Dryland Salinity Management in the Murray-Darling Basin

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Summary
There has been growing concern over the rapid and unexpected growth of dryland salinity affected land and water resources in the Murray-Darling Basin.

The Murray-Darling Basin (1 million km²) comprises approximately 75% of New South Wales, 56% of Victoria, 15% of Queensland, 7% of South Australia and the entire inland portion of the Australian Capital Territory. The Basin is responsible for approximately 45% of Australia’s agricultural production. Its importance to the nation cannot be overstated.

Dryland salinity has affected the natural resources of the Basin to varying degrees over geological time in response to gradual climate changes. However, since European settlement the conversion of native vegetation to dryland and irrigated agriculture has drastically modified the natural hydrologic balance and exacerbated the problem.

The current extent and rate of spread of dryland salinity is now a cause for serious concern and in some areas, has grave implications for water quality, land and environmental degradation, and the economic and social viability of individuals, communities and regions.

Bio-physical processes, such as dryland salinity, do not recognise political boundaries. Decisions taken on one side of a border may, and frequently do, have profound effects on the other. Rivers and streams provide a conduit between the Basin States through which the disbenefits of land management activities, such as salinity, are transported.

The Murray-Darling Basin Commission has convened an inter-government, technical working group to report on the current status of dryland salinity in the MDB, and to make recommendations for its future management. This paper summarises the Working Group’s findings to date.

Introduction
The inter-government Murray-Darling Basin Ministerial Council, was established in 1985 to provide a strategic focus for coordinating the planning and management of the Basin’s natural resources for sustainable use. The Murray-Darling Basin Commission (MDBC) is responsible for the provision of advice to the Ministerial Council on Basin-wide land, water and environmental management issues and for managing the River Murray. This initiative provides a formal mechanism for delivering Basin-wide coordination of activities to manage dryland salinity.

The Commission has a two part role in the management of dryland salinity:

• The provision of a Basin-wide “context” within which current and future management of dryland salinity is undertaken, particularly with regard to water resources (ground and surface).

• The Basin-wide coordination and, if appropriate, acceleration of dryland salinity management activities, including research, investigations and on-ground actions by Governments and the Basin community.

Before the Commission’s role can be optimised, two fundamental questions must be addressed:

1. Is dryland salinity a significant, Basin-wide, problem?

2. If dryland salinity is a problem, is management technically and economically feasible?

Answering the first question involves understanding the processes driving the development of dryland salinity, quantifying the current bio-physical and socio-economic impacts, monitoring the rate and direction of change, and being able to predict future impacts.
To answer the second question it is important to establish which are the most suitable physical options for management, what degree of management is "acceptable", and where resources can be applied most cost effectively.

To address these questions, the Commission established the "Dryland Salinity Management Working Group". The Working Group comprises membership from the MDBC, the Governments of the Commonwealth, New South Wales, Victoria, South Australia, and Queensland, and the CSIRO.

The Study Area (Figure 1) comprises the entire Murray-Darling Surface Drainage Basin (MDB) with the exception of all significant irrigation areas, and includes that part of the Murray Hydrogeological Basin which lies outside the MDB.

The Working Group's terms of reference prescribed a two stage review process. Stage 1 requires that a statement of the current and anticipated future bio-physical and socio-economic impacts of dryland salinity be prepared. Stage 2 requires that the current management of dryland salinity be evaluated, and that recommendations be made in relation to future management.

The Working Group commenced the review in early 1991 and is required to complete its final report by mid 1992. The information provided in this paper summarises the important findings of Stage 1 of the review.

Dryland Salinity Processes

Definition of Terms

For the purposes of the review, the Working Group agreed on the definition of a number of terms:

Salinity

Salinity refers to the presence of dissolved salts in soil and water (surface and ground). A broad range of dissolved salts may occur naturally in soil and water, but sodium chloride (NaCl) is currently the focus of concern in the MDB.

Units

There exists, in common usage, an confusing array of units to express the concentration of salts in soil and water. The Working Group adopted the Australian Standard of deciSiemens per metre (dS/m) as the unit for soil and water salinity measurement.

Dryland Salinity

The term "primary salinity" refers to "naturally occurring" salinity (ie. not induced by the introduction of "European style" land uses), while "secondary salinity" refers to salinity that has developed in response to the introduction of "European-style" land uses.

The distinction between "dryland" and "irrigation salinity" relates to the process by which groundwater is recharged. If recharge occurs in a dryland situation (ie. non-irrigated), then

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**Figure 1** Composite Study Area and Case Study Areas

![Composite Study Area and Case Study Areas](image-url)
regardless of whether the land surface or streams are affected by saline watertable rise, the process is dryland salinity.

Hereafter, the term “dryland salinity” is used exclusively in reference to secondary, water table related stream and land salinisation.

Areas “at risk”
Areas with the potential to develop dryland salinity in response to changed land use are said to be “at risk”. It is important to note that not all areas are at risk. Whether an area is at risk or not, depends on the complex interaction of a suite of bio-physical factors.

The Cause of Dryland Salinity
It is now generally accepted that the “cause” of dryland salinity is a net annual reduction in plant water use in response to changed land use, particularly the broadscale clearing of native vegetation and its conversion to dryland farming systems.

To date, the agricultural development of the Murray-Darling Basin has involved the clearing of approximately 1/2 million km² of native vegetation (ANON, 1989). This is equivalent to the removal of approximately 12-15 billion trees (Walker et al, in press).

The Commonwealth and all Basin States have in place a broad range of policies and practices which address the management of remaining native vegetation. New South Wales and Queensland have clearing controls applicable to specific locations and under specific conditions. Their frequency of application and effectiveness is, however, difficult to gauge. South Australia and Victoria have State-wide controls regulating the broadscale clearing of native vegetation for agriculture.

In addition to outright mechanical or chemical clearing, there are a number of threats, such as overgrazing and changed frequency and timing of fire, which may constitute de-facto clearing.

Appropriate management of remaining native vegetation and the re-establishment of perennial vegetation (both native and introduced trees, shrubs and pastures) is considered central to confronting dryland salinity.

Groundwater Recharge-Discharge Model
Under many circumstances, changed land use has led to increased groundwater “recharge” and consequent watertable rise. Where rising groundwater (even of low salinity) intersects (or comes within capillary reach of) the land surface or plant roots, discharge may occur by evaporation from the soil surface or evapotranspiration by plants. In the case of low salinity groundwater, non-saline waterlogging may occur initially but if there is insufficient salt export from the discharge site (either horizontally or vertically), salts may be concentrated in the groundwater and/or soil over time. Where highly saline groundwater is involved, salt affected land may develop rapidly.

Where hydraulic connection and gradients make it possible, groundwater may discharge directly into surface waters. Where the groundwater is saline, rising watertables may lead to increased salt accessions to streams. Stream salt loads may also be increased through saline surface runoff from salt affected land.

Hydrologic Equilibrium
Although quantities of water imported through irrigation can be significant, the principal hydrologic input to most catchments is precipitation, generally in the form of rainfall. The principal outputs are evaporation from the land surface, transpiration through vegetation and the natural export of ground and surface waters.

Given sufficient time and stable climatic conditions, all catchments might be expected to establish a state of dynamic hydrological equilibrium, with inflows of water balanced with outflows. It seems reasonable, therefore, to assume that most catchments in Australia were in a form of dynamic equilibrium at the time of European settlement.

As water is the principal vehicle for salt transport, a salt mass balance would also be established under these conditions (Shaw, 1991). At equilibrium, the amount of salt in storage may vary, however, the net input of salt will be equal to the net output.

Accelerated recharge will cause a catchment to move into disequilibrium. Salt export will increase in catchments where salt storage is accessible to the increased throughput of water. It is important to note that not all catchments will become salinised in response to changed land use.

For catchments “at risk”, there is generally a time lag between changed land use and the expression of dryland salinity. This is due to a number of interrelated factors including climate, land use, topography, soils and aquifer system characteristics. The lag time can vary from almost immediate to hundreds of years as is the case for areas in the Mallee Region of South Australia.
Episodic Recharge Events

Dramatic watertable rises at both regional and local scales have been observed in response to exceptionally wet seasons. These episodic "recharge events" are thought to dominate the recharge process in parts of the Murray Hydrogeological Basin, while recharge appears to be more uniform in the local flow systems of the uplands (Macumber, 1990).

Little is known about this episodic recharge phenomenon, other than its threshold nature. Intuitively, it appears likely to be related to effective root depth and perenniality of plants. Conventional wisdom holds that soil depth and effective root depth should be indicators of the recharge buffering capacity of landscapes. Many annual crops and pastures exploit only the upper one or two metres of soil, while perennial pastures may exploit soil to depths of ten metres or more. Native trees and shrubs may exploit much greater depths. Mallee trees have been observed to exploit depths of 28 metres and are extremely efficient at extracting soil water (Nulsen et al, 1985).

It seems likely that episodic recharge events have always occurred, but now occur more frequently where native vegetation has been cleared.

Direct Effects of Salinity

High concentrations of salt may limit plant growth, and adversely affect soil structure and the quality of water supplies (surface and groundwater).

Concentrations of salt in the soil profile may affect the ability of plants to extract water from the soil, even when abundant soil water is available. This is called an osmotic effect, because the plant is required to obtain soil water through its roots against an osmotic (or concentration) gradient. The ability to extract soil water against a range of osmotic gradients varies considerably between species and between individuals within a species (cultivars and varieties in the case of crop plants).

Another adverse effect of salinity on plant growth is that of the toxic (or poisonous) effects of specific ions. When dissolved in water, sodium chloride dissociates into sodium and chloride ions. Plants vary widely in their ability to cope with these ions. Some plants are highly tolerant, while others are extremely sensitive.

Osmotic or toxic effects may range from reduced vigour (yield in the case of crop plants) and symptoms of ill health, to death in extreme cases.

High levels of salt in the soil may cause adverse soil properties such as surface crusting, reduced air and water permeability and mechanical resistance to root penetration (Loveday and Bridge, 1983). These effects have implications for plant growth and accelerated erosion by water and wind.

Where saline irrigation waters are used, salts may be further concentrated in the soil profile by evaporation and evapotranspiration to concentrations which have adverse effects on plant growth. Where water salinities are very high, adverse effects on plant growth may be experienced immediately without further concentration in the soil.

Animals (humans, livestock, native and feral) vary considerably in their ability to tolerate high levels of salt in their drinking water.

Indirect Effects of Salinity

Examples of the indirect effects of salinity include:

- threats to agricultural viability at all levels (individual, community, region and Basin-wide);
- social dislocation of rural communities due to reduced economic activity;
- nature conservation implications due to the degradation of important habitats;
- adverse effects on the quality of water supplies due to turbidity and silation arising from accelerated erosion of salinised soils.

The Bio-physical Dimension of the Problem

Serious concern over dryland salinity in the Basin has a relatively short history (Victoria-early 1980's). This is reflected in the quantity and quality of survey data available. The availability of relevant data varies considerably from State to State, roughly according to the length of time since recognition of the significance of dryland salinity.

Currently, there is considerable activity in this regard, particularly associated with the dryland salinity programs of New South Wales and South Australia. Victoria is well advanced in this and other areas, but for Queensland, where the expression of dryland salinity is relatively minor, few data are available.

For this reason it is not possible, at this stage, to construct a detailed picture of the current extent, severity and rate of change of dryland salinity. Despite the patchy nature (space and time) of biophysical data across the Study Area, the Working Group has aggregated relevant data where available to produce "coarse estimates" of the
extent of dryland salinity affected land and water resources.

Baseline Estimates (1987)
To quantify the rate and direction of change in the expression of dryland salinity it is essential to establish a baseline data set from which to monitor change. An attempt to do this was made in 1987, when it was estimated that there were approximately 52,700 ha of dryland salinity-affected land in the MDB (ANON, 1987). However, no distinction was made between the relative extent of primary and secondary forms, or the degree of severity.

Investigations associated with the development of the Salinity and Drainage Strategy1 had provided an understanding of the effects of irrigation salinity on the water quality of the main stem of the River Murray. However, there was little understanding of the effects of dryland salinity on the Basin’s surface or groundwater resources.

Current Estimates (1992)
Affected Land Resources
Table 1, summarises the best estimates available for the current extent of dryland salinity-affected land and the area of land “at risk” of developing dryland salinity for each of the four Basin States. With the exception of Victoria, the figures expressed should be regarded as broad estimates only and are subject to a high degree of uncertainty.

### Table 1 Estimated Extent, Rate of Growth and Area of Land at Risk

<table>
<thead>
<tr>
<th>State</th>
<th>1992 Estimate</th>
<th>Estimated Area at Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extent (000's ha)</td>
<td>Rate (% per yr)</td>
</tr>
<tr>
<td>NSW</td>
<td>20.0¹</td>
<td>10-15</td>
</tr>
<tr>
<td>Qld</td>
<td>1.2</td>
<td>4</td>
</tr>
<tr>
<td>SA</td>
<td>2.5²</td>
<td>?</td>
</tr>
<tr>
<td>Vic</td>
<td>100.0³</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>74.3⁴</td>
<td>2-5</td>
</tr>
<tr>
<td>Total</td>
<td>198.0</td>
<td>-</td>
</tr>
</tbody>
</table>

¹Acknowledged as a gross underestimate.
²Mount Lofty Ranges component of study area.
³Upper South East component of study area.
⁴Not estimated, actually measured and mapped.

The estimates are for grossly affected sites only (ie. visibly obvious seepage sites or greater than 30% yield loss). As the onset of dryland salinity is difficult to detect in the early stages, current estimates may significantly underestimate the actual area of affected land.

The Working Group is preparing a generalised, Basin-wide dryland salinity occurrence map which will depict areas of “scattered outbreaks” and “isolated occurrences” of affected land. In addition, an attempt is being made to integrate watertable data to provide an overview of watertable rise and groundwater salinity.

Affected Water Resources
As streams act as a conduit to transport salts, the impacts from dryland salinity-affected surface waters may be experienced by downstream water users and the natural environment. The effects may be felt locally, as is the case for the now salt-affected water supply of Yass township, through to Basin-wide, as is the case for the effects on Adelaide’s water supply from the River Murray. A sound understanding of the impacts of dryland salinity on the Basin’s water resources is, therefore, identified as pivotal.

The availability of reliable stream flow data is very patchy across the Basin. Work is being undertaken in all Basin States to monitor and estimate stream salt loads and to develop an understanding of the processes involved.

There can be significant technical difficulties in monitoring surface water salt loads. This is generally due to the large natural fluctuations (noise) in stream salt loads and the relatively slight increases or decreases in long term trends. To date, there has been no concerted attempt to correlate the incidence of dryland salinity with trends in salt loads (quality and quantity) of the Murray or Darling Rivers.

The Working Group has noted the pressing need for an integrated, Basin-wide surface water salt load monitoring program, and the importance of using continuous sampling stations is stressed.

Future Estimates
To date, responding to the threat of dryland salinity has consisted largely of reacting to the problem when it occurs. There is an urgent need to predict where and when the effects are most likely to occur under a range of land use/management options.

With this knowledge, it should be possible to determine those management options which would minimise the effects of salinity, and to
strategically implement preventative actions before the problem is expressed.

As the MDNC is principally concerned with the Basin-wide perspective, attempts are being made to predict the areas of land and streams at risk throughout the Basin. The Working Group is evaluating the potential for combining the outputs of three coarse scale mapping and modelling projects to provide such an overview. The projects are summarised below.

1. Hydro-ecological Modelling

Hydroecological models couple hydrological aspects of water movement through landscapes with plant water use. This approach is being attempted at the regional scale by Dr Joe Walker and Dr Tom Hatton (CSIRO-DWR) in collaboration with Dr Steve Running (University of Montana).

The approach is based on Bio-physical processes and uses soil, vegetation, climate and topographic parameters spatially defined for a region. Leaf area indices (LAI) are defined using AVHRR satellite data, and for this reason the cell size is 2.5 km².

The models output provides the spatial distribution of soil wetness at daily or weekly intervals given the existing vegetation or other vegetation type scenarios. Data can be summarised as maps of mean soil wetness for a particular month or season. These indicate the parts of a region where waterlogging (and hence dryland salinity) can be expected to occur.

In one application, the differences in soil wetness between pre-European and present day vegetation was mapped. This can be interpreted as a waterlogging or salinisation potential map for the region. The method has the potential to predict the likely distribution of dryland salinity in the uplands and upland fringe areas of the MDB.

The limitations of the method lie in the present assumption that salinisation and waterlogging are mainly controlled by topographic influences. This assumption is most likely to be true in the upland areas, but even there it is not always true (refer to Walker et al this conference). Methods are being investigated to estimate salt stores and fluxes using hydrogeological and geomorphological methods and to include these considerations into the modelling approach (J. Walker, pers comm). If this can be achieved, it would be possible to consider the response times for salinisation to occur, or for rehabilitation measures to be effective.

The principal limitation to the application of this modelling approach is the availability of relevant data inputs. If collation of existing data and some active data collection were to commence now, it is anticipated that the approach could be applied Basin-wide within three years (J. Walker, pers comm).

2. Murray Hydrogeological Basin Modelling

A suite of five regional numerical models is being developed for the hydrogeology of the Murray Hydrogeological Basin. The project is being undertaken under the auspices of the MDNC “Groundwater Working Group” and involves collaboration between relevant State and Commonwealth agencies.

The objectives of this modelling exercise are to:

- Determine the scale and timing of the effects of broad scale land-use (both existing and proposed) on recharge and discharge processes in the Murray (Hydrogeological) Basin (MHB);
- Predict the time scale for the spread of groundwater discharge zones within the MHB under existing and modified land-use practices;
- Identify and quantify the major flow components of the groundwater system, and their inter-relationships;
- Evaluate the impact of broadscale control measures upon the hydrologic system, ie. large scale tree planting in the Mallee Region;
- Highlight data deficiencies that can be rectified in future investigations;
- Evaluate the impact of major climate events upon the system, and
- Predict the long-term salt accession from groundwater to the river system under the existing and modified land use.

This regional scale modelling exercise is well advanced. It is anticipated that the project will be completed by mid 1993.

3. Darling River Drainage Basin Hydrogeological Mapping

Commonwealth and State agencies are collaborating in a 1:1 million mapping project in the Darling Drainage Basin (overlies the Great Artesian Basin). The objectives of the project are to:

- Provide early advice on the potential of the Darling River Basin groundwater system to generate both on-site and off-site salinity effects;
• Provide information on current groundwater use and future potential;
• Define groundwater discharge zones;
• Provide information on surface water/groundwater interactions.

This regional scale mapping exercise is due for completion at the end of 1993.

Long Term Climate Change

It has been suggested that warming of the global climate because of the Greenhouse Effect could cause an increase in the Basin’s summer rainfall, a decrease in winter rainfall and a southerly migration of the summer rainfall zone.

The implications for dryland salinity are not clear. One possible outcome is that it may contract. This is based on the assumption that the shift of rainfall patterns from winter to summer dominance would result in more rainfall coinciding with a period of high evaporation and high plant water use. When compared with the present situation, the net result might be a reduction in groundwater recharge.

The Socio-economic Dimension of the Problem

The fundamental prerequisite for any assessment of the economic, financial and social impacts of dryland salinity is the availability of relevant bio-physical impact data upon which to base the assessment. However, as previously stated, the availability of reliable bio-physical impact data is spatially and temporally patchy across the MDB.

All States have conducted, and are continuing to conduct, economic and financial analyses of the costs due to dryland salinity in priority areas.

Table 2  Estimates of Dryland Salinity Costs in Case Study Areas.

<table>
<thead>
<tr>
<th>Catchment Area Dryland (000's ha)</th>
<th>Total Annual Costs (millions $)</th>
<th>Decline in Capital Value (millions $)</th>
<th>Percentage of Gross Catchment Revenue (Agricultural)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Australia:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Upper South East</td>
<td>730.0</td>
<td>7.2</td>
<td>48.0</td>
</tr>
<tr>
<td>Victoria:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Burke’s Flat</td>
<td>0.9</td>
<td>0.015</td>
<td>0.03</td>
</tr>
<tr>
<td>3. Goulburn-Broken</td>
<td>1,900</td>
<td>1.050</td>
<td>3.0</td>
</tr>
<tr>
<td>New South Wales:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Kyeamba</td>
<td>100.1</td>
<td>0.239</td>
<td>0.109</td>
</tr>
<tr>
<td>5. Scenic Road</td>
<td>39.0</td>
<td>0.371</td>
<td>1.75</td>
</tr>
<tr>
<td>6. Liverpool Plains</td>
<td>750.0</td>
<td>25.348</td>
<td>15.0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>3,520</strong></td>
<td><strong>34.348</strong></td>
<td><strong>67.889</strong></td>
</tr>
</tbody>
</table>
Conclusions

The principal conclusions to emerge from Stage 1 of the MDBC Working Group review are:

1. The basic processes associated with the development of dryland salinity are relatively well understood.

2. The availability of relevant bio-physical and socio-economic data is very patchy across the Study Area (spatially and temporally).

3. Despite this patchiness, it is estimated that approximately 198,000 ha of land are currently grossly affected and the area “at risk” is far greater (> 1 million ha).

4. It is estimated that the annual economic costs due to dryland salinity in the Case Study areas alone amount to approximately $34 million. In addition, the decline in capital value is estimated to be $68 million. These costs are particularly significant because the total of the case studies is roughly equivalent to only 3.5% of the MDB. These costs are already affecting the viability of individuals, communities and regions.

5. There is currently a substantial amount of Government and non-government activity to address dryland salinity and considerable scope for its improved coordination.

6. Further clearing of native vegetation should be discouraged, at least, until areas at risk of developing dryland salinity are better defined.

7. The Basin-wide impact of dryland salinity on water resources (particularly surface waters) is poorly understood. There is a pressing need to implement a Basin-wide surface water salt load monitoring program.

8. There is considerable potential for developing a Basin-wide, coarse scale, bio-physical predictive capability within 3 years.

Acknowledgments

The Interim Report of the MDBC Dryland Salinity Management Working Group has formed the basis of this paper. Thanks are expressed to the members of the Working Group for their considerable inputs to the Report.

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References


