Derivation of a salinity target for the Lower Murray Darling Valley

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Abstract The NSW Government commissioned catchment management boards (CMBs) to set the direction and process for catchment scale natural resource management. In the Lower Murray Darling, Rivers are highly regulated and water resources shared between three states. The Catchment Board only has jurisdiction over the northern bank of the Murray but salt and water enter the river from many locations upstream and along the area boundary. River salt and flow modelling has continually been improved to reflect and contribute to an increased understanding of salinity processes. The MDBC Salt Load study correlates 10 years of actual measured data with its modelled outputs, and estimates river salinities for 2020, 2050 and 2100. Routing models such as SALTFL0 and MURKEY generate percentile salinity levels at different nodes in the River Murray downstream of the Lower Darling confluence.

National, Murray-Darling Basin and NSW salinity management policy and legislative requirements were considered, MDBC model output was used to ensure the interim targets are achievable, auditable, and appropriate to the catchment.

The method for an end-of-valley river based target for salinity is described. A target of less than 463 µS/cm for Lock 6, a point in the lower reaches of the Murray River is recommended for year 2010. Catchment management targets that express the main river salinity risk in five hydrologically distinct management zones are also recommended. Salinity management changes are needed in each zone to meet the end-of-valley target.

Keywords Catchment blueprints; catchment management board; end-of-valley target; Lower Murray Darling; MDBC models; Murray-Darling Basin; river salinity; salinity targets

Introduction
The Lower Murray Darling (LMD) Catchment covers an area of 6.2 million hectares and is located in the far south-western corner of New South Wales (Figure 1). It is a semi-arid region that contains the lower reaches of the Murray and Darling Rivers, as well as the Great Anabranch of the Darling River. The Menindee Lakes storage, Lake Victoria and the Willandra Lakes World Heritage Area also lie within the Catchment’s boundaries. Wetlands of various character and significance occur along the river reaches.

Regulation of water through the Menindee Lakes, the Lower Darling River and Lake Victoria systems is a major resource management feature of the catchment. Water storage and release is managed through these systems in conjunction with Hume and Dartmouth dams to achieve water supply requirements for the three states under the Murray Darling Basin Interstate Water Sharing Agreement. River regulation and water storage has resulted in extensive salinisation of floodplains, and damage to riverine environments from reduced variability and frequency of flows. Under current water management regimes, important wetlands and riverine environments, such as Lake Cawndilla and the Darling Anabranch, are acting as salt sinks and without intervention are expected to continue to degrade. Grazing, land clearing and cropping and irrigation practices are resulting in salt movement to wetlands and rivers from higher than natural recharge of groundwater aquifers (Murphy et al., 1996).

Salinity levels in the Darling River are expected to rise and further impact on towns, irrigation and industry in future (MDBMC, 1999).
High dependence on the river system for consumptive water use has led to development of strategies to address salinity issues. The Salinity and Drainage Strategy (S&D Strategy) of 1989 was developed by the Murray Darling Basin Ministerial Council (MDBMC, 1989) to coordinate the management of salinity in the Murray and lower Darling Rivers and to address land salinisation and water logging in the Murray Darling Basin (MDB). It aimed to reduce salinity in the “shared rivers” of the MDB to ensure that salinity at Morgan in South Australia should be less than 800 µS/cm, 95% of the time.

The Salinity Audit of NSW conducted in 1999 (Beale et al., 2000) provided information on salinity trends. This, together with the setting of salinity targets, offered a new approach to managing salinity. Salinity targets were used to quantify desirable salinity outcomes, manage the cumulative impact of actions at various sites and compare the overall costs and benefits of different actions.

This study is the first step towards developing a new approach to addressing future threats to river salinity in a shared catchment with its different state policies and management approaches. A practical example of setting an end-of-valley salinity target in the LMD valley is presented.

**Issues to consider in setting river salinity targets**

**Policy background**

The NSW Government commissioned catchment management boards (CMBs) to set the direction and process for catchment scale natural resource management and produce a draft Catchment Blueprint. The purpose of the draft Blueprint is to ensure the health of the landscape is maintained by meeting key targets. Blueprints provide focus and direction to individual and community initiatives, facilitate coordinated government investment, such as
extension work and grant funding, and contribute to the implementation of legislation such as the Native Vegetation Conservation Act of 1997 and Water Management Act of 2000.

The NSW Salinity Strategy (DLWC, 2000) document acknowledges the difficulty of setting a target in the LMD area and does not provide a target recommendation. Difficulties arise because salt concentrations are significantly affected by upstream catchment contributions in 3 states, Victorian influences along the South bank of the Murray in the catchment area, and river regulation at a Murray Darling Basin scale.

On average the NSW Salinity Strategy recommends catchments within NSW be expected to achieve approximately a 1% per year reduction in the long term projected increase in river salt concentrations. This means that the NSW Government is expecting salinity management actions to achieve a 10% reduction in the projected salinity in rivers over the 10-year planning period. Planning for management actions to achieve concentration control of this order would be consistent with NSW policy and equitable in terms of financing regional works or initiatives.

The Murray Darling Basin Salinity Strategy (MDBMC, 1998) focuses on achieving a target, which maintains the long-term useability of water in South Australia. They chose protection of Adelaide’s drinking water supply quality as the Murray Darling Basin overall target. This means keeping river water salt concentrations at Morgan below 800 µS/cm for a high proportion of the time (a 95 percentile target prevents undue focus on extreme events).

The approach described includes consideration of the Murray-Darling Basin and NSW salinity management policy and legislative requirements.

**Principles used for setting an end-of-valley target**

The rationale for setting an “end-of-valley” target is that it is all encompassing of the actions within the valley (adverse land use and management or positive management activities). It allows one to summarise the progress in the Catchment Blueprint area towards an accepted outcome for salt management, over a defined time frame.

If the target assessment point is beyond the end of the valley, the outcome achieved is influenced by actions (positive and negative) outside the valley, outside the planning process and outside the Board’s jurisdiction. This reduces the Board’s effectiveness in ensuring that the target is deliverable and reduces the regional accountability. For example if Morgan is chosen as a target site, approximately 30% of the salt passing the audit point will be contributed from sources downstream of the LMD Catchment area. Attributing success or failure to the LMD Blueprint for changes at the point will be difficult because outcomes will be masked by these downstream contributions.

If an overall catchment target is set at a single point within the catchment, audit and progress evaluation relates only to those areas of the catchment that will affect conditions at the site (upstream activities). In effect, the Board is abdicating responsibility for areas downstream of the audit point and issues in the area become, by default, of low priority for funding or government assisted management. For example, if the catchment wide salinity monitoring point were based at Lock 9 (Figure 1), all management actions associated with Lake Victoria would be irrelevant to the Blueprint. Compliance (or meeting the target) could be achieved through actions, resulting in a poor outcome for Lake Victoria.

**Rationale for within-valley target sites**

Using a multiple site approach is most valid where there is a need to protect internal assets and values.

An end-of-valley site is suitable for overall performance evaluation because it provides a summary of all catchment activities. However, this also means that it is not effective as an
adaptive management tool where the cause and effect relationships of specific management actions need to be evaluated. Adaptive management requires monitoring and audit at a smaller scale to ensure that management is focused. Similarly, some parts of the catchment may have serious local problems which are not evident from looking at whole valley average or summary values.

Blueprint compliance can be evaluated using a single river monitoring point close to the South Australia border, but effective adaptive management will require use of several within-catchment monitoring points.

The role and use of models
It is necessary to effectively separate out the salt contributions of changing catchment conditions outside the Blueprint area from those in the area. External contributions are from Victorian tributaries; Victorian floodplain depressions and riverside land management along the Murray; upstream catchments in Queensland, NSW and Victoria; and South Australian contributions as the monitoring point is west of the catchment border.

Separation is only possible with the use of system scale salt mass balance models which track the route of salt through the river system accounting for ground water intrusions or losses, evaporation, river regulation and rain events.

In determining the end-of-valley target, whenever information is available, the Victorian and other contribution have been separated from the NSW contribution and taken into account. These results have been calculated by estimating salt loads from the electrical conductivity (EC) and flow data available for most major tributaries. Accounting style salt mass balance analyses have been performed using the MDBC SALTFO model. Estimates and assumptions in the model still need to be tested and refined over time using new water quality data (the models need further calibration and ground truthing).

We need to use the model to predict compliance or breach of the target under different management scenarios, and climatic conditions. If our target is stated as a percentage of the time a concentration is exceeded; the monthly model will only be precise enough to detect an 8% change in time while daily modelled figures can detect changes of more than 0.3% of the time.

At present the MDBC daily step model (BIGMOD) is used to model flow using a hydrologic technique and model solute concentration up to Lock 9. Therefore MDBC’s Monthly simulation model (MSM) which interfaces with 2 other computer programs, SALTFO and MURKEY, have been used to model and evaluate effects of changed river salinities.

Using estimated salt exports into the future and modelled flow regimes for rivers; MDBC models predicted salinity levels at key stations in the river. The States estimated the salinity predictions used in the model runs for various tributaries.

Selection of an end-of-valley target site
Following the principles outlined above, Lock 9, 7 and 6 sites (Figure 1) were considered. These sites are all nodes within the MDBC monthly model, so there is adequate information for modelling output at these locations.

The river section between Lock 7 and 9 has considerable influence from Victoria, which needs to be removed from the analysis of salinity impact evaluations for the CMB catchment area, but the NSW contributions in this section are small. As such, lock 9 is a better site than lock 7.

Lock 9 is located about 120 Km upstream from the end of the catchment area (Figure 1). Lake Victoria storage leaves the River Murray upstream of Lock 9 and therefore excludes monitoring of the effects of management changes to Lake Victoria and floodplain areas. Potential changes from Lake Victoria management for both total annual salt load and
(through the use of “shandying”) concentration spikes are expected to be highly significant.

Lock 6 is located approximately 30 Km past the end of catchment (Figure 1). Releases from Lake Victoria are made through the outlet regulator into the Rufus River, which joins the River Murray downstream of Lock 7. Hence Lock 6 is considered a better site than Lock 9 and Lock 7 as it can monitor the impacts of any change in management of Lake Victoria and the lower NSW Murray River wetlands. Results will be partly masked by inputs from the Victorian floodplain in the region between Lock 9 and Lock 6. Currently no estimates of salt inflows in between Lock 7 and Lock 6 are included in models.

Lock 6 has sufficient data to allow use of the current model for benchmark and trend evaluation. Lock 6 was neither included in the Murray-Darling Basin Salinity Audit nor documented as a salinity target site in the NSW Salinity Strategy, due to the complexities associated with the shared catchment. However, under these strategies all other inland catchments in NSW have salinity target sites located as close as possible to the end of catchment and incorporating the influences of all tributaries and diversions within those catchments. Selection of this site is therefore consistent with NSW policy, although account must be taken of the influence of the Victorian and South Australian contribution to EC.

Gauging Station Number 426510 down stream of Lock 6, in the Murray River is the closest modelling node to the catchment end. It is an MDBC funded monitoring station operated currently by South Australia Water. It is not located in a weir pool or where substantial local anabranch occurrence would make measurement of salt concentration or flow inaccurate. These issues do affect the other sites considered.

On this basis the CMB selected Lock 6 as the preferred end-of-valley site. The site will now be used to evaluate and monitor the cumulative effects of management actions in the catchment during the implementation phase of the Blueprint.

Climatic variations

When predicting future salt trends, it is generally assumed that changes will occur gradually or smoothly. In practice, this is incorrect, because the weather conditions in any given year strongly influence components of the system such as flow, the source of runoff (surface or groundwater) evaporation and river regulation patterns (water source). The range of concentration values are larger and the pattern of their occurrence in time and space more marked between a dry and a wet year than they are from one year to the next due to long term trend.

To account for climatic variation we can either use modelling to adjust the target value expected for a given year for climatic variation, or ignore the results of individual years and examine the change only at the end of a long period of time. Historical data for a period of up to twenty years still does not provide for accurate prediction of the number of wet and dry years and there is strong evidence that reliability will be further undermined by global climate changes. This means that even if we wait for ten years before interpreting the results of monitoring data to determine compliance with the target, our results will be biased by the climatic conditions specific to the Blueprint period. This is partly why the MDB strategy predictions and processes are based on longer time frames. This leaves the option of model adjustments as the preferred method of accounting for climatic variations.

The effect of removing climatic variations from target assessments provides greater clarity of long-term progress and “softens” the target so that it does not protect against extreme events. For example, if dry conditions tended to result in higher salt concentrations at a monitoring point, without correction, the target would tend to be breached in dry years. When the target is breached, assets are impacted. If we accept impacts on assets in dry years we should correct targets for climatic variation. If we do not, we should not correct targets.
The actions required to protect assets in critically dry years are likely to be very different from those required to protect assets in average years. Accordingly it is recommended that within valley targets set for asset protection purposes should not be climatically corrected but an end-of-valley Blueprint compliance target should be.

Using percentiles
Because the climate in NSW is extremely variable, river flows, salt loads and salinities change significantly over time and location. In setting the targets these climatic variations were accounted for using percentiles. Targets express how often we need or want our rivers to be below critical salinity concentrations. That critical concentration should be determined by considering when crops, drinking water, infrastructure and in-stream ecology are threatened.

The NSW salinity strategy used 50th and 80th percentile values for both load and concentration in expressing salinity targets while the MDBC Salinity strategy used 95th percentile for salinity levels only. These values give an indication of median condition (50th percentile) and extreme conditions (80th or 95th percentile). However, to be consistent with the MDBC target for the Murray River at Morgan, only 95th percentile has been used for the end-of-valley site.

Results and discussion

MBDC’s target at Morgan
In 1989 in order to improve the salinity at Morgan, MDBC set the notional target of 800 µS/cm 95% of the time based on the threshold for desirable drinking water (ANZECC 1992). From 800 µS/cm onwards it becomes increasingly difficult to manage irrigation to prevent damage to tree crops (Ayers et al., 1976).

In order to maintain consistency with the MDBC Salinity and Drainage Strategy (MDBMC, 2000) it was important to study their model and use a similar approach to mathematical calculations to establish a target. MDBC modelled values at Lock 6, which will result in achievement of the MDBC target at Morgan (800 µS/cm 95% of the time), would be appropriate. Unfortunately this value is not available because there are large and variable inputs and extractions of salt from sources downstream of Lock 6 and upstream of Morgan.

The MDBC Salt Load study correlated 10 years of recorded data (1975–85) with its modelled outputs, and estimated river salinities for 2020, 2050 and 2100. It shows that river salinity at Morgan exceeded the 800 µS/cm threshold 42% of the time. Following the implementation of the Salinity and Drainage Strategy between 1990 and 1999, exceedence at this threshold was reduced to 8% of the time. This was achieved mainly because river operations (dilution flows) guaranteed flow entitlements to SA and because pumping schemes, which intercept saline groundwater discharge to river, were established. Also the climatically induced extreme salinity levels experienced before the strategy came into force did not occur.

For comparison, river salinity monthly mean 95% exceedence values at Morgan and Lock 6 have been predicted for 2020, 2050 and 2100 as shown in Table 1.

Predictions in this table are based on output from a monthly time step model. The benchmark data used for this analysis were based on 10 years of actual monthly values. This small sample size is insufficient to forecast trends with great reliability or sensitivity. Future daily time step models will use 25 years of recorded data making 95 percentile predictions more accurate and reliable.
Target setting at Lock 6

At Lock 6, based on actual measured monthly mean EC data for 1975–85, the 42-percentile value was 480 µS/cm. Between 1990 and 1999 river salinity exceeded 467 µS/cm 8% of the time as a nett result of the Salinity and Drainage Strategy (MDBMC, 1999), thus demonstrating marked improvement over pre strategy implementation period. By 2020 the 95% exceedence value of 463 µS/cm at Lock 6 is predicted to increase by 15% from 2000 levels (Table 2) if there are no new interventions other than those in the existing Salinity and Drainage strategy.

With a target of improving salinity at Lock 6, it is proposed to set an end-of-valley target of less than 463 µS/cm 95% of the time by 2020. This represents a decrease of no more than 15% from predicted 2020 levels.

What would the CMB like to achieve in 2010 compared to what will be achieved with no more action? What level of change is required? These questions are addressed by examining the values we want to protect, such as:

- Drinking water quality needs as set out by 800 µS/cm 95% of the time at Morgan in 2020;
- The water needs of saline sensitive crops;
- Important ecosystems; and
- Other assets.

As the targets in NSW have been set for 2010, a end-of-valley Catchment Target of less than 463 µS/cm 95% of the time by 2010 representing a decrease of 8% from predicted 2010 levels has been proposed.

Future directions

As the Murray River is a shared and highly regulated system, the influences of diversions and tributary inflows from Victoria must be clearly accounted for. The use of the MDBC River Murray Modelling suite has enabled us to predict the impact of projected salt export from the NSW Lower Murray Catchment at the end-of-valley target site and at various locations along the River Murray including Morgan in South Australia.

Ideally, to account for climatic variability, more time is needed to evaluate the impacts of management actions and the strategies set in place. Further complications arise from interstate issues, particularly differences in the assumptions the MDBC River Murray Modelling Suite and the way it applies the methodology for estimating their salt inflows.

### Table 1 Predicted river salinity at Morgan and Lock 6

<table>
<thead>
<tr>
<th>Year</th>
<th>Morgan</th>
<th>Lock 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>820</td>
<td>463</td>
</tr>
<tr>
<td>2020</td>
<td>1003</td>
<td>534</td>
</tr>
<tr>
<td>2050</td>
<td>1256</td>
<td>591</td>
</tr>
<tr>
<td>2100</td>
<td>1416</td>
<td>665</td>
</tr>
</tbody>
</table>

### Table 2 Predicted salinity (EC) at Lock 6

<table>
<thead>
<tr>
<th>Target location</th>
<th>Percentiles</th>
<th>Predicted salinity under a current management and trend. (µS/cm EC) Benchmark</th>
<th>Predicted % increase from the year 2000</th>
<th>LMD catchment target for 2010 EC (% of 2000 value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lock six in the Murray River</td>
<td>50</td>
<td>368 393 417</td>
<td>7 13</td>
<td>463 (100%)</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>423 450 477</td>
<td>6 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>463 499 534</td>
<td>8 15</td>
<td></td>
</tr>
</tbody>
</table>
In order to be able to identify new management options and the exact EC benefits a number of projects will need to be undertaken. These include:

- Updating the existing groundwater models to predict actual salt contribution from the LMD area, including a new model for the Lake Victoria area.
- A river salinity monitoring network and surface water models developed compatible with MDBC’s model. This is particularly applicable to the Anabranche, Talyawalka, Frenchman’s Creek and Rufus River systems.
- Extension of the daily model to Lock 6 (already scheduled).

This will significantly increase the previous cost estimate for salinity target monitoring and auditing. However, this work is also recognised in other planning processes.

A status quo salinity level “less than 463 µS/cm 95% of time at Lock 6” appears to be a reasonable target. During or prior to the target timeframe, options can be identified and further reductions made to the target as part of the adaptive management process.

Daily time step modelling will be required to provide the required level of precision and the model will need to account for climatic variations to adjust the target for each year in which compliance evaluation occurs.

Conclusions

The Lower Murray – Darling Catchment Management Board has agreed to adopt a “catchment wide, measurable and achievable salinity target” for the Murray River at the valley end. In order to achieve this Catchment Target, a series of management actions will be required within the valley. The Catchment Salinity Target is a single point summary of salinity concentration and intended to protect water-based assets downstream. Within-catchment concentration targets and load based monitoring has also been developed and recommended to focus management on smaller scale issues. There is a need to complement changes to river regulation with land and vegetation based management action to sustainably achieve the desired salinity changes.

References


