SunRise 2003 data	SunRise 2021 data	Change from assumptions to current
Grapes	43,012	65,930	59,700	Significant increase
Almonds	4,033	7,635	46,260	Significant increase
Citrus	15,500	13,985	14,250	Not significantly different
Seasonal field crop / Annual pasture	96,524	62,815	14,005	Significant decrease, although highly variable
Stone fruit: Peach & Plum	3,098	4,250	3,445	Not significantly different
Vegetables: Carrot, Onion, Potato, Pumpkin	17,573	13,610	14,080	Not significantly different, and variable
Olives	0	1,615	4,505	Significant increase

Note: 1000 hectares is used as a broad measure of whether a change in area is 'significant'.

Source: Frontier Economics analysis and SunRise 2022.

Table 8: Changes in grape, almond and olive crop areas (ha), cost function to current

	Cost Function (<2005)	SunRise 2003 data	SunRise 2021 data	Change from assumptions to current
SA Grapes	15,351	30,620	28,520	+13,169
VIC Grapes	22,501	26,340	21,520	not significantly different
NSW Grapes	6,291	8,970	9,660	+3,369
SA Almonds	2,755	3,150	11,440	+8,685
VIC Almonds	1,278	4,155	26,405	+25,127
NSW Almonds	0	25	7,300	+7,300
SA Olives	0	840	735	not significantly different
VIC Olives	0	755	3,745	+3,745
NSW Olives	0	20	25	not significantly different

Source: Frontier Economics analysis and SunRise 2022.

Crop prices have similarly changed in the past twenty years. Given they are commodities the prices are somewhat volatile. Many agricultural commodity prices have increased significantly, through general inflation and food commodity price movements. Almond prices are a notable exception. **Table 9** compares the assumed price in the cost function to the most recently available ABS data on commodity prices from the 2021 Agricultural Census.

Table 9: Comparison of price assumptions

Selected crops	Price in cost function ($/t)	2021 ABS data ($/t)
Grape	448	2771 (Non-wine grapes)
Orange	200	1477
Rice	195	412
Wheat	140	309
Almonds	5500	4893
Hay	66 (Annual pasture) 96 (Perennial pasture)	197

Source: ABS Value of Agricultural Commodities Produced, Australia, 2020-21; ABS Agricultural Commodities, Australia–2020-21.

Discussions with horticultural experts also identified that the way in which water is used on horticultural crops has changed significantly in the past twenty years. Salt tolerant rootstocks are now used in areas where salinity costs are significant, and overhead sprays (foliar application) is limited with irrigation under canopy. Both of these innovations will tend to reduce the impact of salinity on crop yield. However, another observed change - the use of misting to cool plants during hot conditions - may exacerbate the impacts as it potentially directs saline water on to the salt sensitive foliage.

Modelling was undertaken to assess the impact of the identified changes in crop areas on salinity cost function results. Working collaboratively with the MDBA, this modelling considered how register entries may change with a change in the cost function parameters from increased in horticultural development in the lower Murray. It became apparent that it was not feasible to recalculate all the salinity register entries — given it was estimated that doing so would require applying the cost function to over 300 BigMod output files.[27] Instead, 20 salinity actions were examined and these are presented in **Table 10**. These actions were chosen due to their relatively large impact on the register, location spread, and a mix of credits and debits.

For convenience and ease of assessment, a $/EC index measure is provided that has been indexed such that salinity change at Morgan represents an index of about “1”. Actions will generally have a higher $/EC index if they occur further upstream.

[27] The overall impact on the salinity cost effect of all register entries could be estimated by reprocessing (both with and without the revised cropland and urban input files) the costs for the first and last model runs on the Register and taking the difference. It was noted that this would be slightly incorrect as there are a number of intermediate runs that are not accountable (i.e. their impact is not added to the Register).

Table 10: Register items: for revised calculation of salinity cost effect

	Register item	$m	EC (2015)	Index of $m/EC*
1	Waikerie Lock 2 SIS	0.42	-6.13	1.0
2	Woolpunda SIS	3.94	-43.46	1.4
3	Loxton SIS	0.69	-5.76	1.9
4	Bookpurnong SIS	0.51	-4.36	1.8
5	Pike Stage 1 SIS	0.46	-2.96	2.4
6	Murtho SIS	1.04	-5.75	2.8
7	MM SIS Refurbishment 2015	0.18	-0.86	3.2
8	Improved Buronga SIS	0.16	-0.71	3.5
9	Mallee Cliffs SIS	1.50	-4.88	4.7
10	Upper Darling SIS	1.47	-4.56	5.0
11	New Operating Rules for Barr Creek Pumps	1.21	-4.95	3.7
12	Pyramid Ck GIS	0.82	-3.52	3.6
13	SA Improved Irrigation Efficiency and Scheme Rehabilitation Reg A	3.68	-27.49	2.1
14	Qualco Sunlands GWCS	0.36	-5.19	1.1
15	RISI NSW	0.85	-3.94	3.3
16	NSW MIL LWMP's	0.68	-4.04	2.6
17	Nyah to SA Border SMP - Irrigation Development	-4.02	17.56	3.5
18	SA Irrigation Development Based on Footprint Data	-1.03	10.57	1.5
19	Shepparton Irrigation Region Land and Water Management Plan	-1.05	5.38	3.0
20	NSW Sunraysia Irrigation Development 1997 to 2006	-0.19	0.87	3.4

*Note: Data from MDBA custom model runs rather than salinity register, so as to be consistent with analysis below. * Based on -$0.065/EC having a value of 1.*

Source: Frontier Economics analysis of custom MDBA model results.

The changes to the salinity cost function were not intended to fully represent the change from the historical values to current knowledge on all aspects of the cost function. Rather, the modelling focussed on a single highly significant change (namely increased horticultural crop areas) that is expected to alter the relative impact of salinity costs. This is because there are significant entries in the register associated with actions both up- and down-river of the location of the large areas of horticultural redevelopment.

The changes in models assumptions adopted were the crop area changes from **Table 8**. To model these changed crop areas, it was assumed that all existing grapes had been reconfigured to salt-tolerant rootstocks and were using under-canopy irrigation. New grapes areas were based on salt-tolerant rootstocks and were using under-canopy irrigation, and with a soil type in line with the observed mix in the region. The limited area of existing almonds were assumed to retain their existing characteristics, while new almond areas were assumed to be using under canopy irrigation, and with a soil type in line with the observed mix in the region. Also, lucerne was used as a proxy for olives given they are both relatively salt tolerant.

Table 11 set out the results of the remodelling of the 20 register entries. The entries have been grouped due to their approximate location along the river, in order to best interpret the results. As can be seen in the table, the changed assumptions on crop areas do not lead to significant changes to the $/EC index for Groups 1 and 2 which are closest to Morgan. As the assessment progresses upstream to subsequent groups, the change to the $/EC index is more pronounced. This is because there has been a larger change in the area of affected crops in the horticultural zones.

Table 11: Comparison of $/EC index, given change in horticultural crop areas

	Current $/EC index	Revised $/EC index	Change
Group 1			
Waikerie Lock 2 SIS	1.04	1.05	1%
Qualco Sunlands GWCS	1.07	1.09	2%
Woolpunda SIS	1.39	1.61	16%
SA Irrigation development based on footprint data	1.50	1.75	17%
Group 2			
Loxton SIS	1.85	2.17	17%
Bookpurnong SIS	1.80	1.77	-2%
SA Improved Irrigation Efficiency and Scheme rehabilitation Reg A	2.06	2.48	20%
Group 3			
Pike Stage 1 SIS	2.38	3.12	31%
Murtho SIS	2.79	4.12	48%
Group 4			
RISI NSW (Scaling Factor 0.33)	3.33	5.12	54%
Nyah to SA Border SMP - Irrigation Development	3.52	5.21	48%
NSW Sunraysia irrigation development 1997 to 2006	3.43	5.10	48%

Group 5			
MM SIS Refurbishment 2015	3.16	5.09	61%
Improved Buronga SIS	3.46	5.29	53%
Mallee Cliffs SIS	4.72	6.87	46%
Group 6			
Upper Darling SIS	4.96	7.11	43%
Group 7			
NSW MIL LWMPs	2.58	3.69	43%
Group 8			
New operating rules for Barr Creek	3.75	5.15	37%
Pyramid Creek GIS	3.59	5.84	63%
Shepparton Irrigation Region LWMP	3.01	5.27	75%

Source: Frontier Economics analysis of custom MDBA model results.

Although there is potentially a significant impact on the assessment of individual accountable actions by revising crop areas, the aggregate impact on the States' overall balances in the salinity register is less pronounced. **Table 12** compares the State and Total salinity register outcomes given the modelled change in horticultural crop areas. To do this, the results for the 20 sites were used as the basis to revise all register entries (using the $/EC index as proxy). Therefore, this should be considered an illustrative example of the impact on overall register balance outcomes.

Table 12: Comparison of register outcomes, given change in horticultural crop areas

	NSW	Vic	SA	Total
Register A				
Current	5.34	4.94	3.45	19.37
Revised	6.70	5.44	4.35	27.70
Registers A+B				
Current	5.74	4.85	7.25	23.48
Revised	6.94	5.04	8.56	28.67

Source: Frontier Economics analysis of custom MDBA model results.

This limited impact on overall register balance outcomes suggests that there is not an urgent need to change the function and its assumptions, with regards to agricultural information, to maintain the underlying integrity of the register function. When it does become appropriate to update the cost function, this could build on the existing agreed and accepted model structure as well as incorporating the identified updated crop area and price information from SunRise and ABS sources. That would also be an opportune time to implement the RMCG recommendation of removing the long-term salinity effect.

The significantly outdated assumptions do, however, significantly limit the usefulness of the cost function for estimating the salinity benefits of salinity management to agricultural water users for evaluation purposes.

4.3 Urban/commercial water users

The current urban and commercial elements of the salinity cost function were the result of the Allen (2004) review of multiple alternative model structures. Discussions with SA Water[28] suggested that there was limited new information to inform the functional forms for this type of water use.

One significant factor affecting the monetary estimates of salinity costs is inflation. The ABS CPI index was 81.5 in December 2004, and was 130.8 in December 2022. This represents a 60.5% increase. For example, if the salinity benefits were estimated at $100m/yr then (if the other assumptions remained valid) updated estimates would be $160m/yr once an adjustment has been made for inflation.

Another parameter which has changed since the salinity cost functions were first developed is the number of connections and industrial water volumes to which the model structure is applied. In particular, there has been significant changes to water supply in the Adelaide region:

- The proportion of Adelaide's water supply sourced from the Murray supply has exceeded the range assumed in the salinity cost function. In 2006-07, during the Millennium Drought, 91% of potable water was sourced from the River Murray.[29] The construction of the Adelaide Desalination Plant (operating since 2012[30]) —has the capacity to provide the city of Adelaide with up to 50% of its drinking water needs or up to 300 ML per day with an annual potential production of 100 GL/year. Discussions with SA Water confirmed that the high cost of desalinated water means that it is used for water security purposes (rather than the dilution of salinity for water quality concerns) and that the hierarchy for water supply utilisation is firstly, Adelaide Hills supplies, then River Murray, and finally desalinated manufactured water.

- The number of connections in Adelaide would be expected to have increased given the population of Adelaide has increased by more than 20 per cent. The ABS estimate of the population of Greater Adelaide in 2001 was 1.15 million, increasing to 1.42 million in 2022.[31]

28 Pers comm, (Steve Kotz — Manager Metropolitan Water Security, 4th May 2023.

29 cdn.environment.sa.gov.au/environment/docs/water-for-good-full-plan.pdf

30 www.epa.sa.gov.au/environmental_info/water_quality/water_quality_monitoring/adelaide_desalination_plant

31 ABS Regional population, 2021-22

- Despite the population growth, the most recent ABS Water Account (October 2022, for 2020-21) found that South Australian (state-wide) water use by households has significantly dropped from 2000-01 to 2020-21 — a shift from nearly 160GL/yr to around 140GL/yr (**Figure 16**). Discussions with SA Water identified that household water use has significantly changed since the Millennium Drought, with significant declines in 'per connection' usage. However, the change mainly comprises reduced outdoor water use and therefore the domestic salinity impacts represented in the cost function remain highly relevant because these affect indoor appliances.

Figure 16: Changes to SA household water use, 2000-01 to 2020-21

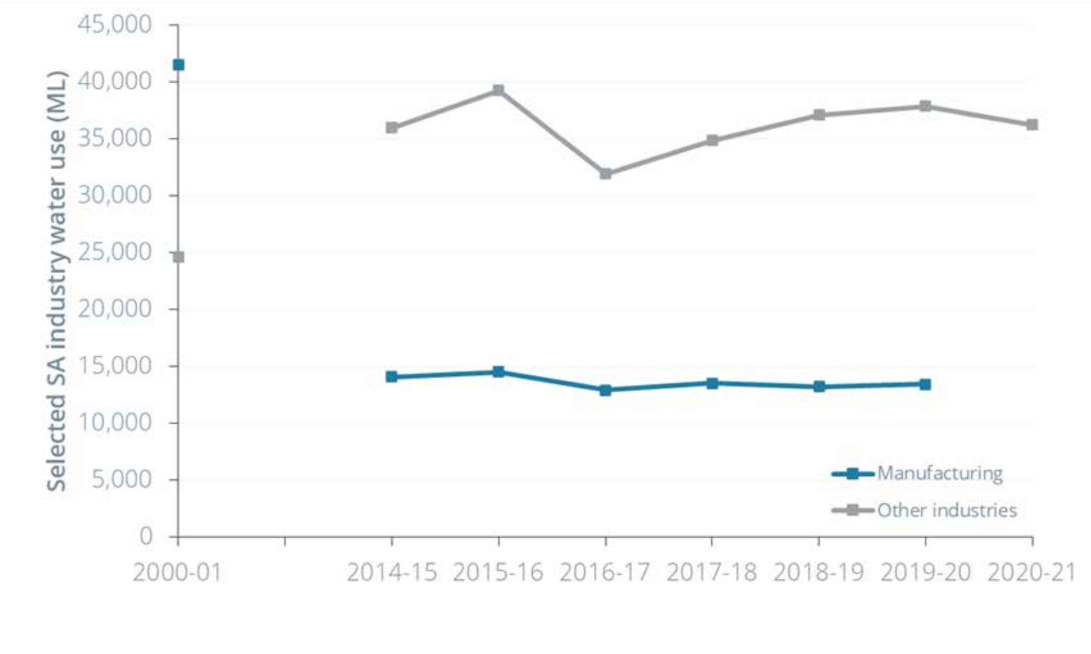
Source: ABS Water Account 2000-01 & 2020-21

- The volume of commercial/industrial water use has significantly decreased in the Adelaide region since 2005. For example, South Australian (state-wide) water use by manufacturing industries dropped considerably between 2000-01 and 2020-21 — a shift from 41.5GL/yr to around 13GL/yr (a decline of 69%). We note there has been a change in data presentation from the 2000-01 Water account to current (**Figure 17**). Despite this, it appears that the both manufacturing and other industry water use has significantly dropped from 2000-01 to 2020-21 (so it is estimated that commercial/industrial water use more broadly has declined by 45%).

A response to a data request is currently being completed by SA Water, and this will provide:

- Historical data on the proportion of Adelaide water supplied from the Murray (as prepared for the upcoming water security statement), annual data from 2000 to current.
- The current number of Domestic/Household connections in Adelaide.
- The current volume of Industrial/Commercial water use in Adelaide.

Figure 17: Changes to SA industrial water use, 2000-01 to 2020-21



Note: Excludes agriculture, mining, electricity and gas supply. Manufacturing water use includes Food, beverage & tobacco, Textile, clothing, footwear & leather, Wood & paper products, Printing, publishing & recorded media, Petroleum, coal, chemical & associated products, Non-metallic mineral products, Metal products, Machinery & equipment and Other manufacturing. Other industries water use includes Construction, Wholesale & retail trade, Accommodation, cafes & restaurants, Transport & storage, Finance, property & business services, Government administration, Education, Health & community services, and Cultural, recreational & personal services.

Source: ABS Water Account 2000-01 & 2020-21

The salinity cost function assumption of the relationship between EC and TDS remains sounds with the current value of 0.6. SA Health states that the conversion factor of "0.55" is used for River Murray water (but this value ranges from 0.5 to 0.7 depending on the water source).[32] Our understanding is that 0.6 is an acceptable value to MDBA and Basin States (the Basin Plan uses 0.6 for the southern Basin).

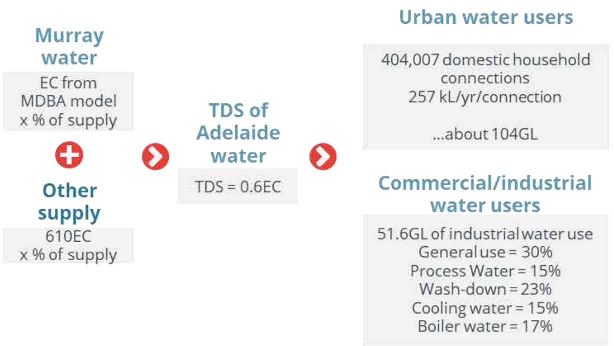
Given that the offtakes to Adelaide are downstream of the sites for accountable actions reflected in the salinity register, it is not expected that updated urban/commercial water use assumptions would have a significant change on the locational signals of credits and debits. On the basis that the update of data assumptions would mean that the measured salinity benefits to Adelaide are greater than under the current model, the magnitude of the current surpluses on the register would increase. Therefore, similar to the above discussion of salinity cost impacts on agricultural users, we expected that the continued use of the cost function assumptions would be acceptable to States for the purposes of register function.

As for the assessment of agricultural impacts, however, the significantly outdated assumptions limit the usefulness of the cost function for estimating the current benefits of salinity management to urban/commercial water users.

32 SA Health 2023, *Salinity and drinking water*, https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/public+health/water+quality/salinity+and+drinking+water

In the absence of the revised data assumptions (that could be adjusted based on the SA Water data request), the significant value of salinity management to urban/commercial users can still be seen by considering the recent experience during the Millennium Drought (as identified in section 4.1). Given the large reduction in estimated salinity that was attributable to management actions, under the 2008 conditions the salinity benefits would be in the order of $71 million, compared to the largest observation in the benchmark period of $43 million (**Figure 18**).

Figure 18: Urban/commercial salinity benefits under 1975, 1982 and 2008 conditions



Difference in salinity costs ($m/yr) adjusted for inflation			
	1975	1982	2008
Household plumbing fixtures	1.4	10.5	17.2
Hot water	0.8	6.2	10.2
Domestic filters and rain water tanks	-	-	-
Water softeners	1.5	11.4	18.7
General Comm/Industrial water use	0.4	2.8	4.5
Process Water	1.1	8.3	13.6
Cooling Towers	0.2	2.1	3.5
Boilers	0.3	1.9	3.2
Total	**5.6**	**43.1**	**70.9**

606→471EC
28% of supply
1006→641EC
81% of supply
1150→550EC
81% of supply

Source: Frontier Economics analysis

4.4 Coverage in the cost function

The current salinity cost function has no consideration of social, cultural or environmental impacts from salinity — implicitly assuming that they are zero.

These are considered as potential gaps, and considered in the following section.

5 Gaps in the scope of the salinity cost functions

Key findings:

- Managing landscape and river salinity brings a wide range of broader benefits
- The existing salinity cost function does not give a robust assessment of the economic, social, cultural and environmental benefits of salinity management
- Social, cultural and environmental benefits of salinity management have not been quantitatively analysed in the past, and there is also a limited qualitative understanding of these impacts. This presents a knowledge gap in current practices.
- It is recommended that the MDBA undertake further work to demonstrate the quantum of economic benefits and range of multiple benefits of current salinity management. Providing a robust narrative of the benefits of ongoing salinity management in recent years through a benefit estimation will be essential for securing ongoing funding for salinity management in Basin States.

The ongoing State cooperative management of salinity relies on funding from State Governments. Increasingly, demonstrating the economic, social, cultural and environmental value of investments is important to justify ongoing funding from State Governments. While the salinity cost function demonstrates many of the economic impacts of salinity management, it does not capture the social, cultural and environmental impacts.

Reviews to date have found that while social, cultural and environmental impacts from salinity exist, they are unlikely to be significant enough to include in the salinity cost function framework. These impacts are often caused by significant peaks in salinity which can damage fish and riverbed fauna for example. Due to effective salinity management today there are few social, cultural and environmental impacts that are occurring from excessive salinity. Yet it is widely agreed that had salinity not been managed, these impacts are likely to be worse. This means it is difficult to robustly establish each impact in a formula to embed in the cost function. Quantitatively estimating these avoided impacts is likely to be challenging and would require agreement amongst the MDBA and States on the counterfactual and estimation timeframe.

A qualitative description of the social, cultural and environmental impacts is likely to be more compelling and representative. The MDBA noted that there is strong evidence of the impact to riparian vegetation along the river. This qualitative analysis can be supported by quantitative information on economic impacts as included in the updated cost function. We explore the social, cultural and environmental impacts of salinity in turn below.

5.1 Social impacts

The social impacts of salinity are not well understood and are also hard to quantify. As such, they are not included in the current cost functions. In their 2009 review, RMCG found that “there is no compelling case to include social or recreational values into the model. The influence of river salinity on these values is not strong and pales into insignificance compared with lack of flow or incidence of blue green algae"[33].

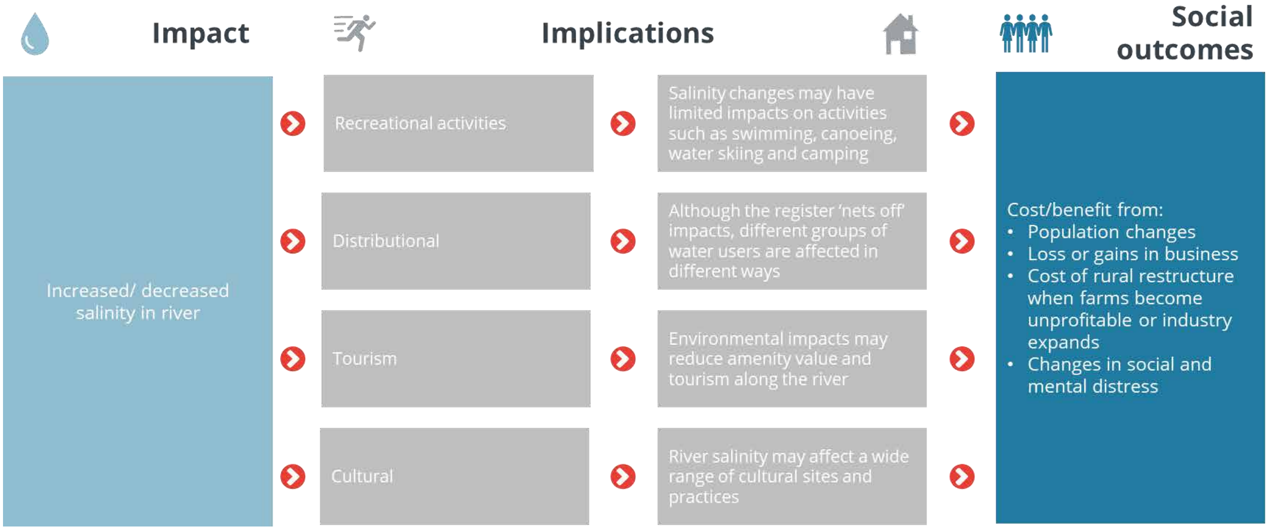
We know that some social impacts result from high levels of salinity, yet the scale of these impacts are hard to determine. The benefit assessment should in principle include social impacts of salinity either qualitatively or quantitatively.

The Murray River and its floodplains offer numerous nature-based recreational activities such as kayaking, bushwalking, fishing, birdwatching and camping. These activities and the associated tourism industry rely on the health and attractiveness of the rivers, lakes and wetlands. Factors such as water clarity, quality and accessibility, and local plants and animals have all been identified as important factors influencing the tourism.[34] We know that high salinity levels can have adverse biological effects, and this may flow through to impact tourism and social values.

Beyond use values, the Murray River and its floodplain also offers non-use value to society. Non-use values are a class of economic value, reflecting the benefit people receive from knowing that a particular environmental resource, exists. It is the value of the benefits derived from the asset's existence alone. Non-use values are generally separated into existence, altruism and bequest values.

Figure 19 summarises potential flow through impacts that stem from high levels of river salinity.[35]

Figure 19: Social outcomes from changes in river salinity



Source: Frontier Economics

33 RMCG (2009), Basin Salinity Management Strategy (BSMS) Cost Function Review, Final Report

34 MDBA, *Social and economic benefits from environmental watering: 2017 Basin Plan Evaluation*, December 2017.

35 https://www.qld.gov.au/environment/land/management/soil/salinity/impacts#:~:text=Salinity%20affects%20production%20in%20crops,plant%20is%20poisoned%20and%20dies.

The incorporation of these types of impacts into a monetised and formula-based model would be challenging, and the magnitude of these impacts may be small because of ongoing actions to manage salinity, as found by RMCG. Quantitatively estimating these avoided impacts is likely to be challenging and would require agreement amongst the MDBA and States on the counterfactual and estimation timeframe.

In our view, a qualitative description of the social impacts is likely to be more compelling and representative. This qualitative analysis can be supported by quantitative information on economic impacts as indicated by the cost function.

5.2 Cultural benefits

There is also a link between salinity levels and cultural outcomes. However, there are few papers that focus on the issues of cultural and salinity outcomes that might assist in quantifying this relationship. One exception is the 2005 paper *Living Land – Living Culture: Aboriginal Heritage & Salinity*.[36] This is a NSW focused report and therefore considers the impact of salinity on cultural values beyond the Murray, including areas where salinity is significantly higher than the Murray. Further, the report considers the impact of salinity in the landscape.

The report emphasises that cultural values should not be ignored, "Understanding the social values of landscape and generating land-use change requires engaging with people, not simply with economics or biophysical systems"[37]

Cultural benefits of salinity management are not experienced uniformly across the Basin.

> *"Specific potential impacts on Aboriginal heritage are varied. They include damage to a range of pre- and post-contact sites, and the degradation of culturally valued landscape features. Salinity can reduce people's capacity to find and utilise wild foods and medicines, and increase the threats to totemic species. It can jeopardise the economic viability of Aboriginal-owned lands and enterprises. It can damage services used by Aboriginal people such as roads, pipelines and buildings. All of these problems can affect people's health and well-being."*[38]

The paper undertook a case study which an Aboriginal community in Wellington NSW on Wiradjuri land. One Wiradjuri elder, Evelyn Powell, travelled from Coorong South Australia to Wellington NSW via the NSW Riverina and witnessed the range of salinity stressed landscapes in NSW and the Murray Darling Basin. Her words express the effect that this country had upon her:

36 https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Land-and-soil/aboriginal-heritage-salinity.pdf

37 English, A., Gay, L. (2005), Living Land – Living Culture: Aboriginal Heritage & Salinity, NSW Department of Environment and Conservation

38 English, A., Gay, L. (2005), Living Land – Living Culture: Aboriginal Heritage & Salinity, NSW Department of Environment and Conservation, p. 3

> *One of the disturbing things is that I've never ever seen the country like that. Where you just see the masses of white. Like it was a cancer eating away into everything as it went along. The gum trees were dying, and all the grass, and everything, like a lot of white salt or something ... It's really upsetting for me just to see that salt. That white dirt eating away at the land. It's just like a cancer, gobbling everything up in its path. I'd never seen anything like it before. It makes me feel no good inside, because when you relate to the land, in the spiritual, Aboriginal way, and seeing these things, it makes me feel no good.*[39] *(p.9)*

One interpretation of these views is that salinisation of land on country is a pressing cultural concern. Therefore a relevant link to cultural benefits is where the cooperative salinity and drainage strategies have been effective at reducing landscape salinity that would have otherwise developed (as a consequence of historical development and land clearing).

> *"...salinity problems may occur at, or threaten, actual places where wild resources are obtained. For example, a stand of medicine plants may be directly threatened by a salinity outbreak. To date, though, there is no research into the susceptibility of valued species of food and medicine plants to salinity. Some may be significantly affected by problems like waterlogging, while others may be more tolerant. Equally, the effects of salinity on terrestrial and aquatic fauna are poorly understood and at present are largely restricted to general analyses of threat. It is unclear whether salinity is a direct threat to species' survival. Other problems like altered fire regimes, clearing and pest species are probably more significant in some areas. Despite this, the implications of salinity should not be played down."*[40]

Demonstrating the existence of these cultural impacts is important, but understanding the scale of them will be difficult for the benefit estimation. As with social benefits of salinity management, in our view, a qualitative description of the cultural impacts is likely to be more compelling and representative.

39 English, A., Gay, L. (2005), Living Land – Living Culture: Aboriginal Heritage & Salinity, NSW Department of Environment and Conservation, p. 9

40 English, A., Gay, L. (2005), Living Land – Living Culture: Aboriginal Heritage & Salinity, NSW Department of Environment and Conservation, p. 23

5.3 Environmental benefits

The riverine ecosystem needs to be carefully managed to protect native fish and plant species. There are several factors that can impact the environmental health of the river amongst high salinity levels including cold water, low dissolved oxygen levels, agricultural chemicals, and discharges from industries and sewage treatment works.

High salinity levels can cause ecosystems distress and damage in freshwater rivers.

Environmental impacts include:

- **Floodplain impacts**: Most ecological values are associated with river floodplains rather than the river itself. There are over 30,000 wetlands in the MDB, ten are internationally significant. Environmental flows are important to managing wetland health.[41]
- **Animal susceptibility:** "Whilst many adult fish are tolerant of increased salinity, eggs or larvae have been shown to be highly susceptible, resulting in greatly lowered survival of these early life stages."[42]There is uncertainty about **what level of salinity** is harmful to animals, yet most animals have a threshold up to which they can survive.
  - Newly hatched larval Murray Cod and trout cod cannot survive 750 EC
  - Other research suggests Macroinvertebrates and aquatic plants would survive at 1500 EC and below
  - For example, platypus occupy rivers and streams where salinity can peaks at 10,000 EC units (short term)
  - Salinity alone is the physico-chemical variable best correlated with fish assemblages[43]
- **Flow regime**: Wetland health depends both on salinity and on flow regime (related to but distinct from salinity)
- **Tree susceptibility**: High salinity can affect river red gums growth and ability to regenerate from injury. Trees provide essential breeding and feeding habitat for animals.

While small changes in salinity may not cause significant degradation, many plants and animals have tolerance salinity thresholds that if breached can result in detrimental impacts. Hart et al. found that adverse biological effects are unlikely provided salinity is kept below approximately 1500 EC.[44] Yet, "It is known that freshwater organisms have varying sensitivities towards salinity stress and thus increasing salinity can safely be expected to alter community compositions whether directly (species loss due to toxicity) or indirectly through altered species interactions,

[41] RMCG (2009), Basin Salinity Management Strategy (BSMS) Cost Function Review, Final Report

[42] Lintermans, Mark (2009), Fishes of the Murray Darling Basin: An introductory guide, Murray Darling Basin Authority

[43] Crossman et al (2011), Status of the aquatic ecosystems of the Murray-Darling Basin and a framework for assessing the ecosystem services they provide, An interim report to the Murray-Darling Basin Authority from the CSIRO Multiple Benefits of the Basin Plan Project, 28 November 2011

[44] Hart et. Al (2020), Salinity Management in the Murray-Darling Basin, Australia, p.

irrespective of whether acting as a single stressor or in concert with multiple stressors.[45] Further, salinity can impact the health and density of floodplain vegetation including river red gums as salt accumulates in the soil profile.

Environmental impacts have not been included in the salinity cost functions to date. In their 2009 review of the cost functions, RMCG did not recommend changes to the cost functions to include environmental impacts - "There are several unknowns that relate to separating salinity effects from water regimes. However, no immediate changes to the model are recommended".

Even if modelled environmental impacts were to be included in the cost functions, the target EC at Morgan does not recognise locational impacts of high river salinities experienced at important ecological sites in the mid river – Barmah Millewa, Gunbower-Perricoota, Hattah Lakes, Chowilla/Lindsay Walpolla.

Although the benefits of managing salinity are evidenced through the literature, it is difficult to forecast or model the magnitude of these potential benefits. To ensure environmental impacts are considered moving forward, we recommend including a qualitative assessment as part of the benefit evaluation.

5.3.1 Future salinity impacts

While it is evident today that managing salinity brings social, cultural and environmental benefits, consideration needs to be given to factors that may change these outcomes in the future.

Significant land clearing and horticulture development in the Mallee region has led to changing salt loads in the landscape. A Salt Loads Study as part of the 1999 Salinity Audit of the Basin found that salinity levels were expected to increase through to 2100 due to rising water tables. In some parts of the river, salinity was expected to increase the 800EC threshold by 2100 – including Morgan at 900EC by 2100. This study also found that this increase in salinity can be attributed to native vegetation clearance in the Mallee since European settlement, and the rising saline aquifers infiltrating the groundwater that has occurred in the past 200 years.[46]

This Salt Load Study was re-assessed in 2009 by DECC which suggested that the salt loads in NSW upstream tributary catchments were overstated. It concluded that salinity management should focus on reducing the cyclical variations in stream salinity due to climate variation. However, these findings could be influenced by the millennium drought causing a reduction in groundwater.[47]

Despite these mixed findings about the materiality of adverse environmental impacts, it is clear that ongoing salinity management is necessary in the future to manage these impacts.

45 Berger, E., Frör, O., & Schäfer, R. B. (2019). Salinity impacts on river ecosystem processes: A critical mini-review. Philosophical Transactions of the Royal Society B: Biological Sciences, 374(1764). DOI: 0.1098/rstb.2018.0010 https://royalsocietypublishing.org/doi/10.1098/rstb.2018.0010

46 Crossman et al (2011), Status of the aquatic ecosystems of the Murray-Darling Basin and a framework for assessing the ecosystem services they provide, An interim report to the Murray-Darling Basin Authority from the CSIRO Multiple Benefits of the Basin Plan Project, 28 November 2011

47 Crossman et al (2011), Status of the aquatic ecosystems of the Murray-Darling Basin and a framework for assessing the ecosystem services they provide, An interim report to the Murray-Darling Basin Authority from the CSIRO Multiple Benefits of the Basin Plan Project, 28 November 2011

Climate change is expected to lead to a hotter, drier Basin with more frequent and longer droughts. Hart et al explored the notion of climate change on expected salinity levels. They found that ultimately the impact of climate changes on salinity levels are uncertain:

> *"increased droughts should lead to reduced salt loads and impacts, but this may be partially offset by an increased flooding and groundwater recharge from higher intensity rainfall or lesser dilution effects from reduced run-off. The changes in climate are also likely to affect the spatial distribution, size, crop types, and management of irrigated agriculture in the MDB, and this may dominate the direct effects of climate on salt discharge"*[48]

Although the salinity cost function details the many salinity impacts on water users, it does not consider social, cultural and environmental impacts. As discussed above, although in-river changes may not have significant impacts in these dimensions, managing salinity is nevertheless a positive impact. Further, salinity management preventing further landscape salinity is important.

The successful management of river salinity to date has been enabled through joint venture funding of SISs and other salinity management actions. While ongoing average salinity levels are important for river management, large peaks in EC can have significant consequences. Note that these peaks can still occur within the target of 800EC at Morgan 95% of the time. The use of SISs and river management has resulted in reducing the occurrence of peak salinity events. As such, salinity management has led to avoided costs associated with peak events and insurance benefits.

Increasingly, demonstrating the economic, social, cultural and environmental value of investments are important to justify funding from State Governments. The incorporation of these types of impacts into a monetised and formula-based model would be challenging, and evidence suggests that the magnitude of these impacts may be small.

We heard from Basin States in our Stage 1 workshop that the cost functions are not fit for the purpose of establishing the economic impact of the BSM2030 strategy to justify continued funding of the program. Reasons for this included (as already discussed in section 2.4):

- The salinity cost effect is reported in 2005 dollars without escalation for inflation
- The salinity cost effect is calculated as an average across a historical benchmark period, that is not reflective of current or future hydrological conditions
- The salinity cost effect does not currently incorporate the broader environmental and social benefits of salinity management. As discussed above in sections 5.1, 5.2 and 5.3, due to in-river salinity levels being managed in the Murray, there are limited environmental, social and cultural impacts from salinity that are realised. However, it is understood that a number of impacts can unfold if salinity levels reach high levels (greater than 1500 EC).

As such, it was discussed that a benefit evaluation of total salinity change from cooperative management should be undertaken as it can be used to provide justification for cooperative

48 Hart et. Al (2020), Salinity Management in the Murray-Darling Basin, Australia, p.

action funded through joint ventures. The benefit assessment could be a once-off analysis with the assessment updated using prevailing conditions and new information. This would provide a readily communicated rationale for continued salinity management investment, timely for the next BSM review and next strategy.

In our view, delivering a robust assessment of quantitative economic impacts will be supported by modelling results to support the analysis — namely, the application of an updated salinity cost function on MDBA hydrological modelling results of potential future river conditions. The MDBA have indicated that it would be possible to do sensitivity tests on the potential impact of future climates. Work is currently underway to develop a consistent whole of basin approach to future climates, which may be available within the next 12 months. Ideally, all jurisdictional and Murray models contributing to the registers would be run under the future climate scenarios in a consistent manner to do a future scenario.

We explore the methodology of a benefit estimation further in Attachment 1.

6 Pathway forward

Key findings:

- Accountability for individual and joint State salinity actions is essential for effective future management of salinity
- The cost functions in their current form can be used to enable the registers to continue to operate as a key accountability mechanism for the States' salinity management
- The cost functions should be updated as part of future processes, i.e. either as part of the shift in hydrological modelling approach from Bigmod to SOURCE, the 2026 review of BSM2030, or in establishing the cooperative salinity management approach for the period 2031-2045
- Options to simplify the modelling approach should be investigated, such as by aggregating similar entries or setting a new baseline from which accountable actions are assessed.
- A benefit evaluation of salinity management should be undertaken by the MDBA to provide a quantitative benefit estimate based on updated information, to outline other benefits such as risk management and to address the key knowledge gaps related to the social, cultural and environmental benefits of salinity management. This benefit estimate could be used to justify funding for SIS operation and cooperative management.

The review has found that the continued use of the cost functions would be acceptable to States for the purposes of the salinity register function. However, the significantly outdated assumptions limit the usefulness of the cost function for estimating the salinity benefits to water users associated with ongoing management programs and thus the case for continued funding of these.

This section considers the pathways forward given these findings, and separately considers the dual roles of the salinity cost function in (1) accountability for salinity management actions and (2) demonstration of the ongoing benefits of salinity management.

6.1 Accountability for salinity management actions

In order to progress the agreed measure of State accountability for salinity management, strategies for the salinity cost function framework range from 'maintain', 'update' and/or 'simplify'. These are not separate or binary decisions, and our recommendation at the conclusion of this section is a progress through these options.

6.1.1 Maintain existing salinity cost function

Register function (i.e. recording the debits and credits in the Salinity Registers) requires an approach that is agreed by all parties to maintain accountability for 'no net negative impact' in an acceptable way.

The RMCG (2009) review adopted a guiding principle that 'Cost functions should not be changed unless the change is with significantly more robust data. There needs to be agreement for any change".

We agree that this is an appropriate principle for managing the salinity cost function for the purpose of register function.

The findings of this review are that the current salinity cost function can adequately perform the register function if all States continue to agree to its use. This ongoing consensus is supported by our findings that model structure of the cost function is robust and appropriate, and that the overall impact of updates to data assumptions would not significantly change State register balances.

This suggests that there is no urgent need to change the cost function for the purposes of the Salinity Registers.

Maintaining the current salinity cost function implicitly requires agreement to base State accountability on early-2000s development and 1975-2000 climate conditions.

This is recommended in the short term.

6.1.2 Update salinity cost function

While we have found that this review has identified that there is no immediate urgency in updating the salinity cost functions, a number of the assumptions are out of date.

However, updating and implementing changed assumptions now as a stand-alone task would require considerable effort and cost for little or no benefit in terms of salinity register function. Rather than update the salinity cost functions now, however, an option is to utilise opportunities for cost functions be updated as part of future processes. For example, it may make sense to do so as part of the proposed shift in hydrological modelling approach from Bigmod to SOURCE, as part of the scheduled 2026 review of BSM2030, or in establishing the cooperative salinity management approach for the period 2031-2045.

The review has identified that agricultural areas and prices can be readily updated with robust data from SunRise and ABS. SA Water is preparing a response to an information request to provide the data to update data assumptions for Adelaide (the urban/commercial users that have significantly changed).

Upon updating the assumptions in the salinity cost function, a decision could be made to reassess the acceptability of data assumptions before the adoption of the next BSMS (or in the next 5-10 years)

6.1.3 Simplify salinity cost function

Another option is to simplify aspects of the accountability measure, such as by simplifying the measure itself, or the calculation of the measure.

Simplifying the measure for accountability

The critical role of the salinity cost function is to enable States and water users to 'internalise' the externality of salinity impacts and serve as the measure of 'no net negative impacts' for the purposes of the agreed Basin salinity management framework. A significant part of this potential externality is the locational element where salt entering higher up the river will negatively impact more water users than if the salt entered further down the river.

This suggests that a simple locational measure of 'equivalent EC' could underpin State accountability for Basin salinity management (this would be similar to the $/EC index discussed in section 4.2, but where location is the proxy for the index value). In the modelling undertaken for this review, a strong link for SIS between "dollar benefit" and "EC at Morgan" and the location where salt entered (or was prevented from entering) the river was observed — with the benefit increasing as the intervention occurred further upstream and thus affected more water users (recall **Table 11**).

However, there are other accountable actions that do not demonstrate the same link in $/EC. This is where other factors such as the seasonality of salinity changes, or the case of dilution flows (rather than the increase or decrease in salt load) are significant. For example:

- It is understood that the accountable action for new operating rules for Barr Creek Drainage Diversion Scheme and the Barr Creek Catchment Strategy are modelled as being associated with preventing salt load entering the river predominantly during autumn/winter months. This seasonality means that it does not have as large an impact on salinity during the months when irrigation crops take water, and therefore these actions have a lower $/EC index than would be expected from their location along the river. The salinity implications still persist, however, to affect urban/commercial water users such as in Adelaide.
- Accountable actions that are adjustments from water entitlement trade that has moved the expected location of take downstream (such as Permanent Trade Accounting Adjustment - NSW to SA) are represented in the model to increase dilution flows between the original and new location of take, but with no significant salinity change downstream of the new water take location. This means that the salinity implications do not persist in the river to affect urban/commercial water users such as in Adelaide.

For actions that have comparable seasonality and other factors, but different salt loads, this suggests that simplifying the calculation of the salinity cost effect using a simple locational measure may be sufficient. However, the simple 'equivalent EC' measure may not acceptably capture the relative impact on water users for actions that have different seasonal characteristics or which relate to dilution benefits.

These limitations suggest that a simplified location measure may not be sufficient to capture the extent of salinity changes and associated benefits since 2005. Further, it may be more complicated for the States to reach agreement on values for a new 'locational' function (with the mentioned concerns and limitations) than to agree to updating the currently agreed function.

A more extreme approach to simplify the measures would be to remove the salinity cost effect altogether.

The salinity cost model would no longer be required if the basis for State accountability was changed from the salinity cost effect to a measure of EC at Morgan. This would represent a significant change to State salinity management — it would mean that different impacts along the shared NSW/Victorian length of the Murray are no longer recognised, while the impact of these upstream States on downstream South Australia is recognised (as per the impact on EC at Morgan). Essentially, under this approach accountability would be tracked by the salinity effect EC balance on the salinity register (and the salinity cost effect would no longer be required).

Simplifying the calculation approach

Another approach to simplifying the current salinity accountability framework is to reduce modelling complexity.

Currently each accountable action on the register is modelled individually (sometimes requiring multiple model runs) and in sequence. This means that over 300 hydrological model runs are required (each with post processing via the salinity cost function) to calculate the salinity register entries (debits or credits). This represents a very significant demand on modelling resources. For example, to undertake the modelling for this review (for one set of changed assumptions for twenty accountable actions) it required reprocessing the salinity cost function on more than 140 hydrological model runs.

Simplifying the modelling could involve aggregating sets of historical accountable actions that have similar characteristics and/or timing (such as the set of nine Former Salinity & Drainage Works and sets of State works that have been in effect for more than 20 years) in order to reduce the resources required for managing salinity register modelling.

Another approach to simplifying the salinity cost function would be to 'roll up' legacy actions into a new current baseline. This new baseline could be defined by the set of salinity management actions that are in place at a given time (such as the commencement of cooperative salinity management approach for the period 2031-2045) and given the assumption that the action would be continued to be managed in a given way. This would mean that only new accountable actions need to be modelled as separate hydrological runs (this includes the 'action' to discontinue a previous action).

To determine the preferred approach to modelling simplification, the MDBA and States need to answer the question: What level of sophistication is adequate, for the purposes of register accountability?

6.2 Demonstrating the benefits of salinity management

This reviewed has identified that the salinity cost function does not accurately reflect the benefits attributable to current contemporary salinity management and therefore does not meet the needs of the States and the MDBA for a measure of the benefits of salinity management and associated investments for the purposes of contemporary investment evaluation or justification of ongoing expenditure on salinity management.

Firstly, the data assumptions used by the current salinity cost functions and the benchmark period it is applied to are not representative of the current and future context of salinity management.

Secondly, it is important to recognise that the financial costs and benefits underestimate the broader economic costs and benefits. This is because comprehensive economic assessments should also consider social and environmental costs and benefits. Future investment in the salinity management program should be guided by economic assessments rather than financial assessments alone. Individual state and Commonwealth governments have guidelines on economic assessments.[49] The benefit assessment should utilise and align with key principles from these guidelines where possible.

Accordingly, this review recommends that the MDBA undertakes a further study to estimate and discuss the range of benefits of salinity management.

The potential scope of such as review is outlined in Attachment 1, with several options for how such an assessment could be delivered. In our view, demonstrating these benefits could be best achieved by an assessment which documents the scope of quantitative and qualitative benefits from salinity management. Such an evaluation should consider the range of annual outcomes in these benefits, and not just the average over a given time period, which would be useful for communication purposes. Where possible, the evaluation of expected benefits also needs to relate to current/recent and plausible expected future conditions.

As part of this more comprehensive benefits evaluation, the salinity cost function could support the quantitative assessment of economic benefits to water users by estimating expected (average) benefits as well as providing examples for individual years to demonstrate range of benefits – and how these may be realised in the future (recall the large benefit to Adelaide urban/commercial water users derived from applying the cost model to 2008 conditions in **Figure 18**).

This quantitative assessment could be supplemented by qualitative analysis of intangible costs and benefits, including social, cultural and environmental impacts (as discussed in section 5).

A robust demonstration of the benefits of current salinity management would enhance the shared understanding and communication of the value of these cooperative efforts. This in turn would assist in making the case for continued funding and inform the goal of BSM2030 to deliver cost-effective and efficient salinity intervention.

Relevance to the Basin Plan evaluation

Under the Water Act 2007 (s13.05), the Basin Plan must be evaluated every 5 years, and the 2025 evaluation will inform the 10-yearly review of the Basin Plan in 2026.

The socio-economic work for the evaluation is commencing, although no detailed framework for the evaluation is yet available.

It should also be noted that the salinity register entries for actions that occurred prior to the commencement of the Basin Plan in 2012 contribute 81-93% of the total change recorded on the registers to date (as measured in EC and dollars of salinity cost effect). Further, entries since the Basin Plan have built on the existing cooperative relationship between the MDBA and the States (evident for at least the past 40 years) (**Table 13**) — and therefore may not be directly attributable to the Basin Plan.

This means that attributing socio-economic benefits associated with salinity management to the Basin Plan would be problematic. However, an assessment (such as recommended above) for the evaluation of the demonstrable benefits of current salinity management would provide a useful basis for the socio-economic evaluation of Basin Plan salinity management.

49 For example, NSW Treasury Guidelines for Cost Benefit Analysis, Victoria Department of Treasury and Finance Economic Evaluation for Business Cases Technical Guidelines, and Infrastructure Australia's Guide to economic appraisal.

Table 13: Salinity Effect and Cost Effect prior/post Basin Plan

	Salinity Effect (2015)	Salinity Effect (2030)	Salinity Effect (2050)	Salinity Cost Effect
Register A only				
Register entries (2012 & prior)	-138.2	-126.7	-111.4	19.1
Register entries (after 2012)	-11.3	-17.9	-26.8	3.4
Proportion of Register entries (2012 & prior)	92%	88%	81%	85%
Proportion of Register entries (after 2012)	8%	12%	19%	15%
Registers A & B				
Register entries (2012 & prior)	-154.6	-136.5	-112.2	19.1
Register entries (after 2012)	-11.3	-17.9	-26.8	3.4
Proportion of Register entries (2012 & prior)	93%	88%	81%	85%
Proportion of Register entries (after 2012)	7%	12%	19%	15%

Source: Frontier Economics analysis of salinity register

6.3 Recommendation on pathway forward

Subject to a decision by the MDBA and States to continue to use Salinity Cost Effect rather than Salinity Effect as the measure of accountability for the Salinity Registers, our key recommendations are that:

- The use of the salinity cost function be retained to enable the registers to continue to operate as a key accountability mechanism for the States' salinity management.
- The MDBA undertakes further work to provide anda narrative that demonstrates the benefits of current salinity management. This would include a quantitative assessment based on updating the data assumptions of the salinity cost function and applying the function to historical, recent and (where possible) expected future conditions, to describe the average/expected economic benefits as well as the risk management benefits of avoiding spikes in salinity. This would also include a qualitative assessment of other impacts of salinity management, including social, cultural and environmental.
- The salinity cost function be updated as part of future processes, i.e. either as part of the shift in hydrological modelling approach from Bigmod to SOURCE, the 2026 review of BSM2030, or in establishing the cooperative salinity management approach for the period 2031-2045. The updated assumptions would be consistent with (or build on) the above demonstration of the benefits of current salinity management.

Attachment 1: Benefit estimation

As discussed in Section 5, a significant gap in the current arrangements is that the salinity cost function does not reflect the benefits attributable to current salinity management. In our view, demonstrating these benefits could be best achieved by an assessment which documents the scope of quantitative and qualitative benefits from salinity management. This should consider the range of annual outcomes in these benefits, and not just the average over a given time period. Where possible, the evaluation of expected benefits also needs to relate to current/recent and plausible expected future conditions.

It is recommended that the MDBA undertakes further work to demonstrate benefits of current salinity management. We scope up what the benefit estimation should involve below.

Scale of benefit estimation

As outlined above, the salinity cost function that underpins the salinity register does not adequately represent the benefits of current salinity management. In our view, this demonstration of benefits could be best performed by an assessment which documents the scope of quantitative and qualitative benefits from salinity management. This should consider the range of annual outcomes in these benefits, and not just the average over a given time period. Where possible, the evaluation of expected benefits also needs to relate to current/recent and plausible expected future conditions.

There are several options for how such an assessment could be undertaken, all of which would build on the existing knowledge accumulated in the current salinity cost function, but align the analysis to be more representative of current requirements:

- **Inferred**: Will include a limited adjustment to the quantitative information from the current salinity cost function and existing modelling, such as to update to current dollars, as well as including descriptive analysis of qualitative benefits of in-river salinity management.
- **High-level**: Will include a high level adjustment to the quantitative information from the current salinity cost function, such as to update to data assumptions that have significantly changed. This could be supplemented by additional disaggregation of results, and application to an agreed timeframe (e.g. current/recent/future) condition. This option would include a descriptive analysis of qualitative benefits of salinity management based on available literature, including social, cultural and environmental and salinity impacts beyond those in-river, such as in the landscape and affecting roads and infrastructure. Findings will be ground-truthed in limited consultation with water users in various sectors. Stakeholders should be identified with the MDBA, but could include Lower Murray Irrigators and SA Water.
- **Detailed**: Will include a detailed recalibration of model structures in the cost function, relying on significant consultation with water users in the various sectors, as well as updating data assumptions. The analysis of other benefits could build on the high-level approach by seeking to modify and adapt information in available literature and draw assumptions around scale and magnitude of key benefits. Further, the detailed benefit estimation could include 3+ ground truthing workshops to assist our understanding of the impacts and assumptions underpinning the benefit assessment with key stakeholders.

Again, key stakeholders should be identified with the MDBA, but could include Goulburn irrigators, Lower Murray Irrigators, SA Water, and a large industrial/commercial water user.

Ultimately, the scale chosen will reflect timing and resource constraints. At a minimum, key foundational analysis will be conducted under each three options and include:

- Problem definition
- Definition of the base case/ counterfactual
- Definition of intervention and how that can be measured
- Identification of range of benefits associated with the intervention.

The benefits of providing a robust demonstration of the benefits of current salinity management would be to increase the understanding and communication of the value of the cooperative efforts. This, in turn, would assisting in making the case for continued funding and inform the goal of BSM2030 to deliver cost-effective and efficient salinity intervention.

Data for the benefit estimation

The quantitative assessment would be based on updating the data assumptions of the salinity cost function and applying the function to historical, recent and (where possible) expected future conditions.

The source of information for the updated data assumptions are discussed in sections 4.2 and 4.3. Updated agricultural data relies on SunRise and ABS data, while updated urban/commercial assumptions are expected to be readily available from SA Water.

Using hydrological conditions beyond the 1975-2000 benchmark period allows the assessment to describe the average/expected economic benefits as well as the risk management benefits of avoiding spikes in salinity.

The MDBA have considered the data challenges in this task:

- The overall benefits of salinity management actions (estimated using the salinity cost) can be obtained through using the 'with all' and 'without all' model runs.[50] It is not necessary to use all of the model runs that underpin the register.
- It is expected to be possible to output the salinity cost for each year of the benchmark period (as opposed to the average across all 25 years), however it requires some changes to the code to get the outputs in the required format.
- Estimating salinity costs over recent years with/without interventions requires more time to configure a scenario that would be a reasonable representation, and would be more difficult to do.

Despite the challenges in modelling recent years with/without interventions, this information would be critical to support a robust assessment of the benefits of current salinity management.

50 The two model runs are essentially the start of the BSMS Registers (representing no intervention) and the last run of the BSBS Registers (representing intervention).

The assessment would also include a qualitative assessment of other impacts of salinity management, including social, cultural and environmental (using or building on the information in sections 5.1, 5.2 and 5.3).

Defining the counterfactual

When undertaking a benefit estimation, it is important to clearly define the counterfactual. This allows us to estimate and analyse the benefits of salinity management in relation to the counterfactual (i.e. the incremental change as a result of salinity management).

The key question in this instance is what would the world look like had no salinity management occurred in the 1990s? For example, would Lower Murray development have occurred (in high impact zone rather than a low impact zone), would downstream trade have occurred? What if there was relationship breakdown between states and cooperative management no longer occurred?

However, history points to the likelihood that cooperation between the states would have occurred through other means such as through legal processes. Box 3 outlines an example where prior to cooperative agreement, South Australia used the courts to stop development in NSW to avoid negative impacts in South Australia. This suggests a potential counterfactual is no negative impacts for development, rather than no *net* negative impacts as occurs today.

A potential method to defining the counterfactual could be to group actions in every 5 years, and seek an agreement amongst the states of each 5 year group.

Box 3: Water Resources Commission of NSW v State of South Australia

Prior to the intergovernmental agreement on salinity, adverse impacts were managed through the courts system. In 1981, South Australia intervened in applications in NSW from irrigators looking to irrigate 541 hectares with water from the Darling River. South Australia was concerned about the increased in river salinity that would result from the approval of the application and the saline water flowing across the border. The Land and Environment Court decided that "South Australia had a right to be heard in opposition to granting of the applications, but that, on evidence before the Court, the water would be released to the applicants without harm to the objections or other irrigations or to the river system by reason of increased salinity."

Source: Preston, The Hon. Justice Brian J, Chief Judge, Land and Environment Court of NSW, (2008), Water and Ecologically Sustainable Development in the Courts, A paper presented to Australian Sustainability Laws and Water Management: The Future Symposium, Adelaide, South Australia

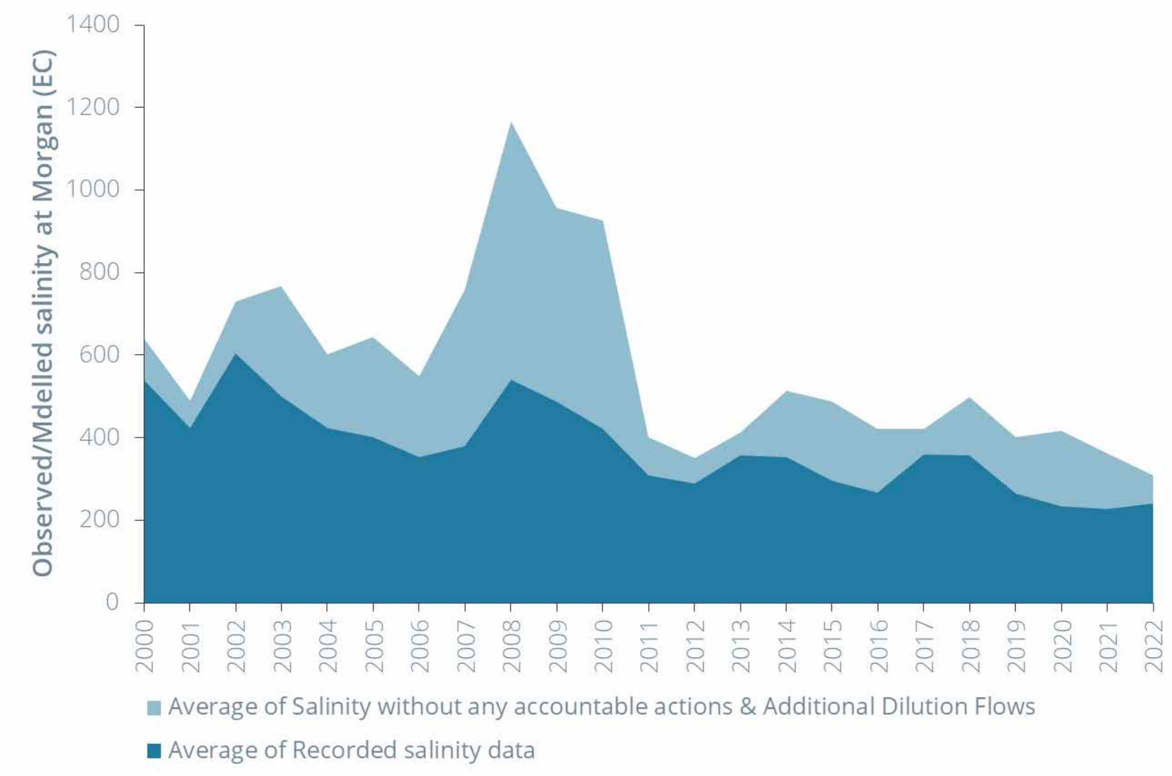
Timeframe

Another consideration in establishing the benefit estimation methodology is to determine the timeframe over which the analysis is conducted. The benefit estimation could be conducted using *observed* salinity changes in recent years, or estimate the benefits of *future* salinity management.

If the benefit estimation is to be conducted on observed salinity, the benefit estimation could be conducted using salinity EC measured as the intervention in comparison to modelled salinity EC without salinity strategies. Effectively, this could be the difference between the dark blue and light blue lines in **Figure 20**.

Importantly, the benefit estimation should focus on an annualised basis. The current cost function averages conditions across the 25 year period. Yet as discussed above, while average salinity levels are important, so are the peaks as these can lead to large negative impacts. As per **Figure 20**, capturing the difference in impacts between 2008 where unmanaged salinity could peak and low levels in the 1990s is worth considering.

Figure 20: Salinity impacts of management (observed salinity and modelled)



Source: Frontier Economics analysis of MDBA data

If the benefit assessment is to be conducted on estimated future changes in salinity, there are two potential options:

- Report the estimated impact of reducing salinity in each of the 25 Benchmark years (1975-2000)
- Estimate the impact of reducing salinity in an expected future sequence.

The former would provide a range of potential outcomes, rather than just an average. This should show the impact of managing salinity in bad years to prevent more significant risks and the risk/ insurance benefits associated with this (supporting large investments by water users). However, in some years the benefits may be limited. Under this approach, we could note which of the 25 years are expected to be most representative of coming seasonal conditions.

Secondly, estimating a future sequence, could enhance a benefit estimation and align closely with a CBA focus. Yet, the MDBA has suggested that it could be very difficult to agree on future scenarios.

Alignment with Basin Plan

There is scope to align the benefit assessment with the Basin Plan evaluation. Ideally the benefit evaluation should be completed by October 2024 to align with Basin Plan timelines.

The Basin Plan must be evaluated every 5 years, and the 2025 evaluation will inform the 10-yearly review of the Basin Plan in 2026.

The socio-economic work for the evaluation is commencing, although at the time of writing no detailed framework was yet available.

It should also be noted that the salinity register entries for actions that occurred prior to the commencement of the Basin Plan in 2012 contribute the vast majority of the total change recorded on the register (EC and $). Further, entries since the Basin Plan was agreed have built on the existing cooperative relationship between the MDBA and the States (evident for at least the past 40 years).

This means that attributing socio-economic benefits of salinity management to the Basin Plan would be difficult. However, an assessment (such as recommended above) for the evaluation of the demonstrable benefits of current salinity management would provide a useful basis for the socio-economic evaluation of Basin Plan salinity management.

Valuation techniques

We propose to include a qualitative assessment of the benefits in the assessment. However, at times some benefits may be possible to value through economic valuation techniques. Cost Benefit Analysis (CBA) is a common tool used to value environmental, social, cultural and economic outcomes. If valuation is required, we will use CBA methodology and frameworks to value impacts. Box 4 provides an overview of CBA methodology.

Box 4: CBA methodology overview

A cost-benefit analysis (CBA) provides a robust framework for assessing the impact of a set of investments or policy options. The general purpose of CBA is to help governments and societies better allocate their scarce productive resources by better understanding and comparing costs and benefits associated with proposed investments or policy options.

A CBA is an assessment tool that compares the costs and benefits associated with the proposals from the perspective of society. CBA includes economic, environmental and social impacts. The analysis is incremental in that it considers whether the proposals generate additional costs and benefits over and above what would happen in a world without the proposals – called the base case.

The conventional output of a CBA is a measure of net-benefit for each option relative to the base case. Typical measures of net-benefit include:

- Net Present Value (NPV), the discounted value of future incremental costs and benefits associated with the proposal
- Benefit Cost Ratio (BCR), a ratio of total incremental benefits to total incremental costs.

If a proposal has an NPV greater than 0 or a BCR of 1 or more, the proposal generates more benefits for society than the costs it imposes. This implies that the proposal is worthwhile pursuing, subject to financial constraints.

Figure 21: Cost-benefit analysis overview

Importantly, some costs and benefits may be challenging or costly to monetise. These impacts are still relevant for decision makers. We will undertake a qualitative assessment alongside the CBA results, as it permits judgements as to whether the unquantified impacts are likely to outweigh any monetised differences between options which can be valued.

Source: Frontier Economics

Appendix 1: Salinity registers

Table 14: Salinity Register A, as at February 2022

	Date Effective	Salinity Effect (EC at Morgan)	Salinity Cost Effect credits ($m/year)			
		2030	NSW	Vic	SA	Total
JOINT WORKS & MEASURES						
Former Salinity & Drainage Works						
Woolpunda SIS	Jan-91	-47.2	0.8	0.8		4.1
Improved Buronga and Mildura/Merbein SIS	Jan-91	-4.2	0.2	0.2		1.0
New Operating Rules for Barr Creek Pumps	Jul-91	-4.9	0.2	0.2		1.2
Waikerie Stage 1 SIS	Dec-92	-13.9	0.2	0.2		1.3
Changed MDBC River Operations 1988 to 2000	Apr-93	-1.6	0.1	0.1		0.8
Mallee Cliffs SIS	Jul-94	-5.0	0.3	0.3		1.5
Changed Operation of Menindee and Lower Darling	Nov-97	0.9	-0.1	-0.1		-0.8
Waikerie Phase 2A SIS	Feb-02	-3.4	0.1	0.1		0.3
Changed MDBC River Operations 2000 to 2002	Feb-02	-1.5	-0.1	-0.1		-0.7
Sub Total - Former Salinity & Drainage Works		-80.8	1.6	1.6	0.0	8.6
Basin Salinity Management Strategy						
Changed MDBC River Operations after 2002	Dec-03	-0.3	0.0	0.0	0.0	0.1
Pyramid Ck GIS	Mar-06	-3.5	0.1	0.1	0.1	0.8
Bookpurnong SIS	Mar-06	-5.7	0.1	0.1	0.1	0.6
Improved Buronga SIS	Mar-06	-0.7	0.0	0.0	0.0	0.2

	Date Effective	Salinity Effect (EC at Morgan)	Salinity Cost Effect credits ($m/year)			
		2030	NSW	Vic	SA	Total
Loxton SIS	Jun-08	-7.8	0.1	0.1	0.1	0.8
Waikerie Lock 2 SIS	Jun-10	-6.1	0.1	0.1	0.1	0.4
Upper Darling SIS	Jun-14	-4.5	0.2	0.2	0.2	1.5
Murtho SIS	Jun-14	-12.3	0.3	0.3	0.3	1.7
Sub Total Joint Works under BSMS		-40.9	1.0	1.0	1.0	6.1
Joint Works Sub Total		***-121.7***	***2.6***	***2.6***	***1.0***	***14.6***
The Living Murray Works and Measures and Water for Rivers						
TLM-RMIF 570 GL	Jun-14					
TLM Works and Measures	Jun-14					
BSM2030						
Responsive Management SIS	Jun-16					
BtG Dilution benefits from delivery&	Jun-15					
MM SIS Refurbishment 2015	Jun-22	-0.9	0.0	0.1	0.0	0.2
BSM2030 and TLM Sub Total		***-0.9***	***0.0***	***0.1***	***0.0***	***0.2***
STATE WORKS & MEASURES						
Shared New South Wales and Victorian Measures						
Permanent Trade Accounting Adjustment - NSW to Victoria	Jun-06	-0.1	0.0	0.0		0.0
Barmah-Millewa Forest Operating Rules	Mar-02	-2.0	0.2	0.2		0.4
Shared Measures Sub Total		-2.0	0.2	0.2	0.0	0.4
New South Wales						
Boggabilla Weir	Dec-91	-0.1	0.0			0.0
Pindari Dam Enlargement	Jul-94	0.7	-0.1			-0.1

	Date Effective	Salinity Effect (EC at Morgan)	Salinity Cost Effect credits ($m/year)			
		2030	NSW	Vic	SA	Total
Tandou pumps from Lower Darling	Sep-94	-0.1	0.0			0.0
NSW MIL LWMP's	Feb-96	-4.0	0.7			0.7
NSW Changes to Edward-Wakool and Escapes	Jan-90	-2.0	0.4			0.4
Permanent Trade Accounting Adjustment - NSW to SA	Jun-06	-0.4	0.1			0.1
NSW Sunraysia Irrigation Development 1997 to 2006	Jul-03	2.4	-0.4			-0.4
NSW Sunraysia Irrigation Development 2006 to 2018	Jul-20					
RISI NSW	Jan-00	-4.1	0.9			0.9
NSW S&DS Commitment Adjustment	Nov-02	0.0	0.9			0.9
New South Wales Works and Measures		*-7.7*	*2.5*			*2.5*
Victoria						
Barr Creek Catchment Strategy	Mar-91	-7.7		2.0		2.0
Tragowel Plains SMP 2002 Drains	Mar-91	0.8		-0.1		-0.1
Shepparton Irrigation Region Land and Water Management Plan	Mar-91	5.6		-1.1		-1.1
Nangiloc-Colignan S.M.P.	Nov-91	0.4		-0.1		-0.1
Nyah to SA Border SMP - Irrigation Development	Jul-03	13.3		-3.0		-3.0
Kerang Lakes/Swan Hill Salinity Management Plan	Jan-00	1.4		-0.4		-0.4
Campaspe West SMP	Aug-93	0.0		0.0		0.0
Psyche Bend	Feb-96	-2.1		0.2		0.5

	Date Effective	Salinity Effect (EC at Morgan)	Salinity Cost Effect credits ($m/year)			
		2030	NSW	Vic	SA	Total
Permanent Trade Accounting Adjustment - Victoria to SA	Jun-06	-0.8		0.2		0.2
Woorinen Irrigation District Excision	Sep-03	0.9		-0.2		-0.2
Sunraysia Drains Drying up	Jun-04	-2.2		0.6		0.6
Lamberts Swamp	Jun-04	-2.7		0.5		0.5
Church's Cut decommissioning	Mar-06	-0.2		0.0		0.0
Mallee Drainage bore decommissioning	Jun-08	-0.3		0.1		0.1
RISI VIC	Jan-00	-8.2		1.8		1.8
GMW Connections Stage 1 and 2	Jun-21					
Victorian S&DS Commitment Adjustment	Nov-02	0.0		1.6		1.6
Victoria Works and Measures		*-1.8*		*2.0*		*2.3*
South Australia						
SA Irrigation Development Based on Footprint Data*	Jul-03	27.4			-2.2	-2.2
SA Irrigation Development Due to Water Trade	Jun-06	-0.1			-0.1	-0.1
SA Irrigation Development Based on Site Use Approvals	Jun-10	1.0			-0.1	-0.1
SA Component of Bookpurnong SIS	Mar-06	-2.6			0.3	0.3
SA Component of Loxton SIS	Jun-08	-0.1			0.0	0.0
SA component of Waikerie Lock 2 SIS	Jun-10	-0.4			0.0	0.0
SA Improved Irrigation Efficiency and Scheme Rehabilitation Reg A	Jan-00	-25.3			3.6	3.6
Qualco Sunlands GWCS	Sep-04	-6.3			0.4	0.4

	Date Effective	Salinity Effect (EC at Morgan)	Salinity Cost Effect credits ($m/year)			
		2030	NSW	Vic	SA	Total
Pike Stage 1 SIS	Jan-12	-3.8			0.5	0.5
SA component of Murtho SIS	Jun-14	-0.3			0.0	0.0
South Australia Subtotal		*-10.5*			*2.4*	*2.4*
Balance - Register A		**-143.8**	**5.3**	**4.9**	**3.4**	**19.4**

Source: MDB Salinity Register as at 11/02/2022

Table 15: Salinity Register B and A+B total, as at February 2022

	Salinity Effect (EC at Morgan)	Salinity Cost Effect credits ($m/year)			
	2030	NSW	Vic	SA	Total
Transfers from Register A		0.7	0.6	1.7	3.1
New South Wales					
Darling Catchment Legacy of History - Macquarie	0.2	0.0			0.0
Darling Catchment Legacy of History - Macintyre	0.0	0.0			0.0
Darling Catchment Legacy of History - Gil Gil Ck	0.0	0.0			0.0
Darling Catchment Legacy of History - Gwydir	0.0	0.0			0.0
Darling Catchment Legacy of History - Namoi	0.3	-0.1			-0.1
Darling Catchment Legacy of History - Castlereagh	0.0	0.0			0.0
Darling Catchment Legacy of History - Bogan	0.1	0.0			0.0
Lachlan Legacy of History	0.0	0.0			0.0
Murrumbidgee Catchment Legacy of History	0.1	0.0			0.0
NSW Mallee - dryland	0.6	-0.1			-0.1
NSW Mallee - Pre 88 Irrigation	0.4	-0.1			-0.1

	Salinity Effect (EC at Morgan)	Salinity Cost Effect credits ($m/year)			
	2030	NSW	Vic	SA	Total
Victoria					
Campaspe Catchment Legacy of History	0.2		0.0		0.0
Goulburn Catchment LoH	0.5		-0.1		-0.1
Loddon Catchment LoH	0.7		-0.1		-0.1
Kiewa Catchment Legacy of History	0.1		0.0		0.0
Ovens Catchment Legacy of History	0.2		0.0		0.0
Victorian Mallee - dryland	1.1		-0.2		-0.2
Victorian Mallee - Pre 88 Irrigation	0.7		-0.2		-0.2
South Australia					
SA Mallee Legacy of History - Dryland	2.9			-0.3	-0.3
SA Mallee Legacy of History - Irrigation	22.2			-2.9	-2.9
SA Improved Irrigation Efficiency and Scheme Rehabilitation Reg B	-40.0			5.3	5.3
Balance - Register B	**-9.7**	**0.4**	**-0.1**	**3.8**	**4.1**
Balance - Registers A & B	**-153.5**	**5.7**	**4.9**	**7.3**	**23.5**

Source: MDB Salinity Register as at 11/02/2022

Appendix 2: Agricultural assumptions

Table 16: Area and yield assumptions

Crop	Total area of crop (ha)	Salt-free yield T/ha
Almonds	4033	1
Annual pasture	276286	11
Apple	3873	38
Apricot	0	18.5
Avocado	542	8
Barley	0	4.25
Carrot	526	30
Cherry	0	10
Cotton	5395	2.43
Grapefruit	294	27.4
Grapes_non_tolerant	27628	20
Grapes_tolerant	16515	20
Lemon	532	25
Lime	0	25
Lucerne	25271	13
Maize)_(grain)	6548	10
Maize_(forage)	7354	18
Onion	734	50
Orange	15707	35
Peach	2925	23
Pear	759	35
Perennial pasture	185401	18
Plum	2019	12
Potato	2283	30
Pumpkin	19379	20
Rice	76965	8.75
Tomato	1006	60
Wheat	82050	4

Table 17: Price and cost assumptions

Crop	Price $/T	Harvest cost $/T	Other costs $/ha
Almonds	5500	1116	1064
Annual_pasture	66	0	121
Apple	360	70.6	3858.4
Apricot	1265	463.3	5734.95
Avocado	2346.95	965.27	4835.56
Barley	145	16.33	283.98
Carrot	200	48.28	1333.27
Cherry	3573	1676.11	2170.87
Cotton	1525	323.73	987.51
Grapefruit	220	52.25	2285.59
Grapes_non_tolerant	448	54.5	730
Grapes_tolerant	448	54.5	730
Lemon	250	55.76	1489.8
Lime	250	55.76	1489.8
Lucerne	120	68.4	198.65
Maize)_(grain)	180	23.85	688.42
Maize_(forage)	85	0	538
Onion	150	98.18	1234.17
Orange	200	52.25	2285.59
Peach	1180	439.52	6324
Pear	270.54	64.46	4239.2
Perennial_pasture	96	0	229
Plum	1265	482	4050
Potato	200	21.3	1566.24
Pumpkin	180	102.3	577.78
Rice	195	29.97	372.34
Tomato	102.5	30	1727.66
Wheat	140	14.6	269.6

Table 18: Soil assumptions

Crop	Intercept_soil	Slope_soil
Almonds	1.5	84
Annual_pasture	1.6	9
Apple	2.5	10
Apricot	1.6	84
Avocado	1.7	64
Barley	3.5	9
Carrot	1	14
Cherry	1.7	84
Cotton	7.7	5.2
Grapefruit	1.8	64
Grapes_non_tolerant	1.5	19.2
Grapes_tolerant	3	19.2
Lemon	1.7	64
Lime	1.7	64
Lucerne	2	7.3
Maize)_(grain)	1.7	12
Maize_(forage)	1.8	7.4
Onion	1.2	16
Orange	1.7	64
Peach	1.7	84
Pear	2.5	10
Perennial_pasture	1.6	8.9
Plum	1.5	72
Potato	1.7	12
Pumpkin	3.2	16
Rice	3	12
Tomato	2.5	9.9
Wheat	2.9	13

Table 19: Assumed foliar responses when overhead spray is the irrigation method

Crop	Intercept_foliar	Slope_foliar
Almonds	0.3	85
Annual_pasture	-999	-999
Apple	0.3	85
Apricot	0.3	85
Avocado	-999	-999
Barley	-999	-999
Carrot	-999	-999
Cherry	0.3	85
Cotton	-999	-999
Grapefruit	0.45	95
Grapes_non_tolerant	0.8	20
Grapes_tolerant	0.8	20
Lemon	0.45	95
Lime	0.45	95
Lucerne	-999	-999
Maize)_(grain)	-999	-999
Maize_(forage)	-999	-999
Onion	-999	-999
Orange	0.45	95
Peach	0.3	85
Pear	0.3	85
Perennial_pasture	-999	-999
Plum	0.3	85
Potato	-999	-999
Pumpkin	-999	-999
Rice	-999	-999
Tomato	-999	-999
Wheat	-999	-999

Note: -999 signifies 'not applicable'.

Frontier Economics

Brisbane | Melbourne | Singapore | Sydney

Frontier Economics Pty Ltd
395 Collins Street Melbourne Victoria 3000

Tel: +61 3 9620 4488
https://www.frontier-economics.com.au

ACN: 087 553 124 ABN: 13 087 553 124