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LOWER MURRAY LANDSCAPE FUTURES

Year 2 Progress Report

Glen Walker[1], Rebecca Doble[1], Brett Bryan[1] , Catherine Johnstone[1], Chris Pettit [2], Chatura Ariyaratne[1], Jeff Connor[1] , Neville Crossman[1], Ray Evans [4], , Jon Fawcett [3], Darran King[1], Kerryn McEwan[1], Wendy McIntyre[1] , Joanne McNeill [2], Thea Mech[3] , Matthew Miles[5], Matthew Stenson[1] and Enli Wang[1]

[1] CSIRO Land and Water, [2] Primary Industries, Victoria, [3] University of Adelaide [4] Salient Solutions Australia, [5] Department of Environment and Heritage,

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The Water for a Healthy Country Flagship is a national research partnership between CSIRO, state and federal governments, private and public industry and other research providers.

The Flagship was established in 2003 as part of CSIRO's National Research Flagships initiative. From 2004 to 2011 the initiative will receive $305 million in primary funding from the Australian Government's Backing Australia's Ability program.

The work contained in this report is a collaboration of the Land Technologies Alliance (LTA), a partnership of 5 State agencies and research organisations, who together are the LMLF Project's proponents:

- CSIRO Land and Water
- Primary Industries Research Victoria (Vic DPI)
- The University of Adelaide
- SA Department of Water Land and Biodiversity Conservation (DWLBC)
- South Australian Research and Development Institute (SARDI).

In addition to research provision by LTA members, other research providers include:

- SA Department of Environment and Heritage (DEH), and
- Salient Solutions.

The LMLF Project is funded with NAP funds via, both, the SA Centre for Natural Resource Management (CNRM) and the Victorian NAP/NHT Office and CSIRO Water for a Healthy Country Flagship Program.

For further information contact:
Glen Walker

Fax: 08 8303 8750
email: glen.walker@csiro.au

www.csiro.au

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EXECUTIVE SUMMARY

The Lower Murray Landscape Futures Project set out to analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to social, economic and environmental outcomes, and to explore future options and scenarios for the Lower Murray in partnership with stakeholders in the region. This is the second year of a three-year project. In broad terms, the first of the above objectives is to be achieved during the course of the second year, while the second during the last year. In reality, the first is mostly complete, while there has been significant progress towards the second goal.

The Lower Murray Landscape Futures Project was separated into two parts – one addressing the dryland parts of the Lower Murray region and one addressing salinity and aquatic biodiversity targets relevant to the river corridor. The rationale for this separation is that the riverine corridor is subject to very different economic, land use and environmental processes, issues and insititutions (e.g. irrigation development, agreements on river salinity and environmental flows, zoning, engineering works, riverine management) than the larger area of dryland agriculture away from the river which is dominated by broadacre cereal cropping and livestock grazing in a mosaic of agricultural land and remnant native vegetation. Prominent issues in the dryland areas include biodiversity conservation, river salinity, dryland salinity, wind erosion and soil health. The separation of tasks enables sufficient focus on both areas, given the key differences. Clearly, there is an interaction between these tasks.

Riverine Corridor methodologytrateg

The River Murray Corridor Systems Model provides a method of relating resource conditions at future points in time to targets and actions that are defined and undertaken now. The model is more quantitative than futures modelling, and operates on a defined timescale by quantifying the links between the current state and a state at some point in the future. The model is not a predictive tool that allows impacts to be calculated with confidence. The RMCSM uses understanding of the current state, and adjusts the trajectory from this state depending on external drivers and NRM policies to gain an understanding of potential land management states and resource condition impacts at given times in the future. This type of trajectory modelling allows future impacts to be reconciled with current land management decisions.

Drivers of change and current land use trends are derived from the synthesis of NRM plans for the region and review of current land use change data. A scenario builder is used to calculate estimations of new land use distribution and salt mitigation from combinations of land management actions. SIMPACT ({MDBC 2005 #24318}) is used to calculate salt and groundwater flow impacts from changes in deep drainage and the Floodplain Wetlands Impacts Model (Holland, K.L. et al. (2005)) is used to estimate salinisation risk to floodplain vegetation and wetlands. The potential impacts from land management change are compared against the resource condition targets, and the economic costs of management decisions are outlined.

The scenario builder compiles future scenarios from an inventory of land management actions including:

- building salt interception schemes and disposal options
- policy for zoning new irrigation development
- policy for improving irrigation efficiency of existing irrigation
- retirement of inefficient irrigation
- investment to encourage irrigation development in low impact areas
- increasing perennial and tree based land use in dryland farming systems; and
- revegetation.

Model outputs include salt loads to the river (tonnes/day, EC at Morgan and Equivalent EC), groundwater inflows, floodplain vegetation and wetland risk area, volume of water from SIS requiring disposal in evaporation basins or similar, deep drainage rates from irrigation, costs of applying NRM actions, and total profits from land use activities. In the project's third year,

Dryland methodology

A comprehensive summary and synthesis of the relevant targets contained in the NRM Plans is provided in this report and, where available, quantitative targets are identified for analysis for the three regions. Review of the five existing and relevant NRM plans identified a set of (mostly) quantitative targets that can be modelled in a Strategic Resource Planning model. Analysis of the regional targets required the compilation, validation, integration, synthesis, and assessment of a large volume of spatial data for the dryland areas of the Lower Murray. Significant challenges were encountered during this stage of the project primarily resulting from the absence of common spatial data standards and priorities of the states and regions. Differences in the types of databases available and the extent of coverage, differences in spatial scale and precision, and differences in attribute types, detail and accuracy were stark especially between states but also at even finer scales. To overcome these challenges a variety of GIS-based methods were used to integrate existing databases. This enabled the assembly of a seamless and comprehensive set of biophysical, land use, and economic databases capturing a high level of spatial detail at a high resolution (1 ha grid cells) over the entire Lower Murray region.

Where gaps in data required to assess regional NRM plans occurred, a varietry of existing models was used to create spatial data layers. The Agricultural Production Simulator (APSIM) was used to quantify the spatial distribution of deep drainage and wind erosion based on land use, soil properties, and long term daily climate data. The Land Use Impact Model (LUIM) was used to quantify the risk to biodiversity from various threats based upon a combination of expert opinion and spatial information. The Salinity IMPACT assessment model (SIMPACT) was also used to quantify the spatial distribution of river salinity contribution from dryland areas.

Where no existing models were available, new models have been created to fill data gaps. New models include the quantification of farming systems in the Lower Murray from existing databases, the calculation of expected economic returns to agriculture, the calculation of dryland salinity risk and wind erosion risk, and the calculation of a suite of landscape ecological indicators, amongst several others. The running of these models and the creation of new models has required significant new research including notably, analysis of the Birds Australia survey data to inform some of the parameter choices required in LUIM.

To assess the impact of regional NRM and catchment management plans we need to link on-ground actions to resource condition targets. On land supporting remnant vegetation, vegetation management is the only NRM option available to landholders. Vegetation management can address biodiversity targets only. On cleared agricultural land, landholders can elect to undertake conservation farming, planting deep–rooted perennial fodder crops, or revegetation with a suite of local native species. Conservation farming can address wind erosion and soil health targets, deep-rooted perennial fodder crops can address wind erosion, soil health, dryland salinity and river salinity targets. Finally, revegetation can address all targets.

However, in order to assess the impact of NRM plans we need to spatially locate on-ground actions. There is little guidance in the regional plans on how to set geographic priorities for NRM actions. We use a GIS-based spatial allocation model called Systematic Regional Planning (SRP) (Bryan et al., 2005) to identify locations for on-ground actions to meet resource condition targets. Sites are identified based on explicitly defined geographic priorities.

Models have been built for the 4 actions of vegetation management, revegetation, conservation farming, and deep-rooted fodder crops. The models identify grid cells for each action based on certain strategies – these include a random allocation, cheapest cost, best for biodiversity, best for integrated natural resource management, most cost effective, and a sustainability ideal. Key layers of spatial priorities have been created to guide the spatial allocation of each action – revegetation, vegetation management, conservation farming, and deep rooted perennials. These spatial priority layers include a biodiversity priority layer, a wind erosion priority layer, a dryland salinity priority layer, a river salinity priority layer, and a cost layer. These are used to spatially allocate NRM actions in the Systematic Regional Planning models and assess the impact of NRM plans.

General results of spatial data compilation, synthesis and analysis have identified the following summary characteristics of the entire Lower Murray that are pertinent to NRM targets:

- 45% (5.4 Mha) of the region is under remnant native vegetation,
- 77% of the region is privately owned,
- 22% of the region is at moderately high to extreme risk of soil erosion,
- 170,000ha of the region experience water tables at less than 2m depth, with watertables between 2-5m depth covering 438,000ha of the region,
- 55% of remnant vegetation in the region is under some form of formal protection,
- 40% (n = 100) of all vegetation communities in the SA MDB receive less than 5% formal protection, with over half of those not receiving any formal protection,
- 97% of all remnant vegetation patches are 50ha or less in size,

- Approximately 32,000 individual privately owned properties are engaged in dryland cropping, grazing and grazing native vegetation within the non-floodplain, non-irrigated areas.

Preliminary results of Riverine Corridor modelling

The riverine corridor model has been completed,for the two resource condition targets relevant to the region, river salt loads and floodplain salinity impacts. The remaining two targets are covered by the dryland modelling section of the project. The RMCSM showed that dryland processes had an almost negligible effect on either river salinity or floodplain salinisation risk.

The River Murray Corridor Systems Model has enabled the aggregated impacts of multiple policy and land management actions to be evaluated against the environmental targets of river salt loads and floodplain salt impacts. It has enabled the results from various combinations of different land management actions to be combined in a way that was not intuitive. The model therefore advances our understanding of the Lower Murray Region as a system.

The results from modelling have shown that:

- There is very little impact in the next 100 years from changes in dryland processes such as revegetation and increasing perennial crops relative to actions that are applied to irrigation regions.
- The impact from historical developments far surpasses the impacts from change in the next 10 years.
- Out of the land management actions that are applied to the irrigation regions directly, interception of salt through groundwater pumping has the largest benefit to river salt loads and floodplain salinity risk.
- There is still a large capacity to improve water use efficiency, particularly through system improvement. Whilst the theoretical capacity to improve efficiency is high, the practical ability to improve is reduced by the cost of changing systems and management and the timeframe required, depending on the age and lifespan of the current systems. Improving efficiency needs to be weighed up against the salt impacts on crops.
- Zoning policies for new irrigation developments and encouraging best practice management do have an appreciable benefit on river salt loads, and may reduce groundwater disposal requirements.

In systems models, the uncertainty in results is a function of the uncertainty in input data and sensitivity of the result to that data. In the River Murray Corridor Systems Model, areas of uncertainty are identified as:

- Legacy of History Data for South Australia. Although this input data has been generated from SIMPACT, a model that uses the same algorithms as SIMRAT, which has been accredited by the MDBC as fit for purpose for calculating the impacts of water trades, it has the highest impact on modelled salt loads to the river. Small changes in Legacy of History data will have observable impacts on environmental targets. Validation of the Legacy of History data against MODFLOW model outputs is currently being undertaken.
- Deep drainage from different irrigation systems and management. Deep drainage inputs will affect the change in salt loads to the river from

new irrigation and improvements in irrigation efficiency. Although this has a smaller impact on final salt load and floodplain salinity outputs than the legacy of history, accurate quantification is required. The model currently uses the best available data. Field based research to quantify changes in deep drainage for different management, irrigation systems and crop types is required, and results used to update the RMCSM input data as it becomes available.

- Current rates of change of crop types and irrigation systems and management are used to define the baseline scenario. Whilst quantifying current proportions of different types of systems and management is possible using crop surveys, the confidence in the rate of change of systems is decreased by a lack of information over a longer period of time.

The areas of uncertainty discussed highlight the intent of the RMCSM as a regional planning tool rather than a method of accounting salt impacts. It provides a means of comparing actions or combinations of actions, and identifying land management combinations with the highest potential to address river and floodplain impacts. Once identified, these actions should go through further more detailed analysis before implementation.

While the target of 800 EC at Morgan 95% of the time is only able to be evaluated with the inclusion of a stochastic flow component within the model, conceptually it may be achieved if the salt loads to the river remain comparable to current salt loads. If the plans do achieve the targets, it will be through the primarily through optimally applied salt interception schemes, with the additional benefits from actions targeting irrigation areas directly, such as technology transfer to improve water use efficiency and zoning policies. Both river salt loads and floodplain salinity are only able to be kept at current levels through the use of salt interception schemes.

Whether the NRM targets are met also depends on external drivers such as the incoming EC upstream of the region and the magnitude and frequency of flows through the modelled reach. It should be noted that the modelling was undertaken for a single ten year period of development, therefore the results represent the minimum salt loads to be expected. If the rate of development continued indefinitely, the environmental impacts would be increased.

The objectives of the LMLF Project are to analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to community well-being, and to explore future options and scenarios for the Lower Murray in partnership with stakeholders in the region. This report represents the achievement of the first objective, analysing the impacts of the existing regional plans and investment strategies.

On inspection of the results, the development of salt interception schemes has the most rapid impact on river salt loads and floodplain vegetation health, but at a great cost. The volumes of water requiring disposal from existing schemes already exceeds the current disposal capacity, therefore further investment in disposal is required. Irrigation zoning reduces the ultimate salt load impacts at 2100 slightly more than improving water use efficiency, but the effects of improving WUE are seen earlier. This is thought to be a result of the large area of current irrigation and the closer proximity to the river than zoned new developments. Any action involving management of irrigation has a significantly greater impact on river salt loads than managing dryland farming practices. The impact of dryland farming management on floodplain salinisation and riparian vegetation health is negligible.

Management implications from this study include:

- The impact from historical developments far surpasses the impacts from change in the next 10 years.
- Out of the land management actions that are applied to the irrigation regions directly, interception of salt through groundwater pumping has the largest benefit to river salt loads and floodplain salinity risk.
- Zoning policies for new irrigation developments and encouraging best practice management do have an appreciable benefit on river salt loads, and may reduce groundwater disposal requirements.
- The ultimate salt load reduction from zoning at 100% efficiency after 100 years was found to be slightly greater than the effects from changing water use efficiency, but the improvement of irrigation systems and management had a more rapid impact on salt loads to the river.
- There is still a large capacity to improve water use efficiency, particularly through system improvement. This is limited by the dependence of this change on capital investment and crop yield reduction associated with too high a water use efficiency.
- There is very little impact from changes in dryland processes such as revegetation and increasing perennial crops relative to actions that are applied to irrigation regions at this timescale
- The Floodplain Impacts Model indicated that floodplain salinity risk was minimally affected by changes in deep drainage from landscape management practices. Interception of groundwater through groundwater pumping was the major driver for improvements in floodplain salinity risk.

Preliminary modelling results for dryland region

SAMDB: Increase vegetation cover by 1%; re-establish 950ha of vegetation.

Performance Indicator	Random	Cheapest	Best 4Bio	Best 4INRM	Most Cost Effective	Sustain ability Ideal
Area of Revegetation (ha)	30,748	30,748	30,748	30,748	30,748	340,279
Proximity to Remnant Vegetation (m)	1,087	705	185	388	573	883
Proximity to High Risk Vegetation Index	2.51	2.31	1.43	1.88	2.07	2.37
Fragmentation Index	4.38	3.63	4.01	3.99	3.99	4.47
Wind Erosion Risk	3.26	3.11	3.97	2.44	2.94	3.11
Dryland Salinity Risk	4.36	4.40	3.91	3.58	3.82	4.23
River Salinity (ECs)	0.0177	0.0024	0.0001	0.2208	0.0886	0.1160
River Salinity (tonnes/day)	0.0025	0.0002	0.0012	0.0361	0.0088	0.0373
Opportunity Cost ($M NPV)	17.6	3.2	16.7	18.4	5.3	136.9
Establishment Cost (Low Estimate, $M)	15.4	15.4	15.4	15.4	15.4	170.1
Establishment Cost (High Estimate, $M)	92.2	92.2	92.2	92.2	92.2	1,020.8

MALLEE: Increase cover of each EVCX to 15% of pre-European extent; 30% cover across each bioregion.

Performance Indicator	Random	Cheapest	Best4Bio	Best4INRM	Most Cost Effective	Sustain ability Ideal
Area of Revegetation (ha)	140,549	140,549	140,549	140,549	140,550	232,771
Proximity to Remnant Vegetation (m)	1,020	1,204	273	487	821	801
Proximity to High Risk Vegetation Index	2.57	2.66	1.54	1.89	2.24	2.29
Fragmentation Index	4.48	4.46	4.36	4.22	4.29	4.44
Wind Erosion Risk	2.92	2.74	3.07	2.71	2.65	2.91
Dryland Salinity Risk	4.22	4.36	4.27	3.87	4.19	4.16
River Salinity (ECs)	0	0	0	0	0	0
River Salinity (tonnes/day)	0	0	0	0	0	0
Opportunity Cost ($M NPV)	1,349.7	273.2	391.3	366.6	287.9	572.5
Establishment Cost (Low Estimate, $M)	261	70.3	70.3	70.3	70.3	116.4
Establishment Cost (High Estimate, $M)	1,566.1	421.6	421.6	421.6	421.6	698.3

WIMMERA: 750ha of revegetation per year in priority EVCs, amounting to 11,250ha by 2020.						
Performance Indicator	**Random**	**Cheapest**	**Best4Bio**	**Best4INRM**	**Most Cost Effective**	**Sustainability Ideal**
Area of Revegetation (ha)	11,250	11,250	11,250	11,250	11,250	412,380
Proximity to Remnant Vegetation (m)	1,197	985	157	403	568	1,024
Proximity to High Risk Vegetation Index	2.31	2.60	1.23	1.68	2.16	2.09
Fragmentation Index	4.50	3.92	3.28	3.73	4.01	4.48
Wind Erosion Risk	3.77	4.97	3.74	3.24	3.42	3.61
Dryland Salinity Risk	3.54	2.10	3.30	2.21	2.05	3.27
River Salinity (ECs)	0.00	0.00	0.00	0.00	0.00	0.00
River Salinity (tonnes/day)	0.00	0.00	0.00	0.00	0.00	0.00
Opportunity Cost ($M NPV)	33.6	13.3	31.7	23.3	14.7	1.1
Establishment Cost (Low Estimate, $M)	5.6	5.6	5.6	5.6	5.6	206.2
Establishment Cost (High Estimate, $M)	33.8	33.8	33.8	33.8	33.8	1,237.1

Regional socio-economic trends

The Review of Social and Economic Trends component of the Lower Murray Landscape Futures Project is the first of four social and economic research tasks. The Review provides a snapshot of trends across Wimmera and Mallee catchment areas in Victoria and the South Australian Murray-Darling Basin region and looks at the relationship between the trends and characteristics and factors that may encourage adoption of practices and behaviours that contribute to actions designed to meet natural resource targets. The focus of the study is on agricultural land and farmers.

Given the geographic scale of the study area, the number of actions identified in catchment and natural resource management plans, availability of relevant data and the resources available for this stage of the social and economic research, the review provides a snapshot rather than a detailed analysis across the study area. Areas or issues that require a finer level of detail and analysis will be identified and examined in future stages of the project.

The trends identified for focus in the study are: terms of trade, size and number of farms, number and age of farmers, changing population characteristics in rural communities, participation in programs, training and learning activities. These trends have been identified by, and are examined from the perspectives of, key informants throughout the study area and review of available literature and data.

The research confirms much of what is already known generally across a wider geographic area – farms are getting fewer and bigger; farmers are getting fewer and generally older; smaller rural communities are mostly losing population, some regional towns are increasing in population – in some cases holding their own and in some cases thriving - and season after season of drought has made life difficult for many people.

A less widely reported or examined issue from the perspective of catchment management is that of labour and skill shortages and the impact of this on productivity, land management and local social infrastructure. Other less anticipated issues included reports of steady increases in land prices in most areas despite successive drought seasons and identification of climate change by a range of study participants as a trend that needs to be addressed and better incorporated into planning.

The implications of these trends for implementation of catchment or natural resource management plan actions are mixed. The potential for younger farmers to enter the sector is seen to provide opportunities for the future but with a need to ensure rural towns provide the social infrastructure to make farm life an appealing prospect for families. Increases in the size and decreases in the number of farms provides potential for entry by those with more resources with a linked assumption of better management, or it may see off-site owners who don't contribute to the community or neighbours buying up farms and trying to manage larger areas with fewer people.

The story from the perspective of key informants in the study is about observing and living with these trends, incorporating considerations about the trends into their lives, decisions and businesses, and looking to the future with a sense of optimism.

Visualisation scoping study

Various options for providing front-end visualisation capability to the scenario modelling have been scoped. Visualisation technologies offer a means for enhancing the scientific communication of existing conditions and likely landscape scenarios to various stakeholder groups including communities, natural resource managers, and policy-makers. The paper provides some background description on visualisation including definitions and discussion of visualisation as a *connecting science*. Taxonomy of fourteen visualisation types is provided with accompanying descriptions and annotated examples. A user needs survey for visualisation in the LMLF project as been conducted, and the results are provided in the accompanying Appendix (A). From the user feedback of stakeholders and modellers four options for deploying visualisation capability within the project have been presented for the LMLF Steering Committee to consider.

Progress against milestones

The milestones for Year 2 are listed in the Table below. There are differences between Victorian and South Australian milestones and the relevant milestones are labelled with ‘V’ for Victorian and ‘S’ for South Australian.

Milestones (V: Victoria, S: South Australia)	**Output**	**Progress**	**Section**
V1: LMLF Phase 2 research workplan and schedules developed and documented, covering environmental, social and economic analyses of Lower Murray landscape futures in the Mallee region, and the Wimmera region.	**O1**: Approved workplan	**Complete.**	
V2: LMLF Phase 2 research workplan presented to, and signed off by, Steering Committee at March 2005 Steering Committee meeting.			
V3: Regional workshop of research team and regional stakeholders held in Mildura to develop landscape futures modelling scenarios for Mallee region.	**O2**: Future scenarios workshops/meetings in SA, Vic. Mallee and Wimmera – future scenarios decided	**Complete**	**5.4**
V4: Regional workshop of research team and regional stakeholders held in Horsham to develop landscape futures modelling scenarios for Wimmera region. **S4:** Engagement with regional stakeholders (PSC meeting at 3monthly intervals, phone hook-ups and ad hoc visits between; workshops to develop scenarios and testing model.	**O7**: Other Evidence of regional engagement	**Complete**	**5.3-5.6**
V5: Interim Year 2 Progress Report charting modelling and scenario testing progress. Prepared as a written report submitted to SC and Vic NAP Office, and Presented to SC at June SC meeting.	**O2**: Interim mid-year report:	**Complete. Sent to NAP Offices**	
V6, S5: Completion of Final Yr 2 Report, and its submission to Steering Committee at Dec 05 meeting, and to Vic NAP Office.	**O6**:Final Year 2 Report	**This report**	

V7: Interactive demonstration of completed Yr 2 landscape futures analyses at appropriate regional stakeholder forum. **S2**: Completion of riverine corridor model with respect to all 4 resource condition targets. • Inclusion of all 4 resource targets • Inclusion of Victorian Mallee • Inclusion of higher resolution study site. **S3**: Completion of broader modelling area, as developed in consultation with stakeholders. • Model specification • Model completion.	**O4**: Riverine Corridor Model including expansion into Victoria and other NRM issues.	**Model and GUI complete. To be demonstrated at next Regional Stakeholder meeting in April**	**Chapter 3**
	O5: Whole-region analyses for biodiversity and wind erosion	**Complete**	**Chapter 4**
S1: Progress of socio-economic component as outlined in the Year 1 report.	**O8**: Review of demographic and adoption data	**Complete**	**Chapter 5**
S6: Project management.	**O10**: Other project management outputs: contracts, meetings, reporting, internal communication	**Complete**	**Chapter 5**

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The LMLF Project receives funding from the National Action Plan for Salinity and Water Quality (NAP) via, both, the Victorian NAP/NHT Office and the South Australian Centre for Natural Resource Management (CNRM), as well as funding from CSIRO Water for a Healthy Country (WfHC) Flagship Program. Thanks and acknowledgements are given to Ms Kate Lottkowitz and Mr Peter Forbes of the Victorian NAP/NHT Office, Deborah Clark and Neil Collins of the CNRM, Dr John Radcliffe, Chair of the South Australian CNRM's Investment Advisory Board, and Dr Sarah Ryan and Warwick MacDonald of the CSIRO Water for a Healthy Country (WfHC) Flagship Program for the continuing support of their respective institutions for this project.

Thanks and acknowledgements are given to all members of the LMLF Steering Committee who together represent a partnership that has come together for the purpose of ensuring that the NRM research undertaken is regional stakeholder-driven, and problem-solving in nature. The LMLF Project Steering Committee enjoys representation from Dr Wayne Meyer of CSIRO Land and Water (Chair), Mr Andrew Beal of the Mallee Catchment Management Authority (Victoria), Mr John Berger of the Murray Darling Basin Integrated Natural Resource Management (MDB INRM) Group (SA), Mr John Johnson of the River Murray Catchment Water Management Board (RMCWMB) (SA), Mr John Young of the Wimmera Catchment Management Authority (Victoria), Dr Sarah Ryan of the CSIRO Water for a Healthy Country Flagship (WfHC), Dr Garry McDonald from Primary Industries Research Victoria (PIRVic), Mr Rod Griffith from the Murray Darling Basin Commission (MDBC), Mr Phil Cole and Mr John Bourne of the South Australian Department for Water, Land and Biodiversity Conservation (DWLBC), Mr Shayne Annett of the Victorian Department of Sustainability and Environment (DSE), Mr Rob Thomas of the South Australian Research and Development Institute (SARDI), Mr Bill Tatnell of the Lower Murray-Darling Catchment Management Authority (LMD CMA, NSW), and Dr David Coventry of the University of Adelaide. The LMLF Project has also welcomed the strong regional NRM stakeholder guidance and input of the Lower Murray Tri-State Forum (Victoria, SA, NSW).

The Technical Working group, formed by the LTA, has provided useful support for the research management of the project. Membership includes Peter Butler (DWLBC), Gerrit Schrale and Peter Hayman (SARDI), Garry O'Leary (DPI), Jim Cox (CLW), Bill Belotti and Thea Mech (University of Adelaide). Reference groups for the riverine and dryland components for the project were formed to develop scenarios for the 3rd year project. Membership included for the Riverine Panel: John Cooke(DSE), Trent Wallace (Mallee CMA), John Bourne (DWLBC), Bob Newman (MDBC), Chris Biersaga (Mallee CMA), Phil Cole (DWLBC), Dan Meldrum (RMWCMB), Lisa Mensforth (DWLBC), Gerry Davies (PIRSA) and Gerrit Schrale (SARDI) and for the Dryland Panel: Glenn Gale (DWLBC), Jo Latta(Mallee CMA), Nigel Willoughby (DEH),Garry O'Leary (PIRVic), Kate Lottkowitz (Vic NAP Office) and Bernie Dunn(WCMA). Technical Input was also received from Tony Adams (Rural Solutions SA) and Tapas Biswas (SARDI).

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1 INTRODUCTION

The Lower Murray Landscape Futures (LMLF) Project is an ambitious collaborative and multi-regional endeavour that brings together a partnership of research organisations, state government agencies and regional stakeholders from across South Australia, Victoria and New South Wales. The LMLF partnership has a shared commitment to broaden and deepen the way we think about natural resources management and our future landscapes.

The project was conceived in recognition of the fact that Australia is ready for an integrated approach to natural resource management, which accounts for the full costs and impacts of land use and development. Fundamental to this is the incorporation of an understanding of social, economic and biophysical processes and, most importantly, their interactions.

The LMLF Project is jointly funded under the South Australian and Victorian National Action Plan (NAP) for Salinity and Water Quality and the CSIRO Water for a Healthy Country (WfHC) Flagship Program.

1.1. LMLF Project aims

The aims of the LMLF Project are to:

- Analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to community well-being (social, economic and environmental outcomes), and
- Explore future options and scenarios for the Lower Murray in partnership with stakeholders in the region.

These aims intend to enable regional communities explore alternative social, economic and environmental landscapes, leading to improved outcomes from investment by regional planning groups, communities, industry and government.

As such, the LMLF Project's conceptual scope includes:

- Enabling regional bodies to evaluate the potential implications of regional plans and investment strategies, particularly the ability to achieve regional targets.
- Establishing a mechanism to enable Regional Bodies in the Lower Murray NAP Region to evaluate the impacts of the Regional Investment Strategies across the whole region.
- Analysing existing regional plans and strategies for their likely impact on the landscape and community well being over the next 5 to 30 years for the Lower Murray NAP region.
- Empowering stakeholders in the region to explore and test alternative "future scenarios", without spending 20 years of trial and error.
- Exploring what are the landscapes that maximise community wellbeing.

- Creating a new standard for bringing together scientific rigour and community aspirations.

The LMLF Project geographical boundaries cover the NAP regions shown in Figure 1.1 below.

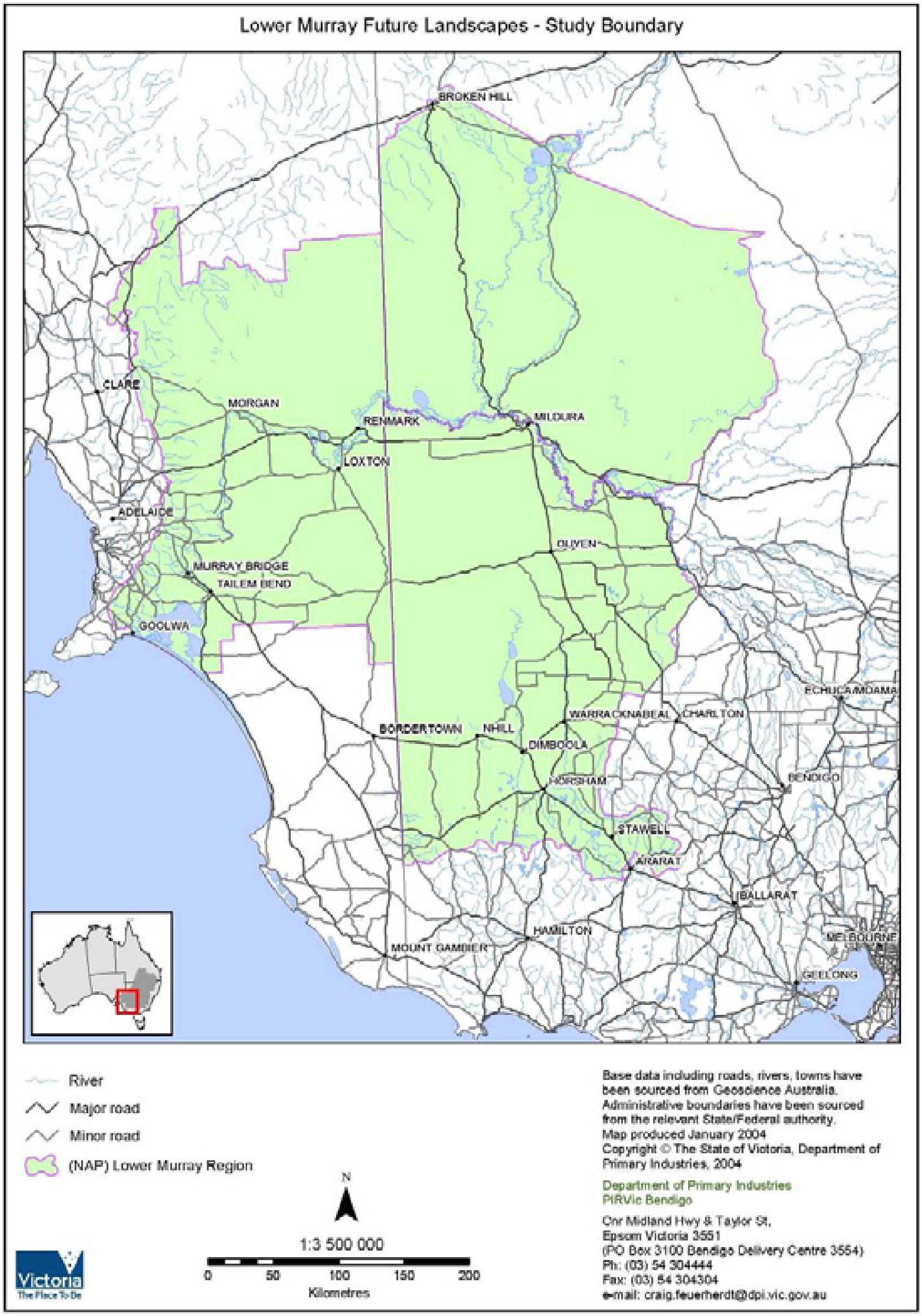


Figure 1.1 Geographical boundary of the LMLF Project

1.2. General Approach

1.2.1. Objective 1

The first objective of the project is to analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to community well-being (social, economic and environmental outcomes). For this purpose, we conceptualise the natural resource process as in Figure 1.2.

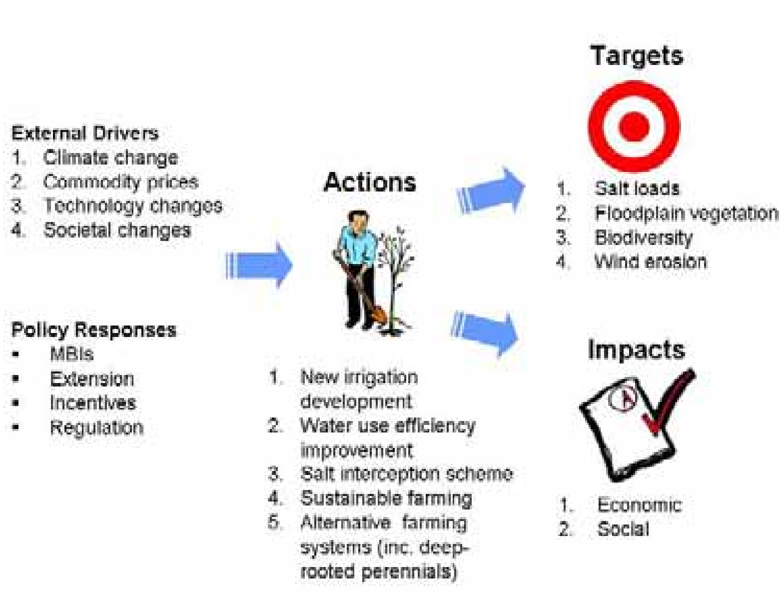


Figure. 1.2 Conceptual approach used in project to relate RCTs and socio-economic impacts of plans

At the heart of Figure 1.2 are the aggregated regional on-ground actions that lead to changes in the resource condition. These may be changes in land use and land and river management. These actions are partly driven by policies reflected in the regional and state NRM plans. An example of policy may be irrigation zoning which aims to shift some of the new development that would have otherwise occurred in areas of high salinity impact to those of low salinity impact. However, we need to recognise that shifts in on-ground actions are mostly affected by external drivers such as commodity prices, availability of water, technological innovation and climate change.

Resource condition targets (RCTs) are the agreed set of regional environmental outcomes being sought. They provide a focus for prioritising actions and investments and for reporting progress against environmental outcomes. However, the current sets of RCT's were often formed without adequate baseline information. The measures of resource condition vary across the region and in the case of the Wimmera have not been set. For the LMLF project, we have chosen a consistent measure of RCT across the region and will assume that the target will change into the future once better information is obtained.

The on-ground actions also affect the regional social and economic status. Individual policies such as irrigation zoning may affect the cost of production through additional pipe-work or increasing the difficulty of keeping properties owned by a single enterprise together. Collectively, a set of policies may inhibit growth or create opportunities. Depending on the industry involved, these flow onto associated processing activities and to the region as a whole.

Figure. 1.2 is necessarily a simplified diagram. It does not show feedbacks such as from social and economic costs to on-ground actions. It also conceals some difficulties in predicting how policies and external drivers may influence on-ground actions and how on-ground actions may affect RCT's and social and economic impacts.

1.2.2. Assessing impact

Figure 1.2 conceals a time delay between the NRM policies to the left and the impacts on RCT's and regional social and economic condition on the right. Figure 1.3 shows this more explicitly.

The resource condition of interested is plotted on y-axis against time (years) into the future. In this figure, at time zero (now), the NRM plans are assumed to be put into place and result in changes in on-ground actions over the next 5 to 10 years. Even without the NRM plans, there may have been a change in the resource condition. This may be due to changes in land-use that may have occurred for other reasons or it may be due to processes already in train. This trajectory of the resource condition is referred to as the 'baseline'. The change in land use may then lead to a change in the resource condition relative to the baseline. This is then assessed at some given time, described in the NRM plans. The change in resource condition is shown in Figure 1.3 as the 'impact'. The NRM plans generally set target values for the resource condition. The NRM plans are judged as successful if the resource condition falls below the Target value.

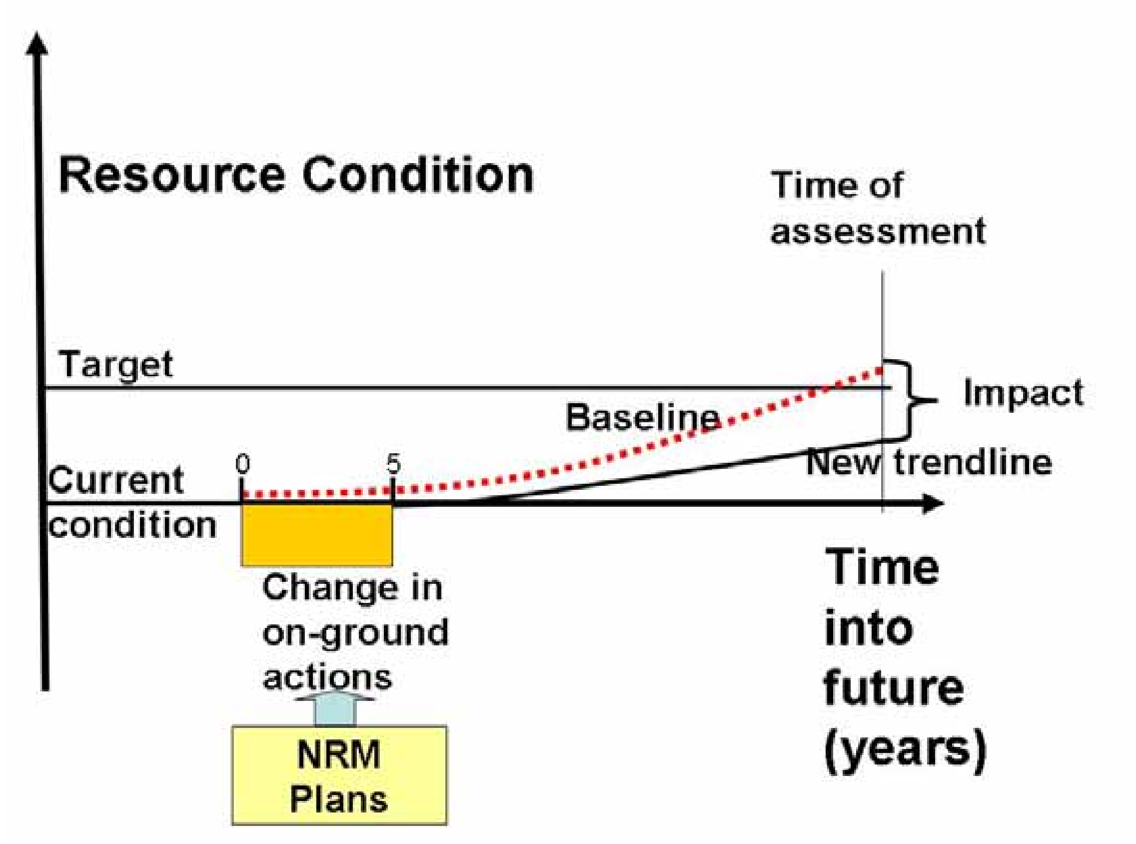


Figure 1.3 Conceptual figure of how the impact of NRM plans may be assessed

1.2.3. Multiple resource conditions

Regional plans will affect more than one resource condition and a number of RCTs have been defined as part of the plan. The above analysis can be done for each of these RCTs (see Figure 1.4). The composite forms an imperfect measure of environmental impacts. Spatial specificity is often important and most measures of biodiversity are poor. There may be trade-offs between different resource conditions and an important part of this project will be to work out how to best represent these trade-offs. Figure 1.4 shows a representation of how some resource conditions may be affected positively while others negatively.

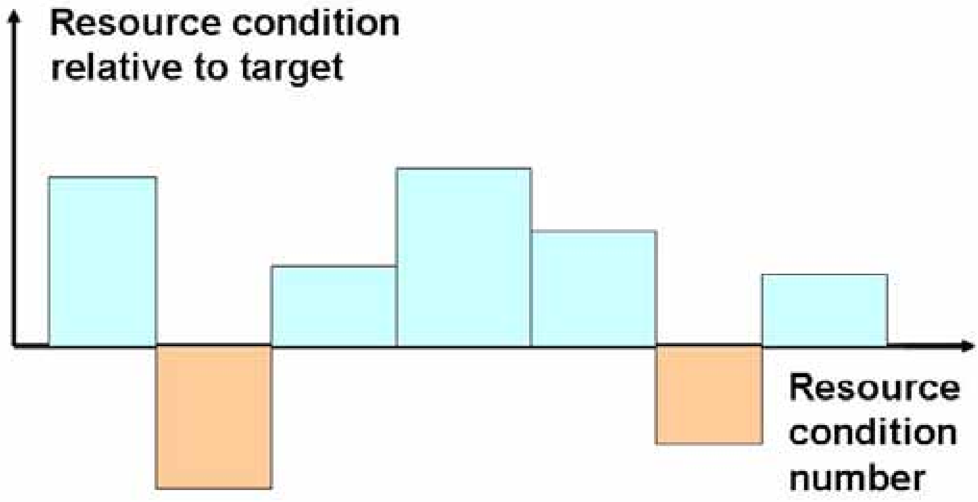


Figure 1.4 One form of representation of multiple impacts

1.2.4. Socio-economic impacts

An important component of the project will be the assessment of socio-economic impacts of the NRM plans. Conceptually, these can be considered in the same fashion (see Figure 1.5). Again, it will important to :

- define practical and relevant socio-economic indicators,
- represent trade-offs between individual socio-economic indicators and between socio-economic indicators and environmental indicators,
- note there will be spatial specificity and for some impacts and
- note there will be no ideal indicators.

Taken together, these indicators form an imperfect measure of the 'triple-bottom line' (social, economic and environmental) values and when combined with some value judgement of social acceptance forms a measure of community well-being. We will refer to the combination of indicators as the system state.

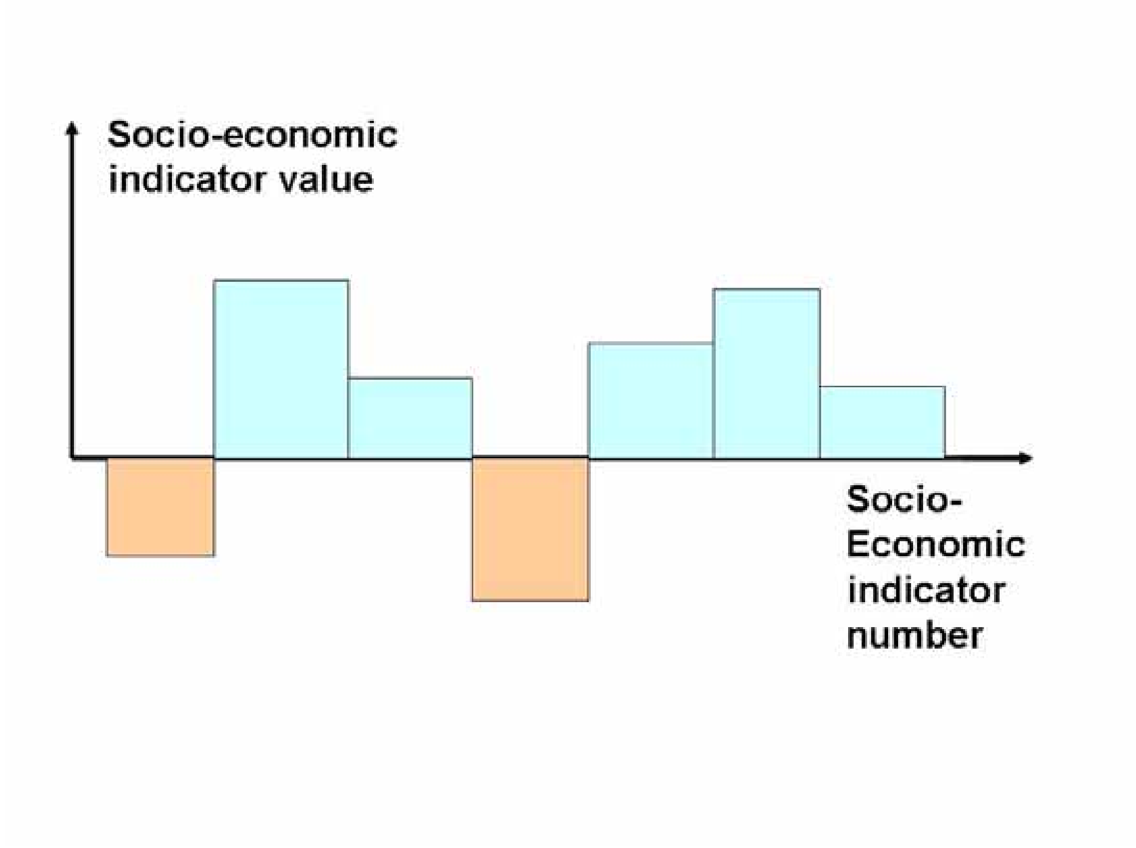


Figure 1.5 One representation of socio-economic indicators.

1.2.5. Different time-scales

In Figure 1.3, it has been assumed that the NRM plan will lead to on-ground actions over the next 5 to 10 years. This can be mixed. Salt interception schemes may be implemented relatively quickly and their impact on stream salinity can be quick. Similarly, their impact is reversed quickly when turned off. On the other hand, the use of infrastructure to encourage irrigation to low impact zones may affect development over 20 or 30 years. In turn, there may be long time delays between shifting water and for the salinity in the river to be affected. It is important within the regional planning context to consider both short-term effects and long-term effects. One may want to mix actions to protect assets in the short-term while longer-term actions take hold.

However, for the longer term, it becomes increasingly difficult to predict on-ground actions and impacts on RCTs and regional social end economic impacts. External drivers such as commodity prices, new technology, water allocation outside of the region and climate may all be changing. Also, NRM plans will evolve over time, as they are reviewed. Even with the current plans, there is considerable flexibility in how actions may be implemented. It is, nonetheless still useful to use models to explore what may occur. The models thus change from being predictive (and hence requiring credibility) to being more of an exploration as confidence decreases.

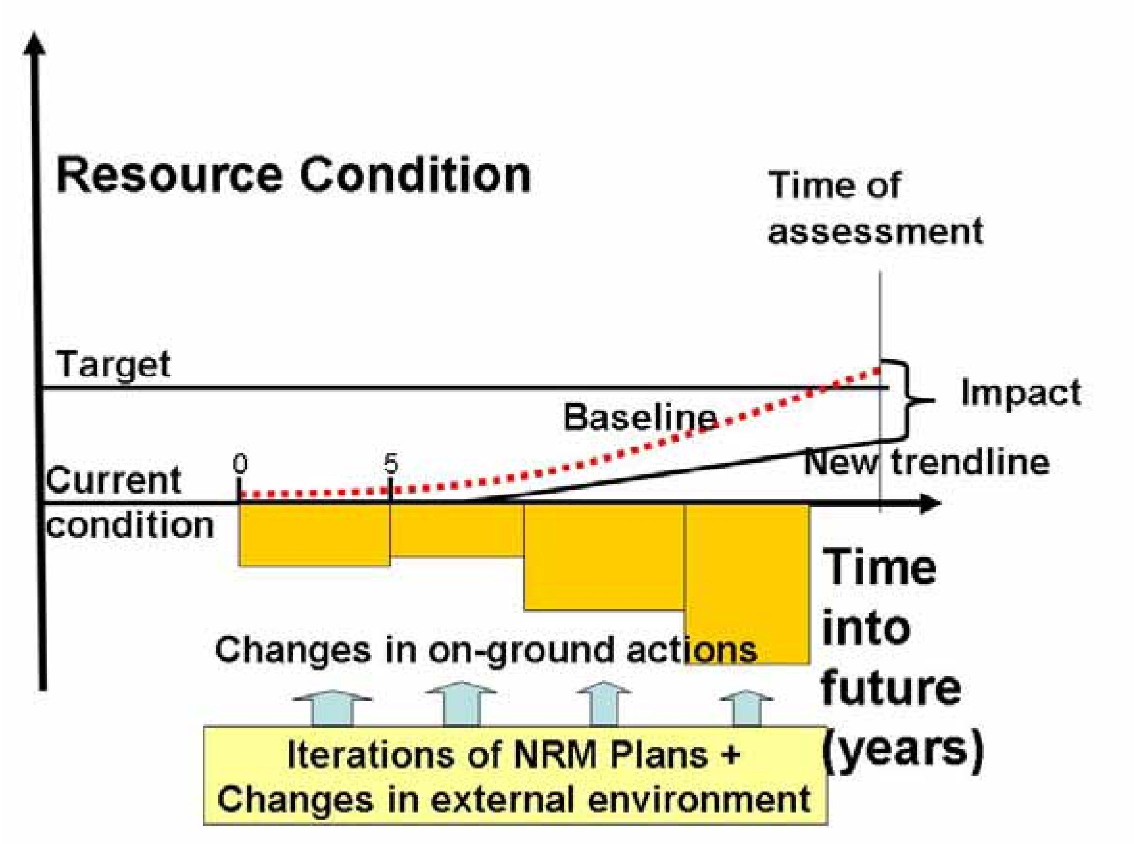


Figure 1.6 Conceptual model of longer-term exploration of NRM plans and impacts on resource condition targets

1.2.6. Objective 2

The second objective of the LMLF project is to explore future options and scenarios for the Lower Murray in partnership with stakeholders in the region. The approach used by the project to achieve this objective is conceptualised in Figure 1.6.

It builds upon objective 1 by developing an analysis of future trajectories of the system. As mentioned in the previous section, different interpretations of the current plans, evolution of NRM plans as social values and knowledge base changes and changes in external drivers can lead to very different outcomes. By considering the ensemble of environmental and socio-economic indicators that describe the system state under the range of potential assumptions, one can follow the evolution of the system state under the different combinations of assumptions. This is conceptualised in Figure 1.7.

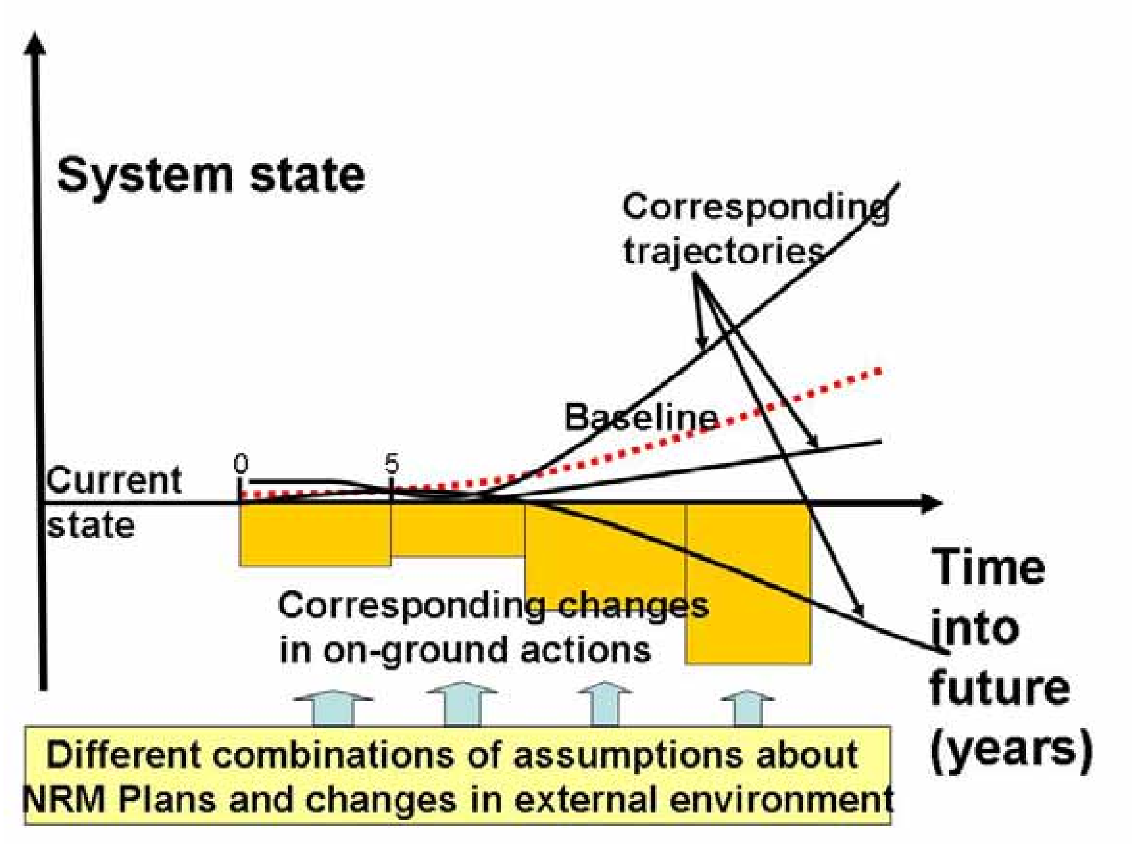


Figure 1.7 Conceptual representation of evolution of system state

The system state is represented by an ensemble of indicators represented simplistically in Figures 1.4 and 1.5. Each of these indicators is assumed to respond differently to each combination of assumptions on the NRM plans and external drivers, leading to different trajectories. When the indicators are taken together, each of these trajectories may lead to very different states into the future. We refer to each of these 'emergent' states as scenarios.

Part of the rationale of exploring these scenarios is to consider the conditions under which different scenarios occur and the sensitivity of these outcomes to for example commodity prices.

Such scenarios are considered in so-called 'futures analysis' (Dunlop et al., 2000;2001; Cork et al., 2005). However, in such analyses, the links between the current state and the future state is not explored in the same detail, making it more difficult to incorporate in planning processes. On the other hand, the thinking is less blinkered by current options.

1.3. Overview of LMLF Project Structure

To meet its overarching objectives, the LMLF Project is grouped into 4 tasks:

A River Murray Corridor Systems Model,

B Dryland Mallee Model,

C Social and Economic Impacts, and

D Project management and Communication.

The integration of these component projects is shown in 1.8.

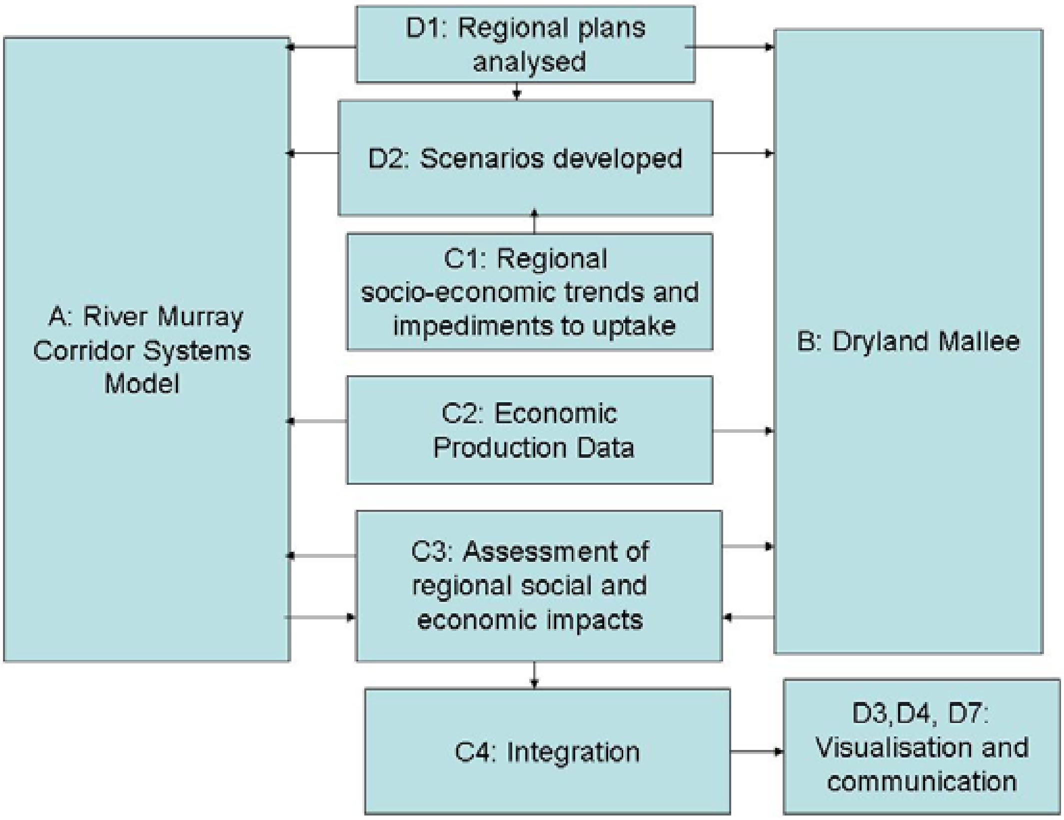


Figure 1.8 Organisation of the LMLF project, showing relationships between dryland, river corridor, economic and social research and visualisation components.

1.3.1. Task A: River Murray Corridor Systems Model

Leader: Rebecca Doble (CLW)

Team: Jeff Connor, Matthew Stenson, Glen Walker, Matthew Miles, Ray Evans, Kerryn McEwan.

Objectives:For the riverine corridor of the Lower Murray:

- Analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to community well-being (social, economic and environmental outcomes); and,
- Explore future options and scenarios in partnership with stakeholders in the region.

This work will focus on actions and environmental outcomes relevant for the riverine corridor, namely those related to water allocations, river salinity and riverine biodiversity.

Outputs: The outputs will be of 2 forms:

- A systems model that relates NRM policies and external drivers to on-ground actions and in turn relates on-ground actions to environmental outcomes (in the form of resource condition targets) and the social and economic impacts of these-on-ground actions. The model will be written in TIME and is a part of the CRC-CH modelling toolkit. The model should allow easy set-up of scenarios and visualisation s of outputs.
- Analyses of current and alternative NRM plans under a range of external conditions with triple-bottom-line outputs.

The Task is sub-divided into a number of sub-tasks:

A1: Prototype model for Riverland: This was developed quickly within the 1st year and was reported on in the Phase 1 report.

A2: Expansion of this model into Victoria: this was completed by July this year and reported within the mid-Year progress Report.

A3: Increased functionality: this is perhaps a never-ending task, but needs to be completed by June 30, 2006. Increased functionality has included:

- a range of WUE options and will include information from other projects as it becomes available
- floodplain salinity – SA included in Year 2 analyses and Victoria will be included following the Mallee Audit in Year 3
- disposal options – included in Year 2
- flow options – included in Year 3
- re-programmed model structure – Year 2
- inclusion of production and input-output modelling as it becomes available in Year 3

A4: Analyses of scenarios. To be completed by September, 30, 2006.

1.3.2. Task B Dryland mallee model

Leader: Brett Bryan

Team: Neville Crossman, Joanne McNeill, Jon Fawcett, Darren King, Enli Wang, Geoff Barrett

Objectives: For the dryland component of the Lower Murray:

- Analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to community well-being (social, economic and environmental outcomes); and,
- Explore future options and scenarios in partnership with stakeholders in the region.

This work will focus on actions and environmental outcomes relevant for the dryland region, namely those related to terrestrial biodiversity and dryland farming.

Outputs: The outputs from this Task will be of 2 forms:

- A GIS-based model that evaluates for a range of NRM policies and external drivers the impacts for resource condition targets and social and economic impacts. The model will be developed in ARCINFO.
- Analyses for a range of scenarios.

This Task consists of a number of sub-tasks:

B1: Collation of data and rules. To be completed by January, 2006.

B2: Model development. To be complete by June 2006

B3: Scenario analyses. To be complete by October, 2006.

1.3.3. Task C Social and economic context

Leader: Thea Mech

Team: Wendy McIntyre, Lorraine Bates, Kathryn Johnson, Jeff Connor, Brett Bryan

Objective: Integrate social and economic knowledge and information into the LMLF Project's construction of alternative landscape futures scenarios.

It consists of 4 Tasks:

C1: Review of social, demographic, industry and economic trends in the catchments. This will be completed in December, 2005

C2: Estimate the changed land use and production implied by the various biophysical model outputs. This will be completed by May, 2006.

C3: Conversion of production change estimates into impacts upon regional economic activity and employment. This may need to utilise both the national TERM model as well as LGA based input-output models. This will be completed in October, 2006.

C4: Integration of the economic findings with regional trends and with local informed knowledge to create integrated scenarios. This will be completed by December, 2006.

Outputs

- Report detailing the social, demographic, economic and employment situation in three projected scenarios: (1) no implementation of catchment plans; (2) likely or probable rate of implementation of catchment plans; and (3) full implementation of catchment plans, possible in short and longer time frames.
- Production economic data as input to 2 models. This will consist of commodity prices, production in relation to management, cost of upgrading irrigation, cost of relocating irrigation systems, salt interception costs, cost of revegetation etc.
- Input-output modelling as input to 2 models. Different industries will require different levels of processing and hence flow-on effects will differ for different commodities. This component will provide a more complete estimate of input to regional economy.
- Regional social and economic impacts of various scenarios. Regional economic impact may be determined by TERM modelling (needs to be assessed at time) and social impacts derived from this. Socio-economic indicators include regional economic activity and consequent social impacts.

1.3.4. Task D Communication and Project Management

Leader: Thea Mech

Team: Glen Walker, Chris Pettit, Marty Bluml, Brett Bryan, Rebecca Doble

*Objective:*To provide linkage between the research team/project and (a) Funders (b) Stakeholders and (c) Land Technologies Alliance.

It consists of a number of sub-tasks:

D1: Analysis of regional plans. This was reported upon in Phase 1 Report. This provides information on regional policies, on-ground actions and resource condition targets into Tasks A, B and the scenario development (D2).

D2: Scenario development with regional stakeholders. This was begun in year 2 and will be completed by June, 2006. This provides the details of scenarios to be modelled in Tasks A and B. Meetings with Stakeholders.

D3: Visualisation. This was scoped in year 2 and to be completed by December, 2006. It takes modelling outputs from Tasks A, B and C and provides communication products for the CMAs.

D4: Communication Plan which details communication activities such as web-sites, newsletters, presentations at meetings and workshops.

D8: Consideration of representing uncertainty and confidence in outputs.

D5: Meetings of PSC and Project Executive

D6: Project management

D7: Water for Healthy Country Booklet on Phase 2 outputs. To be completed by June .

Table 1.1 shows links between aspirational outcomes described in section 1.1 and on original proposal and tasks.

Table 1.1 Links between aspirational outcomes

Aspirational outcome	Relevant Outputs	Tasks
Enabling regional bodies to evaluate the potential implications of regional plans and investment strategies, particularly the ability to achieve regional targets.	RMCSM and Dryland Models link policies, on-ground actions and some RCT's	A, B
Establishing a mechanism to enable Regional Bodies in the Lower Murray NAP Region to evaluate the impacts of the Regional Investment Strategies across the whole region.	Models work consistently across SA and Vic, not NSW	A, B
Analysing existing regional plans and strategies for their likely impact on the landscape and community well being over the next 5 to 30 years for the Lower Murray NAP region.	Integrated analyses	A, B, C
Empowering stakeholders in the region to explore and test alternative "future scenarios", without spending 20 years of trial and error.	Models	A, B, C
Exploring what are the landscapes that maximise community wellbeing.	Not really applicable	
Creating a new standard for bringing together scientific rigour and community aspirations.	Models based on regional plans and linked to RCTs and social and economic outputs	A,B, C

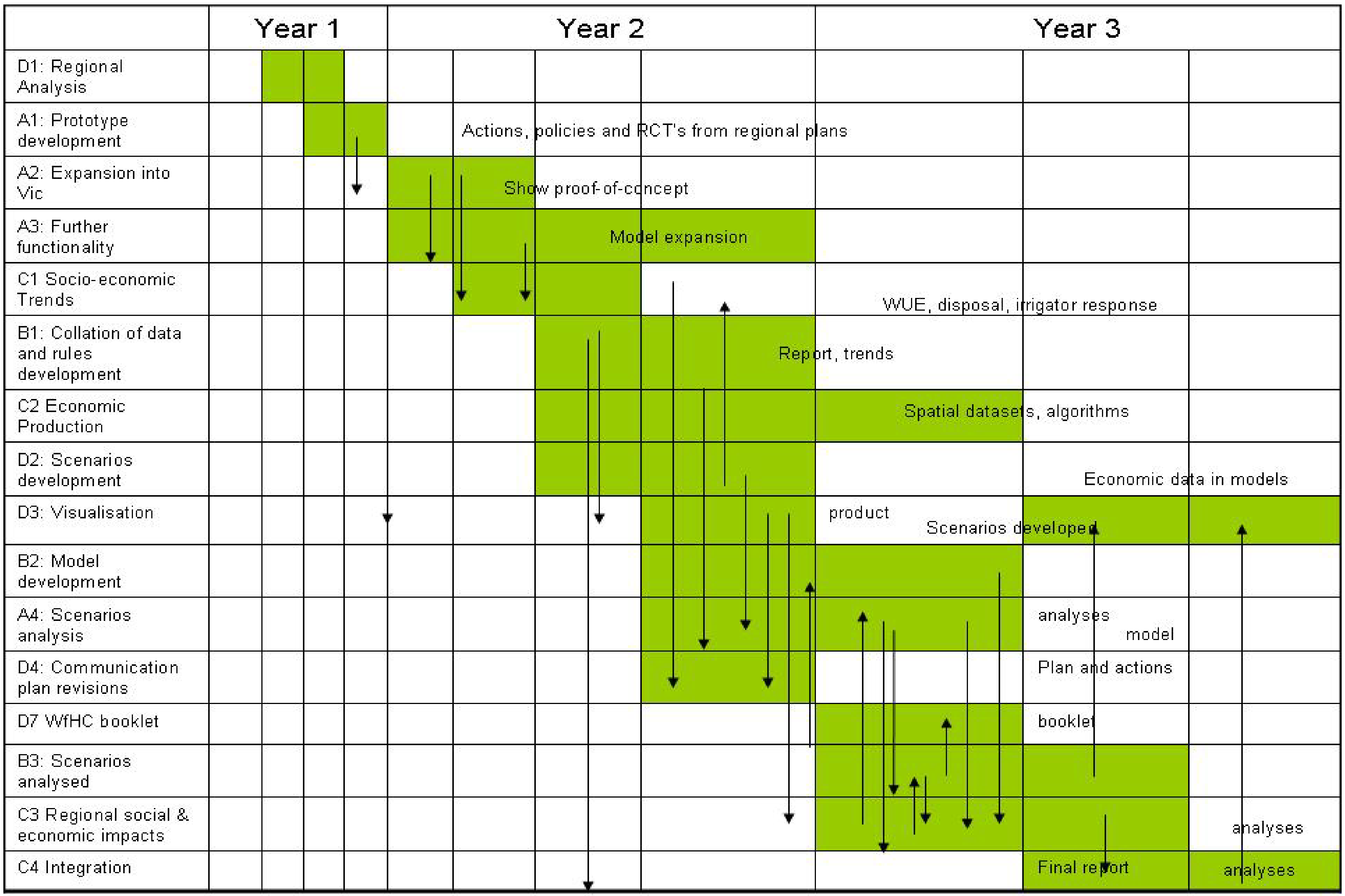
1.4. Work Program and timetable

1.4.1. Overall work timetable

The development of the Lower Murray Landscape Futures project occurred over a long period of time. This led to discrepancies in the initial schedules developed with each of the funders. This was resolved late last year with the following broad workplan:

Year of project	Calendar year	Main activities
Year 1	2005	Analysis of regional plans
		Development of prototype model
Year 2	2006	Assessment of plans with respect to RCTs
		Development of future scenarios
Year 3	2007	Exploration of future scenarios
		Integration of results

A more detailed GANNT chart is shown below that relate to the sub-tasks described in the previous section


Year 1
Year 2
Year 3
D1: Regional Analysis
A1: Prototype development
Actions, policies and RCT's from regional plans
A2: Expansion into Vic
Show proof-of-concept
A3: Further functionality
Model expansion
C1 Socio-economic Trends
WUE, disposal, irrigator response
B1: Collation of data and rules development
Report, trends
C2 Economic Production
Spatial datasets, algorithms
D2: Scenarios development
Economic data in models
D3: Visualisation
product
Scenarios developed
B2: Model development
A4: Scenarios analysis
analyses
model
D4: Communication plan revisions
Plan and actions
D7 WfHC booklet
booklet
B3: Scenarios analysed
C3 Regional social & economic impacts
analyses
C4 Integration
Final report
analyses

1.4.2. Outcomes from year 1

Regional stakeholder engagement to develop the LMLF Model, demonstrate it and seek constructive feedback for further development and use

The need for regional engagement is embedded within the project objectives, and it has been emphasised in achieving all of the project milestones. The LMLF Project is based upon a multi-stakeholder project partnership for the purpose of ensuring that this landscape-scale integrated NRM project is regional stakeholder-driven. The partnership is composed of NRM stakeholders from four NAP regions in the Lower Murray area covering South Australia, Victoria and New South Wales, and of research providers from diverse State agencies and CSIRO.

Quarterly meetings with the Lower Murray Landscape Futures project steering committee were undertaken to provide regular interaction with stakeholders and report on progress. Steering Committee meetings provided an opportunity for on-going dialogue and guidance regarding what was sought from a stakeholder perspective, and what was possible from a research perspective.

Engagement with regional stakeholders was important for the initial conceptualisation of the LMLF prototype model, its development, and in review. Interactive demonstrations of the prototype model were given to the:

- Project Steering Committee (8/12/04)
- Tri-state Forum (9/12/04)
- River Murray Catchment Board (16/12/04)
- Salinity Policy Group in DWLBC. John Rolls and Ingrid Franzmann (7/12/04).
- Irrigation group in DWLBC. John Bourne and Gerrit Schrale (17/12/04.
- RMCWMB. Presentation and discussion with Dan Meldrum (18/11/04).
- Mallee CMA, Chris Biesaga (25/1/05)

The full list of model demonstrations and meetings with stakeholders is given in Phase 1 Report.

Evaluation of regional NRM strategies and catchment management plans

The sheer number of targets and actions contained within the regional plans for the lower Murray Darling Basin in New South Wales, Victoria and South Australia meant that plans had to be collated before assessing to choose key resource condition targets. The methodology used to satisfy this milestone is as follows:

1. Collate the overarching state and catchment plans, and natural resource management strategies for the Murray Darling Basin, Victoria, New South Wales and South Australia (15 in total);
2. Define categories for main aspirations, targets and actions within these strategies;
3. Divide into broad natural resource condition areas; and
4. Choose key resource condition targets, with which to assess strategies.

The themes for the strategy evaluation that were selected were put to the project steering committee, who suggested that the priority order should be:

1. Salinity and Water Allocations;
2. Aquatic Biodiversity;
3. Terrestrial Biodiversity; and
4. Dryland Farming Systems.

Key resource conditions for the targets were identified as:

Theme/ Target	Key resource conditions
Salt loads and water allocations	EC benefits, Water Use Efficiency and Drainage volumes
Riverine Biodiversity	Floodplain vegetation affected by salinity
Terrestrial Biodiversity	% area of native vegetation
Dryland Farming Systems	Wind erosion

Further details of the process undertaken to achieve this milestone can be found in the Year 1 Report.

Delivery of the 'prototype' LMLF Model, with an initial (year 1) focus in the project's SA NAP region.

The pilot study and development of a 'prototype' model within the first year of the project covering the South Australian NAP region, has helped to develop a 'shared' understanding of the requirements of such an analysis. It has assisted the project team develop methods to overcome some of the technological challenges and provides a basis for discussion in terms of:

1. Which form of outputs are most useful e.g. do we use Land and Water Management Plan areas as a basis for reporting, what units do we report resource condition, what form of economic reporting should we use?
2. What flexibility in actions should be considered as part of the future scenarios?
3. Are the big drivers for land use change captured?
4. Does it meet the objectives of the project?

The prototype model structure takes actions derived from regional NRM strategies, considers a series of on-ground actions that result from these strategies, calculates their impacts on resource condition targets, and their economic impacts. Social impacts will be added to the model as work on socioeconomic outcomes progresses.

The prototype model considers the following actions:

- Irrigation zoning: restricting new irrigation developments that would have occurred in high impact areas to regions known to have a lower salt impact on the river;
- Improved water use efficiency: changing a proportion of irrigation that is able to improve its water use efficiency to lower deep drainage rates;

- Salt interception schemes: accumulating the salt and groundwater flow that is intercepted by the schemes, to determine the impact on disposal capacity and reduced impact on river salt loads; and
- Revegetation: planting native perennial vegetation over cleared land in order to reduce deep drainage from rainfall.

These are applied at a decision making scale based on Land and Water Management Plan areas, salt interception scheme catchment zones, salt impact zones and floodplain impact units. The prototype model uses outputs from existing models such as SIMPACT and the FIP model (see Chapter 5) at various deep drainage rates that reflect land use and management changes, and generates target resource impacts under various land management scenarios. Impacts are given for 10, 20, 50 and 100 years from the present time.

In addition to resource impacts, the model also assesses the economic impacts of land management scenarios, using crop market prices and costs of re-zoning and improving irrigation efficiency to determine changes in profitability of the irrigation.

The model was presented to stakeholders in December 2004, who were able to provide constructive suggestions for its further development and expansion into the other NAP regions.

Existence and presentation of a prototype model for the South Australian River Murray NAP region constitutes an achievement of Milestone 2. The problem definition, and details of the Lower Murray Landscape Futures Prototype Model are discussed in Chapters 4 and 5 of this report. Chapter 6 goes beyond the milestone requirements, and outlines two modelling techniques that can be used for more detailed studies of the regions.

Definition of the social and economic research component of the LMLF Project including clear identification of how social and economic aspects of landscape change are to be incorporated in line with project objectives (in years 2 and 3)

The definition of socioeconomic research requirements arose from the project objective to define social and economic outcomes of existing regional plans and investment strategies, and forms an attempt to define 'community wellbeing' against which to assess future landscape scenarios.

The approach taken consisted of 4 steps:

1. Talk to each of the catchment groups about their socio-economic requirements relevant to the LMLF project;
2. Conduct a workshop of experts to explore project ideas;
3. From workshop, develop project concepts; and
4. Ask PSC to prioritise project concepts.

Feedback on the social and economic research priorities of the regional stakeholders was sought through a set of meetings with the Wimmera CMA, the River Murray CWMB, the Mallee CMA, and the Lower-Murray Darling CMB.

A workshop of socio-economic experts was held in Melbourne on November 26th. The workshop agenda was to develop and present potential socioeconomic project ideas relating to landscape futures from the LMLF project aims and the regional stakeholder feedback on social and economic research needs. The list of projects developed and their associated 'champions' were as follows:

1. Integrating social and economic knowledge into alternative scenarios of Lower Murray landscape futures, *Dr Neil Barr, Primary Industries Victoria, Bendigo*
2. Understanding the social drivers of catchment management for improved landscape futures in the Lower Murray region, *Professor Allan Curtis, Charles Sturt University*
3. Assessing landscape values and benefits for regional NRM, *Dr Michael Dunlop, CSIRO Sustainable Ecosystems, Canberra*
4. Towards negotiated landscape futures, *Dr Jacqui Dibden and Dr Sharron Pfueller, Monash University, Ms Blair Nancarrow and Dr Lorraine Bates, CSIRO Land and Water*

The above 4 projects were submitted to the Project Steering Committee for prioritisation, accompanied by recommendations from the Project Team. The resulting priority order was as shown above. The view was expressed that proposal 1 be developed prior to diverting resources elsewhere. While the accepted proposal needs more detail, the basis of the socio-economic plan has been defined.

The key objective of the selected project proposal is to integrate social and economic knowledge and information into the LMLF Project's construction of alternative landscape futures scenarios. To meet this objective and to integrate social and economic aspects of landscape change into the existing LMLF Project, specific research questions for this project are:

- What are the social, economic and demographic trends that are exogenous drivers of landscape change? (Information on these trends is for explicit use in the development of alternative landscape futures scenarios).
- What is the feasibility of the management actions in RCSs and NRM Plans (purportedly designed for the purpose of meeting NRM targets) actually being adopted/implemented?
- What are the economic impacts on regional and rural economies (and the economy in general) of different land uses, implied by the full implementation and probable implementation of CMAs resource condition targets in Regional Catchment Strategies and NRM Plans?
- What are the broader social, community and institutional impacts that flow-on from the regional economic impacts of land use change (i.e.: from the above point).

Additional projects

A number of additional projects under the Water for a Healthy Country Flagship of CSIRO have contributed to the LMLF project. These projects related closely to the project, such as revegetation strategies, developing a hydrogeologic framework for groundwater flow in the Murray Darling Basin, development of models used by the prototype model, and socio-economic studies of sustainable irrigation practises. These projects are listed below:

- applicability of the Unit Response Equation to Assess Salinity Impacts of Irrigation Development in the Mallee Region

- targeting Dryland Areas In The Mallee For Controlling Groundwater Recharge And Salt Load To The Murray River
- combining geology and geophysics to develop a hydrogeologic framework for salt interception in the Loxton Sands Aquifer, Central Murray Basin, Australia
- developing re-vegetation strategies by identifying biomass based enterprise opportunities in the mallee areas of South Australia
- spatial Investment Priorities for Integrated Natural Resource Management: A Case Study in the River Murray Dryland Corridor
- towards sustainable irrigation practices – understanding the irrigator – ARCWIS

All of the aligned projects support the modelling by providing inputs to the systems model, providing greater confidence in the assumptions and providing access to relevant reports and/or experts. Collectively, they provide substantial information to support NRM management.

1.5. Contracted year 2 milestones

The milestones for Year 2 are listed in Table 1.2. There are differences between Victorian and South Australian milestones and the relevant milestones are labelled with 'V' for Victorian and 'S' for South Australian.

Table 1.2 Year two milestones

Milestones (V: Victoria, S: South Australia)	**Output**	**Task**
V1: LMLF Phase 2 research workplan and schedules developed and documented, covering environmental, social and economic analyses of Lower Murray landscape futures in the Mallee region, and the Wimmera region. **V2:** LMLF Phase 2 research workplan presented to, and signed off by, Steering Committee at March 2005 Steering Committee meeting.	**O1**: Approved workplan	**D?**
V3: Regional workshop of research team and regional stakeholders held in Mildura to develop landscape futures modelling scenarios for Mallee region.	**O2**: Future scenarios workshops/meetings in SA, Vic. Mallee and Wimmera – future scenarios decided	**D?**
V4: Regional workshop of research team and regional stakeholders held in Horsham to develop landscape futures modelling scenarios for Wimmera region. **S4:** Engagement with regional stakeholders (PSC meeting at 3monthly intervals, phone hook-ups and ad hoc visits between; workshops to develop scenarios and testing model.	**O7**: Other Evidence of regional engagement	**D2:** Communication with external stakeholders
V5: Interim Year 2 Progress Report charting modelling and scenario testing progress. Prepared as a written report submitted to SC and Vic NAP Office, and Presented to SC at June SC meeting.	**O2**: Interim mid-year report:	**A**
V6, S5: Completion of Final Yr 2 Report, and its submission to Steering Committee at Dec 05 meeting, and to Vic NAP Office.	**O6**:Final Year 2 Report	**A,B,C,D**

Milestones (V: Victoria, S: South Australia)	**Output**	**Task**
V7: Interactive demonstration of completed Yr 2 landscape futures analyses at appropriate regional stakeholder forum. **S2**: Completion of riverine corridor model with respect to all 4 resource condition targets. • Inclusion of all 4 resource targets • Inclusion of Victorian Mallee • Inclusion of higher resolution study site. **S3**: Completion of broader modelling area, as developed in consultation with stakeholders. • Model specification • Model completion.	**O4**: Riverine Corridor Model including expansion into Victoria and other NRM issues. **O5**: Whole-region analyses for biodiversity and wind erosion	**A:** Development of River Corridor Systems Model **B:** Whole regional analyses
S1: Progress of socio-economic component as outlined in the Year 1 report.	**O8**: Review of demographic and adoption data	**C1:** review of demographic and adoption data
S6: Project management.	**O10**: Other project management outputs: contracts, meetings, reporting, internal communication	**D?:** Project contracting **D?** Internal communication

1.6. Outline of Report

The outline of the report is very simple. Chapters 2-5 describe Tasks A-D respectively and the relevant tasks. Chapter 6 brings together the different threads with a discussion and a set of conclusions. Progress against milestones can be found in Chapter 5.

1.7. References

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http://www.lwa.gov.au/downloads/publications_pdf/PK040780_full_report.pdf

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Dunlop, M., Foran, B. and Poldy, F. (2001) 'Scenarios of future water use: Report IV of IV in a series on Australian water futures.' Resource Futures Program Working Paper 2001/05, CSIRO Sustainable Ecosystems, Canberra. (http://www.dwe.csiro.au/research/futures/publications/01-05f.pdf)

2. Task A: River Murray Corridor Systems Model

This Chapter describes progress in Task A during Year 2 of the project. This progress will be reported against relevant project milestones.

2.1. Introduction

2.1.1. Relevant portions from Chapter 1

Chapter 1 sets the scene for the rest of the report. In this section, we bring out those portions relevant to Task A to set the scene for the rest of the Chapter.

The aims of Task A are to:

- Analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to community well-being (social, economic and environmental outcomes); and,
- Explore future options and scenarios in partnership with stakeholders in the region,

with a focus on resource conditions, actions and policies relevant to the riverine corridor. In particular, Task A focuses on resource conditions relevant to water allocations, salinity and riverine biodiversity. During Year 1, it was decided to focus on two key resource condition targets:

1. River salinity; and
2. Riverine biodiversity.

The Task outputs are in 2 forms:

- A systems model that relates NRM policies and external drivers to on-ground actions and in turn relates on-ground actions to environmental outcomes (in the form of resource condition targets) and the social and economic impacts of these-on-ground actions. The model will be written in TIME and should be installed in the CRC-CH modelling toolkit. The model should allow easy set-up of scenarios and visualisation s of outputs.
- Analyses of current and alternative NRM plans under a range of external conditions with triple-bottom-line outputs.

The River Corridor component is sub-divided into a number of sub-tasks or milestones:

A1: Prototype model for Riverland: The River Murray Corridor Systems Model developed quickly within the 1st year for South Australia and was reported on in the Phase 1 report.

A2: Expansion of this model into Victoria: this was completed by July

A3: Increased functionality of the River Murray Corridor Systems Model: this is currently underway, and will be completed by June, 2006. Increased functionality has included:

- a range of WUE options and will include information from other projects as it becomes available

- floodplain salinity – SA included in Year 2 analyses and Vic will be included following Mallee Audit in Year 3
- disposal options – included in Year 2
- flow options – included in Year 3
- re-programmed model structure – Year 2
- inclusion of production and input-output modelling as it becomes available in Year 3

A4: Analyses of scenarios. Description of scenarios is currently underway, and involves a working group of stakeholders from the Mallee Regions of South Australia and Victoria. Analysis of scenarios is scheduled to be completed by September, 30, 2006.

Project milestones specified by SA and Vic NAP are:

V1: LMLF Phase 2 research workplan and schedules developed and documented, covering environmental, social and economic analyses of Lower Murray landscape futures in the Mallee region, and the Wimmera region.

V2: LMLF Phase 2 research workplan presented to, and signed off by, Steering Committee at March 2005 Steering Committee meeting.

V3: Regional workshop of research team and regional stakeholders held in Mildura to develop landscape futures modelling scenarios for Mallee region.

V4: Regional workshop of research team and regional stakeholders held in Horsham to develop landscape futures modelling scenarios for Wimmera region.

S4: Engagement with regional stakeholders (PSC meeting at 3monthly intervals, phone hook-ups and ad hoc visits between; workshops to develop scenarios and testing model.

V5: Interim Year 2 Progress Report charting modelling and scenario testing progress. Prepared as a written report submitted to SC and Vic NAP Office, and Presented to SC at June SC meeting.

V6, S5: Completion of Final Yr 2 Report, and its submission to Steering Committee at Dec 05 meeting, and to Vic NAP Office.

V7: Interactive demonstration of completed Yr 2 landscape futures analyses at appropriate regional stakeholder forum.

S2: Completion of riverine corridor model with respect to all 4 resource condition targets.

- Inclusion of all 4 resource targets
- Inclusion of Victorian Mallee
- Inclusion of higher resolution study site.

2.1.2. Year 2 workplan for Task A

The project workplan for year 2 was accepted by the Project Executive in March (Milestones V1, V2). The main schedule from this is shown in Table 2.1. Achievement of actions A1 and A2 are discussed in more detail in the Year 2 interim project report (Doble *et al.* 2005). Actions A3 to A7 are discussed in this report in more detail.

Table 2.1 Project workplan for Year 2.

Action	Indicator	Responsibility	Deadline
A1 Water use efficiency relationships	More appropriate WUE relationships for RCSM developed	Rebecca Doble	December 2005
A2 Expand model to Victoria	Functioning model including the Victorian NAP region	Matt Miles/ Kerryn McEwan	July 2005
A3 Disposal Rules	Inclusion of disposal feedback in groundwater model	Rebecca Doble	December 2005
A4 Floodplain development and expansion into Victoria	Relationships for floodplain salt impact included in the RCSM	Ian Jolly	December 2005
A5 Development of software	Fully functioning model able to predict land use management impacts	Rebecca Doble/ Matt Stenson	December 2005
A6 Economic analysis	Functional economic analysis contained within the RCSM	Jeff Connor	December 2005
A7 Project management, engagement and reporting	Second year report chapter and evidence of stakeholder engagement meetings	Rebecca Doble	January, 2006

2.1.3. Chapter Outline

This chapter is structured into two major sections, the reporting of the project progress and model development, and the example scenarios and results. Within this, the report covers:

1. Background
2. Analysis of regional plans: outcomes of a synthesis of 15 NRM plans in the Lower River Murray Basin
3. Drivers of change: a description of the river corridor system, and the hydrogeology that underpins it
4. Project methodology: conceptualisation of the River Murray Corridor Systems Model
5. Linking actions to resource condition targets: a description of the River Murray Corridor Systems Model, its spatial and temporal units, and component models
6. Policies and drivers of on-ground actions: a description of the land use change options, scenario builder used to aggregate up various NRM actions, data sources and model outputs.
7. Economic impacts and irrigator response function: a description of the economic analysis undertaken, and the economic and policy drivers of land management change
8. Example scenarios and results: development of scenarios from current NRM plans, and presentation of model results

9. Discussion: scientific findings from the modelling, and relation to project goals; and
10. Conclusions

2.2. Analysis of regional plans

Analysis of regional plans was undertaken in year 1 of the LMLF project, and is discussed in detail in the Year 1 Progress Report (Walker *et al.* 2005). A summary of the analysis is presented below.

Fifteen regional NRM plans from Victoria, New South Wales, South Australia and the Murray Darling Basin were collated and analysed. These State Plans, Catchment Plans and Natural Resource Management Strategies included the following:

Victoria:

- Mallee Regional Catchment Strategy 2003-2008
- Mallee Regional Management Plan 2003/2004
- Draft Victorian Mallee Salinity and Water Quality Management Plan
- Draft Mallee Native Vegetation Plan 2000
- Wimmera Regional Catchment Strategy 2003-2008

Murray Darling Basin/New South Wales:

- Integrated Catchment Management Plan for the Lower Murray Darling Catchment 2002 – Lower Murray Darling Catchment Blueprint
- Integrated Catchment Management in the Murray Darling Basin 2001-2010
- Basin Salinity Management Strategy 2001-2015

South Australia:

- Catchment Water Management Plan for the River Murray in South Australia
- Integrated Natural Resource Management Plan for the South Australian Murray Darling Basin
- Integrated Natural Resource Management Investment Plan – South Australian Murray Darling Basin Integrated Natural Resource Management Group
- South Australian River Murray Salinity Strategy 2001-2015
- Dryland Regional Strategy Murray Darling Basin, South Australia.
- Murray Mallee Land and Management Plan
- Murray Mallee District Soil Conservation Board – District Plan

The overall collation resulted in the documentation of 173 aspirational goals, 252 resource condition targets and 1252 NRM actions defined in order to achieve these targets.
After consultation with the Project Steering Committee, the themes for the strategy evaluation were categorised into 4 key resource condition targets (RCTs):

Four key resource condition targets:

- **Salinity and Water Allocations**,
- **Aquatic Biodiversity,**
- **Terrestrial Biodiversity, and**
- **Dryland Farming Systems.**

For the River Corridor Systems Modelling the relevant actions, resource condition targets and policy drivers were defined as:

River Salinity Resource Condition Targets:

1. (MDBC Salinity) For shared water resources (less than 800 EC for 95% of the time at Morgan).
2. (Vic Mallee RCS) End-of-valley targets under the Basin Salinity Management Strategy achieved.
3. (SA INRM) By 2015 to have salinity of water in the River Murray less than: 800EC for 95% of the time at Morgan, 412EC for 80% of the time downstream of Rufus River, 543EC for 80% of the time at Berri Irrigation Pump Station, 770EC for 80% of the time at Murray Bridge Pump Station.
4. (Vic Mallee Salinity) River salinity reduced by 6 EC through improved irrigation management.

Action targets (These are not resource condition targets, but targets towards achieving these)

5. (Vic Wimmera RCS) By 2020 there will be a 20% improvement in water use efficiency within the Wimmera River basin.
6. (SA CWMP) To achieve an average crop water-use index of at least 85 by 2005 in all areas except for the Angas Bremer irrigation area and Lower Murray reclaimed irrigation area – annually.
7. (SA INRM) To achieve an average crop water-use index of at least 85 by 2005 in all areas except for the Angas Bremer irrigation area and Lower Murray reclaimed irrigation area - annually.
8. (SA CWMP) To achieve a 50% reduction in irrigation drainage volumes by 2006 - 2007.
9. (SA INRM) By mid-2006 to have reduced the total drainage volume from highland irrigation areas by 50%.
10. (Vic Mallee RCS) Average irrigation drainage volumes at annual maximum of 1 megalitre per hectare.
11. (SA INRM Invest) By 2006 to have developed a RCT relative to irrigated and waterlogged land.
12. (SA CWMP) To achieve a 50% reduction in irrigation drainage volumes by 2006 - 2007.
13. (SA INRM) By mid-2006 to have reduced the total drainage volume from highland irrigation areas by 50%.
14. (Vic Mallee RCS) Average irrigation drainage volumes at annual maximum of 1 megalitre per hectare
15. (Vic Mallee Salinity) Impact of water transfers on Salt Disposal Entitlements adequately off-set.
16. (Vic Mallee Salinity) Construction of salt interception and drainage diversity schemes that meet environmental, economic and social criteria, started.
17. (SA INRM Invest) To achieve an average crop water use index of 85 by 2008 in all irrigation areas (except Lower Murray Reclaimed Irrigation Areas) extracting water from prescribed resources.

Actions to address River Salinity Targets

1. Encourage new irrigation development into low impact zones
2. Encourage best management practices on new developments
3. Improve water use efficiency of existing developments through on-farm action

4. Improve system water use efficiency through infrastructure improvements
5. Develop salt interception schemes
6. Minimise dryland recharge through vegetation, perennial vegetation and better dryland WUE
7. Remove disposal basins from floodplains
8. Decommisioning of drainage disposal bores
9. Encourage re-use options (drainage, stormwater, waste water)
10. Limit diversions (e.g. EMLR)

After consultation with stakeholders, only the first 6 actions were used within the River Corridor Systems model. Actions 7 to 10 are less likely to have a significant effect on the targets as actions 1-6 (such as re-use options), or are one off events that are in the process of being undertaken (such as the decommissioning of drainage disposal bores).

Similarly, the key resource condition targets for riparian biodiversity include:

1. (SA INRM Invest) Maintain and improve the extent and condition of 65% of current floodplain vegetation communities in areas of high priority by 2020
2. (Vic Wimmera RCS) Net gain of native instream and riparian biodiversity by 2015
3. (Vic Mallee Salinity) Extent of aquatic ecosystems threatened by rising saline watertables reduced to levels identified in the Regional River Health Strategy
4. (SA INRM Invest) By 2020, a 30% reduction in priority areas of floodplain currently affected by salinity from groundwater discharge

The actions to address these RCTs can be summarised as:

1. Irrigation zoning and improved water use efficiency to decrease salt loads to the River Murray and its floodplains
2. Engineering options for lowering water tables or intercepting cliff seepage
3. Increased flooding
4. Environmental irrigation or regulated flushing.
5. Weir pool manipulations for controlling river level

In the context of this project, only point 1 need be considered, although as before knowledge of salt interception and flows is required.

It was noted that many of the resource condition targets and actions were not expressed clearly or quantitatively. Some interpretation was required to transform these targets and actions into quantifiable changes within the River Murray Corridor Systems Model. The assumptions made are outlined in the following sections of this report.

Some of the resource condition targets are difficult to model solely using a landscape based modelling system. River EC targets, the major one defined as EC less than 800μScm^{-1} for 95% of the time at Morgan, are highly dependent on river flows and can be met much of the time by strategic releases of water from upstream reservoirs such as Lake Victoria. The timing of EC peaks is also critical for irrigators and downstream users. Peaks in summer when the majority of growers are irrigating have a higher cost associated with potential crop losses than peaks in winter. In this case, the target does not reflect the temporal costs of its impacts.

Similarly, vegetation health also depends on frequency of flooding, duration between floods and weir pool level. It is complicated by other pressures such as insect attack and grazing, and incorporates a tolerance lag time, during which vegetation may experience stress, but not show signs of declining health until a catastrophic dieback event once the tolerance time has been exceeded. There is a high degree of spatial variability in vegetation, even at a fine scale, and in mixed tree communities, a decline in one species due to salinity may represent an opportunity for another more tolerant species to become dominant.

Modelling each of the targets literally would require work outside of the scope of the LMLF project to incorporate flow dynamics and other pressures on vegetation health. Incorporation of models such as MSM-BigMOD into the LMLF project to model flow variability would be a complicated process, and draws focus away from the core project objective, that is modelling landscape futures. The complexity of such a model would lead to high levels of uncertainty, and a significant amount of resources would need to be assigned to calibrating the model to allow a reasonable level of confidence in the result. Incorporation of flow processes in a stochastic form is a possibility, however, and should be considered for the third year of the project and beyond.

Although the synthesis of NRM plans has identified a series of resource condition targets, the complex nature of the targets and qualitative nature of the plans makes it very difficult to test whether these targets can be met. The development of the River Murray Corridor Systems Model (RMCSM) has therefore been focused on modelling salt loads to the river, described in tonnes of salt per day or EC at Morgan and equivalent EC as outlined in the Basin Salinity Management Strategy (BSMS; (2001a)). Whilst this does not address the resource condition target precisely, it provides a tested means of comparing the future impacts of various combinations of land management actions. Similarly, vegetation health resource condition targets are represented by vegetation and wetland salinity risk, which can be modelled using the Floodplain Wetlands Impacts model (FWIM; Holland, K.L. et al. (2005)). These outputs represent the most robust methods of representing complex resource condition targets.

2.3. Drivers of change in resource condition

The drivers and processes leading to increased river salinity are generally well-understood for the Mallee. These are described in documents such as the River Murray Salinity Strategy. There has always been naturally been high salt loads to the River in the Mallee. These high salt loads have been exacerbated by irrigation development over the last century. Irrigation is continuing to expand. Dryland agriculture will also lead to increases in salt load, the future impacts of which may be of the order of the impacts from irrigation ({MDBMC 1999 #280}).

The processes leading to salinity in the Mallee are illustrated in Figure 2.1. Irrigation or dryland agriculture leads to increases in deep drainage. There is a time delay between a change in land use and for the full increase in recharge to occur at the water table. The increase in recharge leads to increased lateral gradients to the river and there is also a time delay associated with this. This increased groundwater gradient leads to increased salt movement to the river corridor. Under the floodplain, some of this groundwater can be lost to evapotranspiration leading to salt accumulation in floodplain soils and degradation of riparian vegetation. Some groundwater will move directly to the river and leads to base flow salt loads. Some of the salt that is captured by the floodplains and wetlands is mobilised during and after floods.

There can be time delays from 20 years to thousands of years in salt reaching the rivers depending on distance to the river, depth to water table, deep drainage rate and hydrogeological and soil characteristics. Over recent years, there have been significant improvements in estimating this across the Mallee (Wang, E. et al. (2005)).

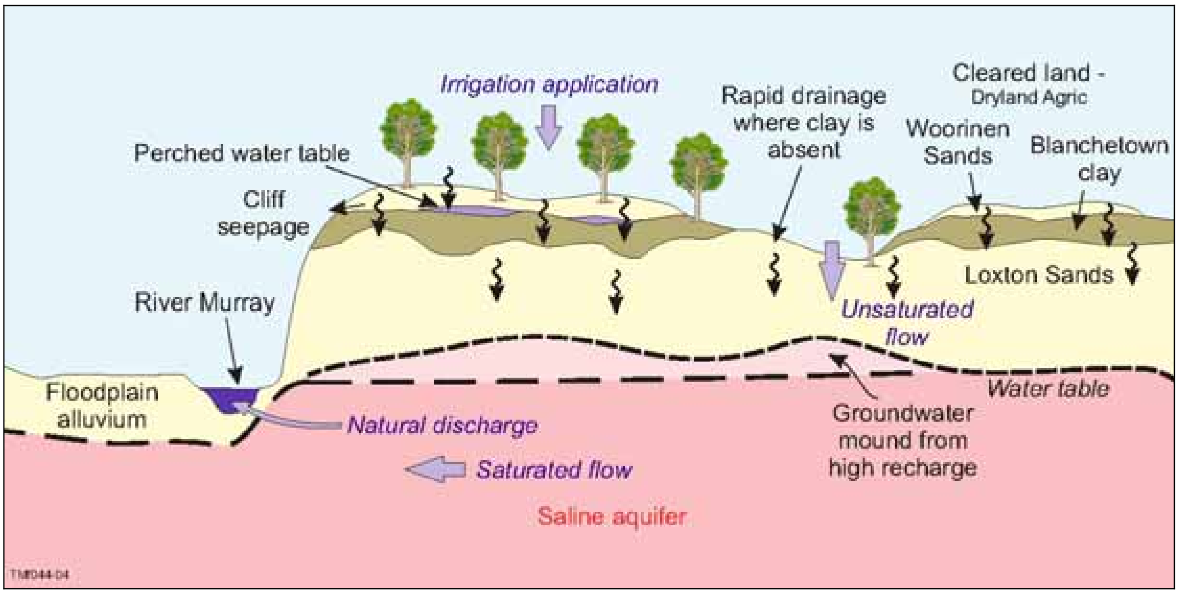

Figure 2.1 Schematic of processes leading to salinity in the Mallee Region

The levers for minimizing salinity impacts can be divided into categories of avoiding the problem through planning and minimizing deep drainage, or providing solutions to the problem through intercepting groundwater before it reaches the river. New irrigation development can be influenced through zoning to avoid sites near the river with high salinity impacts, to avoid high conservation floodplain areas or areas upstream of key water off-takes. Even if no new development took place, there would be a need to deal with the salinity effects of development that has occurred over the last 20 years. Minimising deep drainage can occur through improved water use efficiency, improving infrastructure and to a lesser extent using perennials in dryland areas. There is a limit to the extent that deep drainage under irrigated agriculture may be decreased due to salt accumulation in soil zones. There is evidence now that soil salinity may be affecting crop production in some areas of the Riverland (Schrale, pers. comm.[1]). The only way to deal with short-term salt loads to the river is through groundwater pumping. Unfortunately, this brings to the land surface large volumes of saline groundwater that need to be disposed. While increasing salt loads can be dealt with using more and more groundwater pumping, this becomes both increasingly inefficient and requires larger and larger areas for salt disposal.

It is therefore likely that all 3 measures will be required; groundwater interception for the short and medium term, improved water use efficiency for the medium to long-term and planning for the longer-term. Some thresholds exist:

- There will be a publicly acceptable limit to salt disposal,
- There is a limit to water use efficiency measures,
- There is a limit to the cost of salt mitigation measures that could be justified by public benefits or costs to irrigators, and
- There is a limit to water extraction from the river,
- The Basin Salinity Management Strategy sets a tight limit to salt loads to the river.

It is clear that all 4 resource conditions (salt loads to the rivers, water use efficiency, disposal volumes and floodplain salinity) are linked and need to be considered together if future scenarios are to be explored at all.

These resource conditions are driven by the increase in the area of irrigation, which has been itself driven by higher availability of water due to interstate trade and higher prices for high value commodities. Regional development sets targets for increasing areas of irrigation into the future, but this could be modified through changes in commodity prices, lack of available water allocations or high costs in environmental management.

There are a number of other unknowns: new technology for using saline groundwater, new profitable perennial land uses in dryland areas, new irrigated crops, etc that are simply too difficult to predict. Climate change that may markedly change the viability of some land uses in the region.

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[1] Gerrit Schrale, Irrigation Group, DWLBC, 2004.

2.4. Project methodology

A number of models and data sets have already been developed to model impacts of irrigation on river salinity and floodplains. No framework exists, however, to integrate this information and to analyse the outcomes of land use change and natural resource management strategies against various catchment management targets under a triple bottom line rationale ((2005)). The River Murray Corridor Systems Model (RMCSM) aims to achieve this for the Lower River Murray region, and provide a tool to explore future landscape possibilities under a series of scenarios. The Lower River Murray study area is shown in (igure 2.2). Data sets for the RMCSM model have been developed for both South Australian and Victorian Mallee regions along the river corridor. The data presented for the remainder of this paper are specific to the South Australian Mallee region.

igure 2.2 Lower River Murray modelled area including South Australian and Victorian Mallee regions.

An overview of RMCSM is shown in Figure . Components of the model include system drivers, spatial land use change, calculation of salt and floodplain impacts and economic costs, then presentation of a report card comparing impacts against resource condition targets. System drivers consist of policies such as restricted zoning of new development, requirements for improving water use efficiency, revegetation and installation of salt interception schemes. External drivers of change include market price variation and climate change. The effect of the drivers is expressed by a change in the distribution of land use and management. For example, if a zoning policy is applied, the response module alters the distribution of new irrigation development with a weighting toward the low impact zones. If a revegetation policy is selected, the area of revegetated land will be increased within each land unit by the area specified. This figure does not explicitly show all of the links and feedback within the system, but indicates the structure of the model.

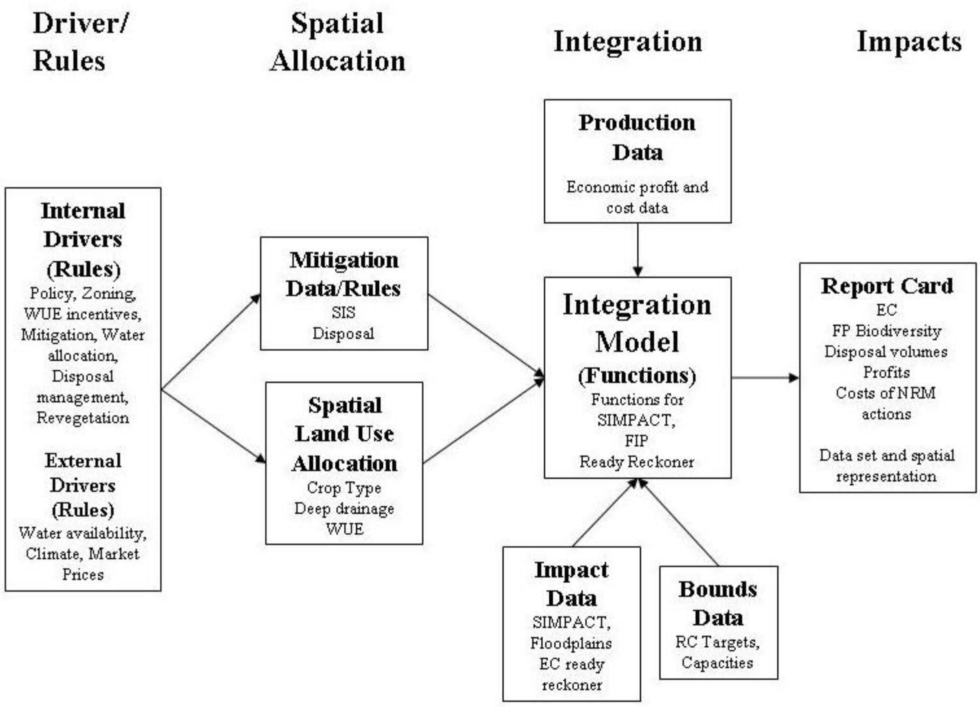

Figure 2.3 Overview of the RMCSM model structure, including drivers of change, on-ground response to drivers as spatial allocation of land use, calculation of salt and floodplain impacts and economic costs, then presentation of the report card comparing impacts against resource condition targets. This figure does not explicitly show all of the links and feedback within the system.

2.5. Linking aggregated on-ground actions to resource condition targets

The key function of the River Murray Corridor Systems Model is to link aggregated on-ground actions to resource condition targets such that the benefits of the set of actions may be quantified. This process is shown diagrammatically in Figure 2.4, where combinations of external drivers and policies drive land on-ground land management actions, which have quantifiable impacts on resource condition targets, economic production and social wellbeing.

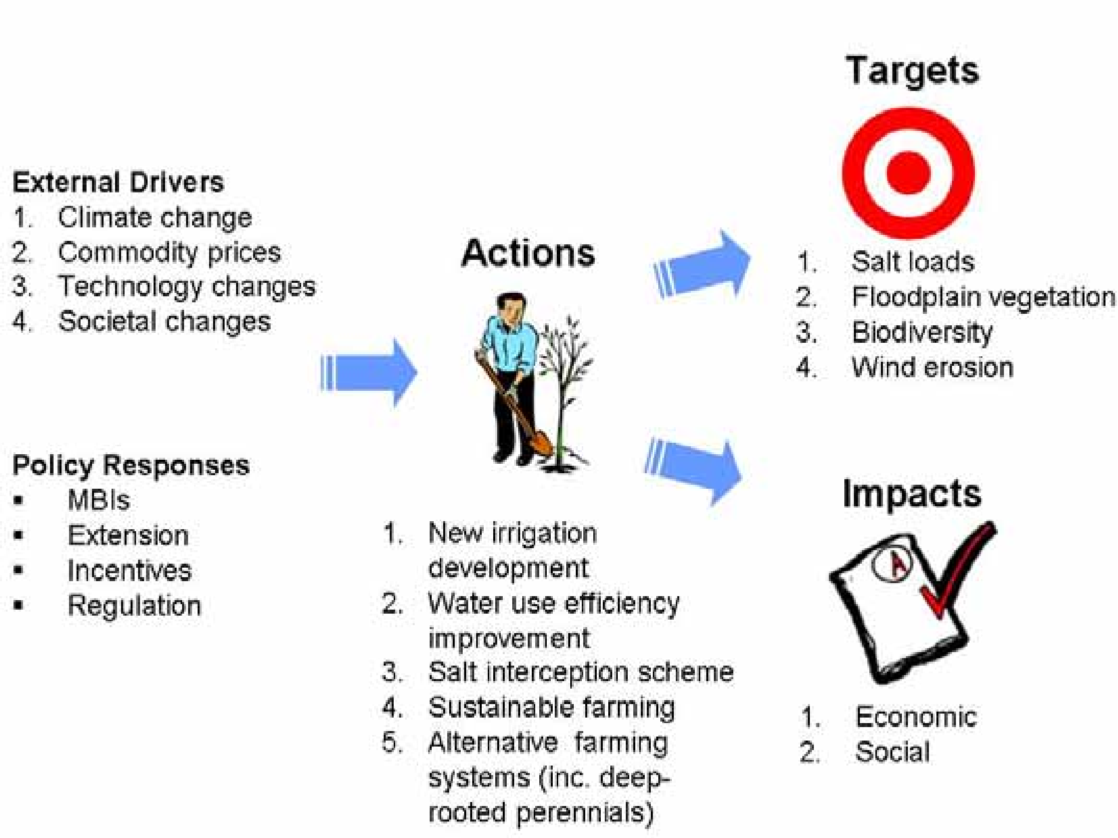

Figure 2.4 Conceptual approach used in project to relate RCTs and socio-economic impacts of plans

The River Murray Corridor Systems Model is an integration of existing biophysical and economic models that determines the salt and biodiversity impacts of land use and management actions. The model is presented in a way that enables users to test future land use scenarios and NRM strategies against various catchment management targets, and measure the economic impacts of land management decisions.

The model has been developed in the same framework as the CRC Catchment toolkit models, and may be integrated with these tools with only a small amount of additional work if required. While the most current relationships have been used to describe the system over time, it is recognised that this is a field that is currently undergoing significant development. The model structure has therefore been developed in a modular fashion, so that improved modules can be substituted in time as new data and information is published.

The River Murray Corridor Systems Model provides a method of relating resource conditions at future points in time to targets and actions that are defined and undertaken now. It is not an example of futures modelling, which does not operate on a defined timescale, and does not quantify the links between the current state and a state at some point in the future. Neither is the model a predictive tool that allows impacts to be calculated with confidence. The RMCSM uses the current state, and adjusts the trajectory from this state depending on external drivers and NRM policies to gain an understanding of potential land management states and resource condition impacts at given times in the future. A conceptual representation of these future trajectories is shown in Figure 2.5

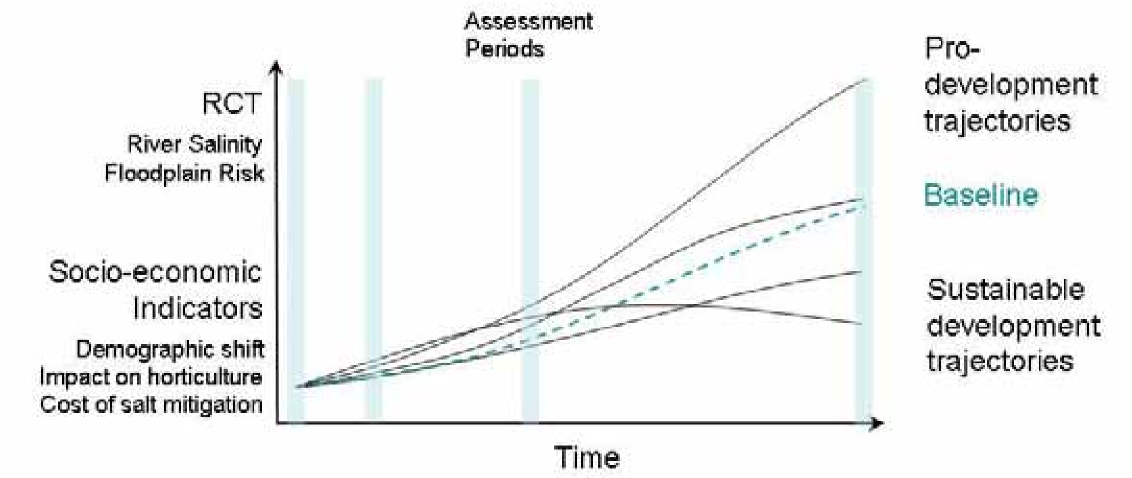

Figure 2.5 Conceptual diagram of future trajectories

Figure 2.6 shows the conceptual outline for the River Murray Corridor Systems Model. Drivers of change and current land use trends are derived from the synthesis of NRM plans for the region and review of current land use change data. The scenario builder is used to calculate estimations of new land use distribution and salt mitigation from combinations of land management actions. SIMPACT is used to calculate salt impacts on the river from changes in deep drainage rates and the Floodplain Wetlands Impacts Model is used to estimate salinisation risk to floodplain vegetation and wetlands. The component models are discussed in more detail in following sections. The potential impacts from land management change are compared against the resource condition targets, and the economic costs of management decisions are outlined.

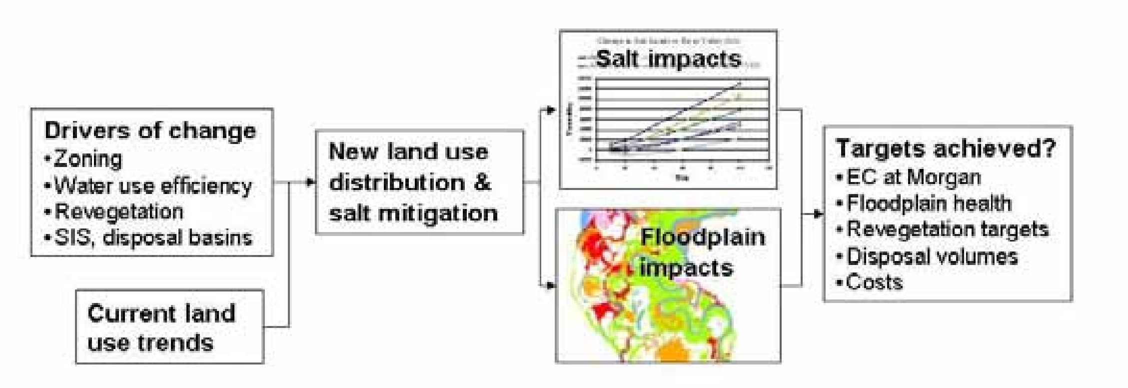

Figure 2.6 Conceptual model for the River Murray Corridor Systems Model

2.5.1. Model Spatial Units

The RMCSM combines a number of existing models within a spatial context. Units that are common to the models include spatial or modelling units, land use and management changes defined by deep drainage rates and the baseline data used for the 'do nothing' scenario. These units are discussed in more detail below.

Spatial Unit Definition

To avoid confusion in the reporting of the prototype model, the various levels of spatial definition are described below.

Reporting Unit: The scale and divisions at which the report card results are presented. Reporting units are generally based on a Land and Water Management Plan Level, which mostly align with lock to lock divisions. Additional reporting units have been added to incorporate regions north of Barmera and south of Riverland North Management Plan regions.

Scenario Analysis Unit: the unit at which land use is distributed through the effects of policy, social and land suitability rationale. This is the maximum level of discretisation of the prototype model, and is based on the spatial union of Land and Water Management Plan regions, high and low salt impact areas defined by SIMPACT (Section 5.7), salt interception schemes and floodplain analysis units (HIPRUS, Section 5.8)).

Model Unit: the unit at which the results from individual biophysical models, SIMPACT and FIP, are analysed. Results from the models at this are aggregated to the scale of the scenario analysis units.

FIPRU: the first scale of integration of the FIP model scale floodplain divisions, which approximates a single floodplain.

HIPRU: the highland unit associated with each FIPRU, based on expected groundwater flow paths from a specific irrigated area to a floodplain.

The biophysical models are run at the model unit (250m^2) for SIMPACT and floodplain divisions for the FIP model. The FIP results are aggregated to a single floodplain level, into FIPRU and HIPRU units. The spatial results of these models are then combined with the land use and management distribution, and giving salt load and floodplain biodiversity impacts. These impacts may then be aggregated again to the reporting unit scale, to be returned to the Land and Water Management Groups.

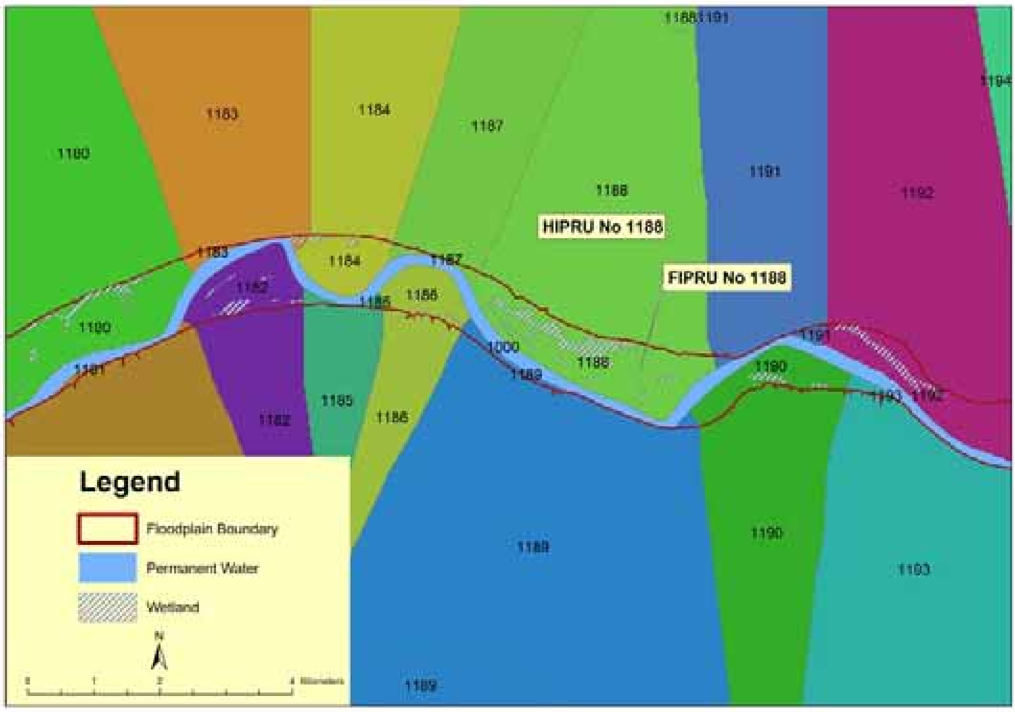

Figure 2.7 Diagram indicating FIPRUS and HIPRUS, FIP model divisions aggregated into floodplain and highland units approximating single floodplains, both wide (eg FIPRU/HIPRU no 1188) and narrow (eg FIPRU/HIPRU no 1187) which are characterised by different salt accumulation behaviour.

Spatial Disaggregation

The scenario analysis units (SAUs) were developed by combining the spatial boundaries of the following GIS datasets to create unique discrete units:

- high and low salinity impact zones, defined by SIMPACT for South Australia, and defined by the HIZ and LIZ zones 1-4 for Victoria;
- Land & Water Management Plan (LWMP) areas for South Australia and Irrigation Regions for Victoria;
- Salinity interception scheme catchment areas (SIS) in South Australia;
- The side of river, North/South (left/right) in South Australia;
- Floodplain Impact Reporting Units (FIPRUs) in South Australia and River Management Zones in Victoria.

The development of the scenario analysis units is described in more detail in the Year 1 Progress Report, and the Year 2 Interim Progress Report. The scenario analysis units for South Australia and Victoria are shown in Figure 2.8and Figure 2.9 respectively.

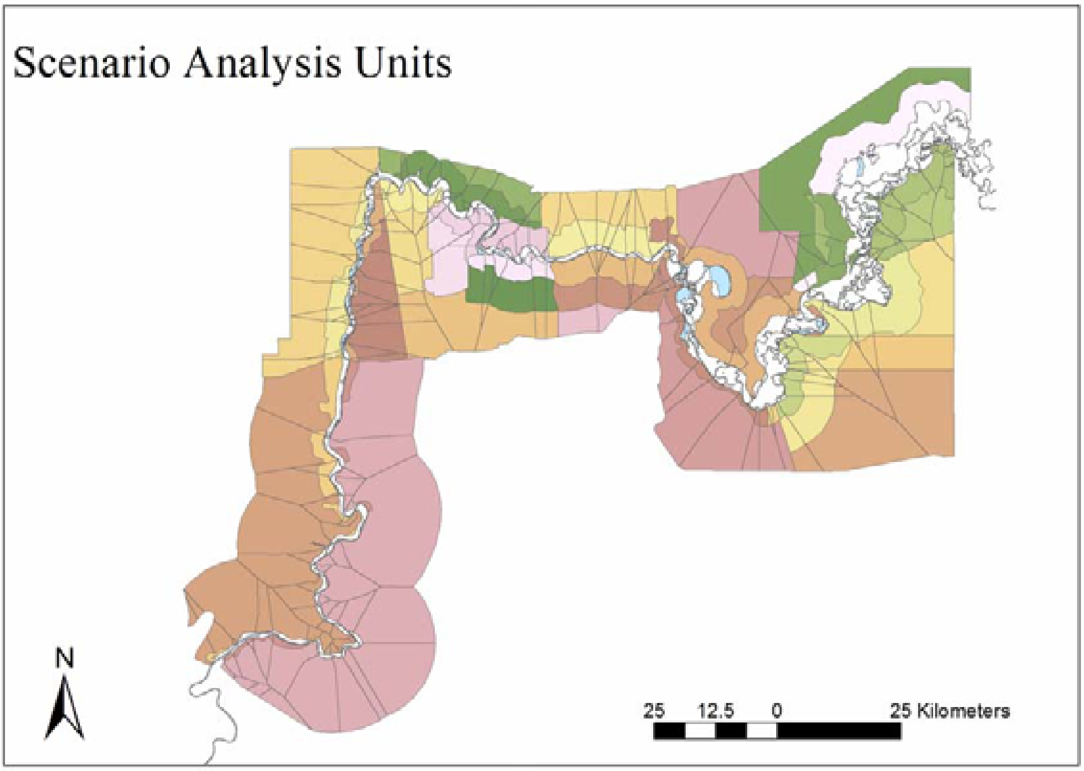

Figure 2.8 Scenario Analysis Units (SAUs) for South Australia based on Land and Water Management Plans, high and low impact zones, floodplain zones, salt interception scheme catchments, and side of the river.

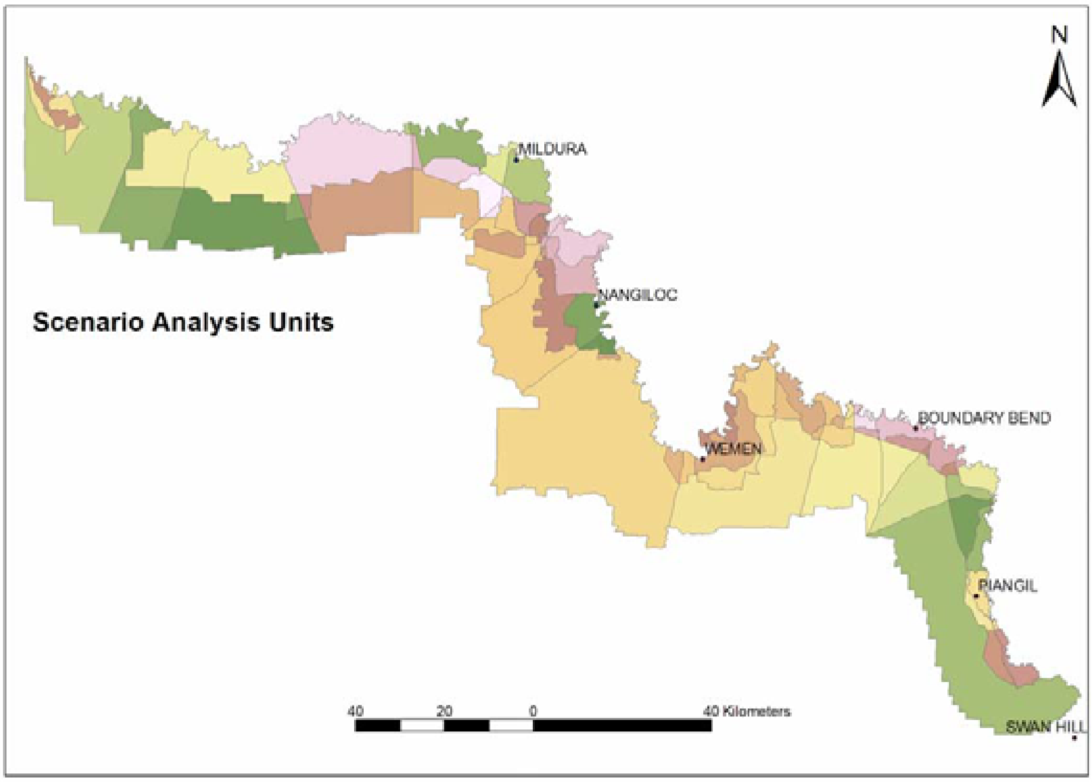

Figure 2.9 Scenario Analysis Units (SAUs) for Victoria based on Irrigation Regions, high and low impact zones (HIZ, LIZ 1-4) and river management zones.

Land use change was aggregated up to the level of the scenario analysis unit.

2.5.2. Component Models

As described in Section 3, the key linkages between land management actions and river salinity and riverine biodiversity targets are the relationships between land management practices and deep drainage, and the hydrology of the river corridor environment. The River Murray Corridor Systems Model therefore uses a series of sub-models to represent these systems, and the economic processes underlying them. Components of the RMCSM include:

1. SIMPACT, an analytical model accredited under Schedule C Clause 38(5) of the Murray Darling Basin Agreement as a model 'fit for purpose' for assessing new salinity impacts from interstate water trade within the Mallee Zone (MDBC, 2005).
2. The Floodplain-Wetland Impacts Model, a GIS applied analytical model relating groundwater inflow to the river valley to estimates of floodplain salinity risk that was developed by CSIRO for the River Murray Catchment Water Management Board (Holland, K.L. et al. (2005)).
3. Estimates of root zone drainage
4. Legacy of History, estimates of salt loads and groundwater inflows from already existing irrigation developments, which will increase in time without any further land use change. These estimates are required to add to the salt impacts of land use change in order to compare the total EC at Morgan with the resource condition target.

SIMPACT

SIMPACT in the form of SIMRAT has been accredited under Schedule C Clause 38(5) of the Murray Darling Basin Agreement as a model 'fit for purpose' for assessing new salinity impacts from interstate water trade within the Mallee Zone ({MDBC 2005 #24318}). SIMPACT is used by the South Australian Government to both report salinity impacts from irrigation developments to the MDBC and to define areas of high and low impact zones for future irrigation zoning restrictions. Salt impacts from irrigation development within the Victorian Mallee are simulated using the Nyah to the Border Model, which gives groundwater flow and salt impact outputs similarly to SIMPACT. Should it be necessary, the prototype model could function equally well using the outputs from the Nyah to the Border Model.

The purpose of the SIMPACT model is to simulate increases in the discharge of saline groundwater to the River Murray resulting from actions that affect the amount of water recharging regional aquifers. Driven by changes in drainage past the root zone, the model calculates increases in salt loads to the river using a two stage process.

Firstly depth to groundwater and vertical infiltration rates through various geologic layers are used to calculate how long recharge takes to start impacting on groundwater flows. The model can account for two layers of varying texture within the unsaturated profile, a sandy layer and a clay layer (eg Blanchetown Clay). Secondly a saturated flow hydrogeological model describing the relationship between recharge, distance from river and aquifer properties is used to quantify how much salt will be delivered over a certain period of time (Figure 3).

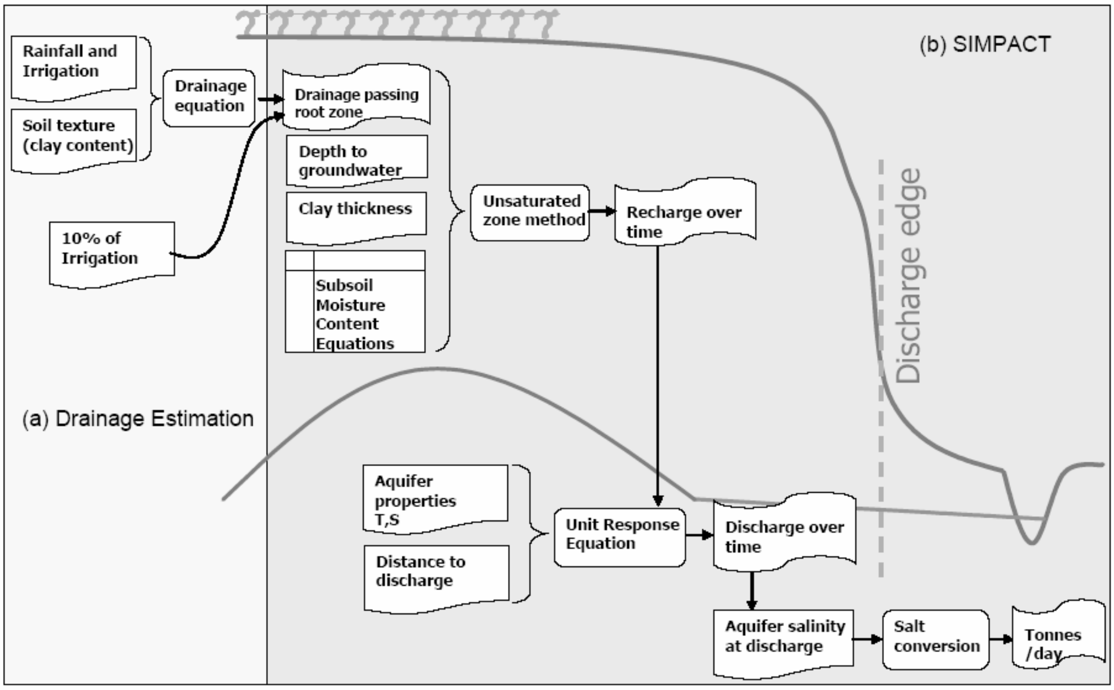

Figure 3 Schematic representation of SIMPACT2. Section (a) represents the drainage estimation; Section (b) represents SIMPACT2 using drainage as input for simulating the recharge process (from Munday, T. et al. (2004)). In the RMCSM, the drainage is estimated by the model, and only the SIMPACT (b) recharge section is used.

In addition to its application as an assessment tool for interstate water trade, SIMPACT 2 outputs have:

- been informing South Australian Murray-Darling Basin salinity policy development through:
  - creation of salinity impact zones to control location of future irrigation development,
  - assessing socio-economic impacts of salinity zoning, and
  - assessing SA accountability to the MDBC for irrigation development since 1988
- calculated recharge rates to regional aquifers from native mallee vegetation clearance for input to numerical groundwater models, and
- calculated potential changes recharge rates from revegetation to inform strategic revegetation prioritisation.

The application of SIMPACT in the Lower Murray Futures project was to run a series of land use change scenarios to analyse impact on salinity targets. The outputs of the SIMPACT scenario runs will be used to run the South Australian Lower Murray irrigation landscape futures scenario generation model and integrated with the Floodplain Impact Model (FIP) to assess impact on vegetation health.

As a part of the LMLF project, the SIMPACT recharge, baseflow and salt load algorithms have been coded into the TIME framework, and incorporated into the RMCSM directly. The algorithms are applied in a vector format for each of the changes in land use for each SAU. This method provides far more flexibility in defining deep drainage rates than using pre-calculated SIMPACT results as inputs, as was the case for the prototype model in year 1. Each of the salt load impacts is the accumulated up to the SAU level, and expressed as spatially and temporal variations in groundwater flow to the river valley, and river salt loads.

The SIMPACT algorithm calculates the salt load impacts of changes in deep drainage for instances of:

- New development, that is changing from close to zero root zone drainage to the new root zone drainage of the development (0 – X mm/year);
- Retirement of irrigation, that is changing from the irrigation root zone drainage to drainage under dryland cropping or pasture (X – 0 mm/year); and
- Decreases in deep drainage from a particular land use, associated with improvements in management or system type (X – Y mm/year, X>Y).

The type of calculation used for the SIMPACT algorithm is dependent on the nature of the change in land use or land management.

Figure and Figure show examples of SIMPACT output at 100 years, for deep drainage rates of 120 mm/year for each of the scenario analysis units within South Australia and Victoria.

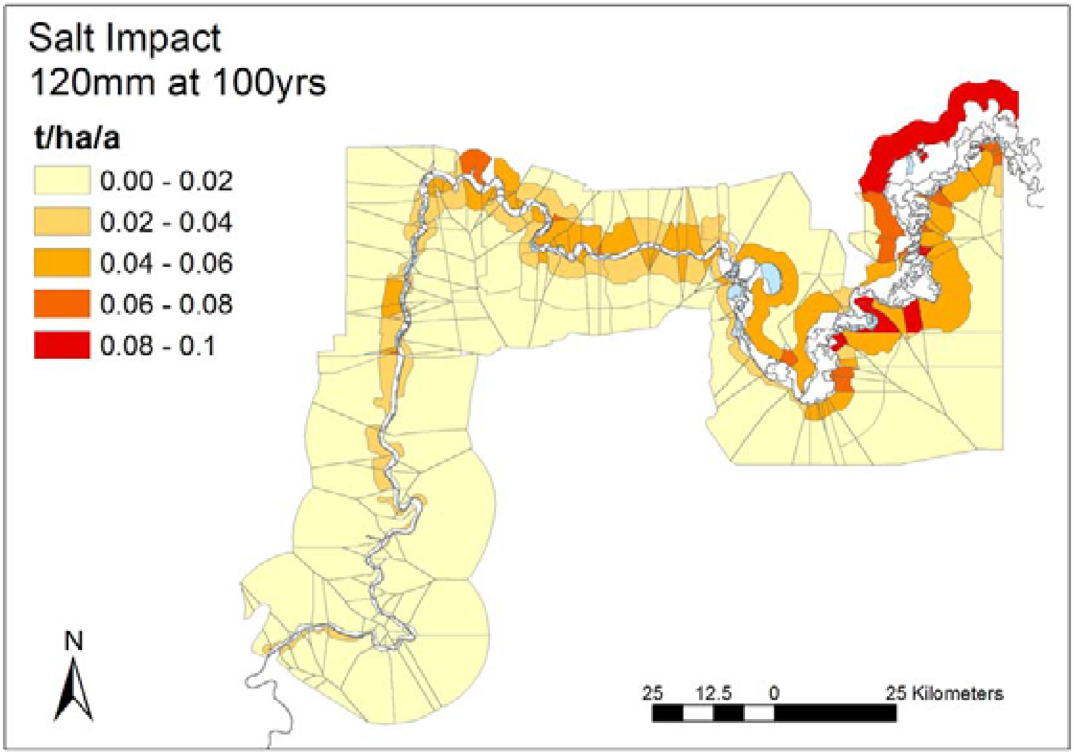

Figure 2.11 Example of SIMPACT output in South Australia: salt impact from establishment of 120 mm deep drainage irrigation after 100 years (tonnes/yr/ha).

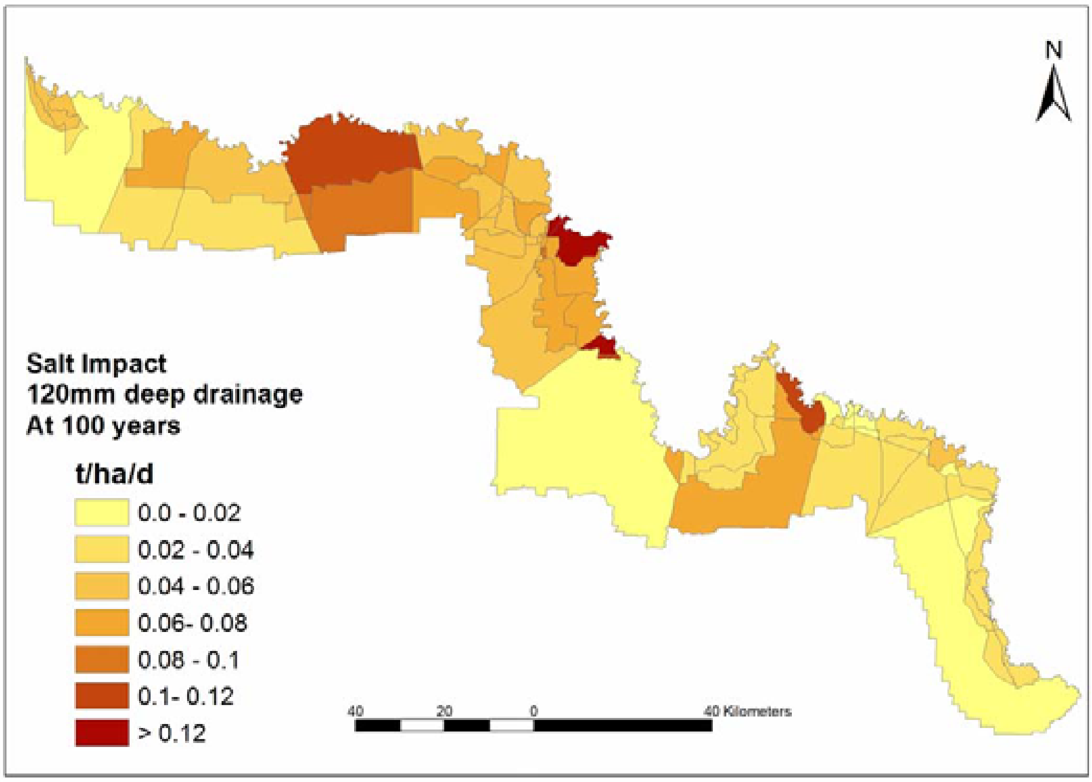

Figure 2.12 Example of SIMPACT output in Victoria: salt impact from establishment of 120 mm deep drainage irrigation after 100 years (tonnes/yr/ha)

An example of the temporal impacts of land use change, calculated from the prototype model, showing the time delay between land use change and full impact on the river is shown in Figure 2.13. The examples include irrigation growth at a baseline rate, improvement of water use efficiency in half of all developments that can be improved, zoning 50% or 80% of new development into low impact zones instead of high, and combinations of the above. Note that the scale expresses salt loads as a change, rather than absolute figures.

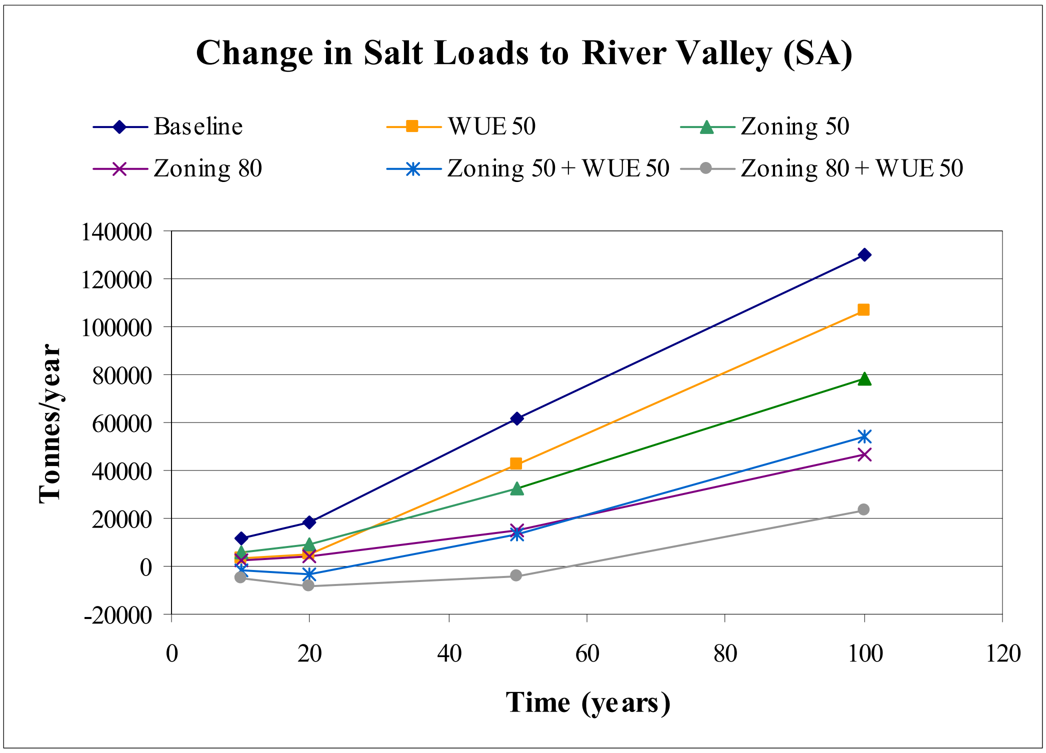

Figure 2.13 Example of the temporal impacts of land use change, calculated from the prototype model, showing the time delay between land use change and full impact on the river. The examples include irrigation growth at a baseline rate, improvement of water use efficiency in half of all developments that can be improved, zoning 50% or 80% of new development into low impact zones instead of high, and combinations of the above.

The ready reckoner data developed for SIMRAT reporting of EC impact (REF) are used to transform salt loads to the river to values of EC at Morgan, and equivalent EC. EC increases are compared with the river salinity target of 800 EC, 95% of the time at Morgan in accordance with the reporting of EC impacts from water trades under the Murray Darling Basin Agreement.

Floodplains Impact Model

Data outputs from the Floodplains and Wetland Impact Model (FWIP) model has been used to assess the impact of various land use and management scenarios on the health of the floodplain environment within the RMCSM. The FWIP model is described briefly in the following section. A more detailed description of the model is found in the Year 1 Progress report ((2005)) and Holland, K.L. et al. (2005)).

The floodplain analysis for the prototype model was based on data and a model developed in the NHT/River Murray Catchment Water Management Board/Department of Water, Land and Biodiversity Conservation/Department for Environment and Heritage/CSIRO Land and Water funded Floodplain Impacts Project. This project carried out a floristic composition and tree health survey for the entire lower River Murray floodplain in South Australia and developed the Floodplain and Wetland ImPacts model (FWIP) to help formulate regional policies to protect floodplains from the impacts of new irrigation developments and for prioritizing management efforts to reduce floodplain and river salinisation. As such, it is appropriate for use in the Mallee Futures project, albeit in a slightly different manner than originally intended.

FWIP is a steady-state analytical cross sectional model, implemented spatially within a GIS framework over the entire lower River Murray floodplain in South Australia, an area of >100,000 hectares ((2003); (2004)). FWIP predicts the partitioning of regional and irrigation-induced groundwater inflows to seepage at the break of slope of the highland/floodplain, evapotranspiration across the floodplain, and baseflow to the river (Figure). It provides a spatial understanding of the balance of salt accumulating in the floodplain and wetlands versus salt accession to the river. It is sufficiently simple to be applied with GIS type applications, and yet powerful enough to determine the groundwater discharge patterns through cross-sections of the River Murray valley.

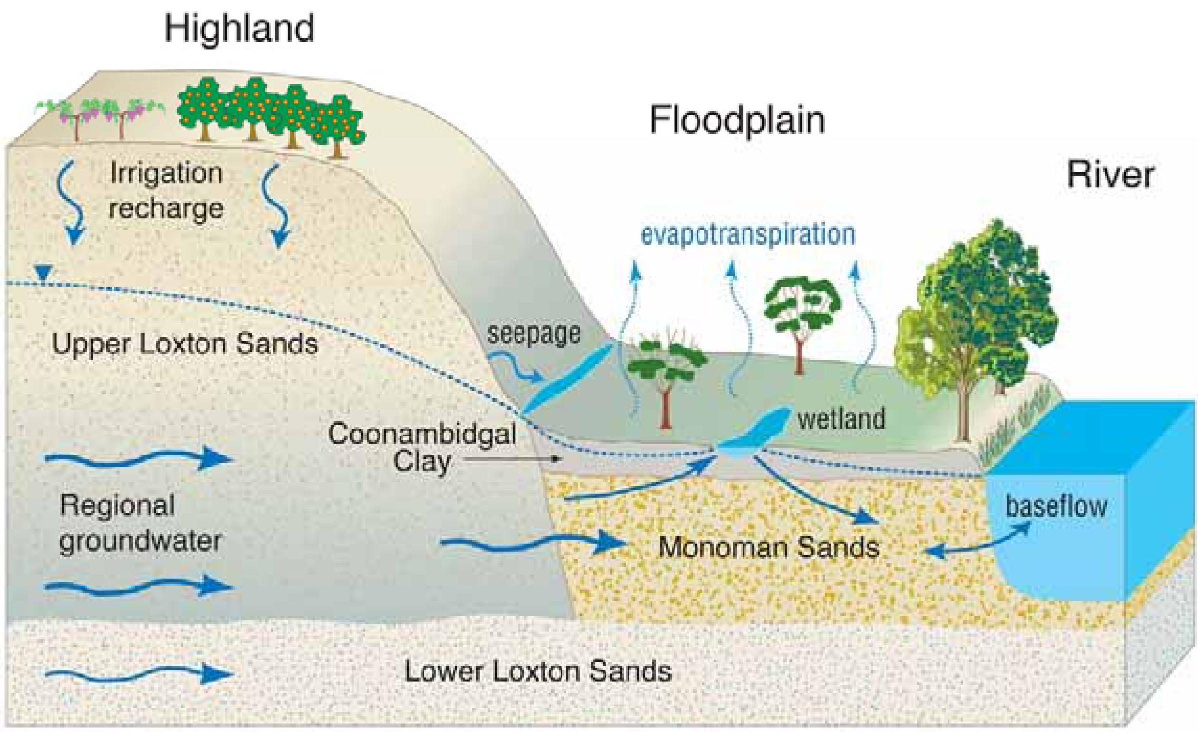

Figure 2.14 Conceptual model of groundwater inputs to the floodplain and potential groundwater discharge pathways within the floodplain, wetland and river. Groundwater entering the river valley can be discharged as either seepage at the break of slope and/or evapotranspiration through the floodplain surface. Groundwater can also move into or out of the wetland or the river. Baseflow can be into the river if the river level is below the groundwater level between the wetland and the river, or out of the river if the river level is higher than the groundwater level between the wetland and the river (*i.e.* just upstream of weirs).

The model has been applied spatially by discretising the floodplain into a series of representative cross sections (divisions) designed to represent the direction of groundwater flow across the floodplain. Approximately 3500 divisions were created of ~250 m wide at the edge of the floodplain. The width of the divisions at the river's edge varies greatly depending on the geometry of the floodplain and the direction of groundwater flow across the floodplain. In spite of its relative simplicity, detailed quasi-3D MODFLOW modelling by Doble, R.C. (2004)) has shown that as long as the divisions follow the groundwater flow lines, FIP can provide accurate predictions of the total volumes of seepage, floodplain ET and baseflow to the river. The model has been calibrated against run-of-river salinity data, observed seepage areas and floodplain vegetation health mapping (this has only been done to date between Locks 3 and 4). In constructing the model groundwater inflows were derived from interpolated contours from observation bores and then manually manipulated to better correlate with irrigation areas and run-of-river data.

The FWIP model generates an output of the proportion of floodplain vegetation and wetlands at risk of salinisation for each floodplain division at years 2003, 2020, 2050 and 2100, assuming that no further land use change takes place after 2003. The proportion of floodplain 'at risk of salinisation' is defined as the proportion of floodplain division that is covered by vegetation or a wetland that has a groundwater depth above the evapotranspiration extinction depth, and therefore has a positive rate of salt accumulating. Initial testing by Holland et al. (2005) showed that floodplain salinisation risk is more sensitive to the presence of a salt interception scheme than floodplain enhancement from weir manipulations or increased irrigation according to growth estimates from prior commitment to irrigate before 2003.

For the second year of the project, the results from the floodplain impacts were used to calculate the risk of salinisation to floodplain vegetation and wetlands calculated from two sets of data:

- temporal changes in risk of salinisation for every floodplain protected by an SIS
- temporal changes in risk of salinisation for only currently installed SIS, otherwise no floodplain protection from SIS.

If a floodplain has a SIS created by the model user, the first set of data is used. If a floodplain has no interception assigned to it, the second data set is used.

Land use combinations and root zone drainage estimations

Currently a detailed analysis of the relationships between deep drainage rates to crop type, irrigation system type and degree of management is underway ((2005)) but data at a fine enough scale to develop and test detailed relationships within the LMLF project is not available. However, the scope of the modelling is to produce broad approximations of deep drainage that limits the number of parameters used, but representative of processes of system and management improvement.

The methodology used to calculate deep drainage follows:

Crop types are limited to:

- vines
- nuts
- citrus

System types are very broadly grouped into:

- drip irrigation

- sprinkler application
- furrow irrigation

Management practise is extremely broadly broken into:

- well managed systems (soil moisture monitoring, efficient scheduling, regular inspection, educated on efficient practices)
- poorly managed systems (scheduling not based on monitoring, some blockages present, little education on efficient practices)

These crop type, system type and management categories are combined to give 18 different land use combinations with different deep drainage rates (Table 2.2).

Table 2.2 Land use combinations

Dryland - Trees
Dryland - Perennial
Dryland - Annual
Vines - Drip - Good
Vines - Drip - Poor
Vines - Sprinkler - Good
Vines - Sprinkler - Poor
Vines - Furrow - Good
Vines - Furrow - Poor
Nuts - Drip - Good
Nuts - Drip - Poor
Nuts - Sprinkler - Good
Nuts - Sprinkler - Poor
Nuts - Furrow - Good
Nuts - Furrow - Poor
Citrus - Drip - Good
Citrus - Drip - Poor
Citrus - Sprinkler - Good
Citrus - Sprinkler - Poor
Citrus - Furrow - Good
Citrus - Furrow - Poor
Other

Assigning deep drainage rates is done by combining crop water application rates, a bulk efficiency for the system, and a change in efficiency for good or poor management. Irrigation application rates by crop, separate system and management efficiencies, and the combined irrigation efficiency for system type and management are shown in Tables 2.2 to 2.4 respectively. The management efficiency factor is added or subtracted from the system efficiency, and multiplied by the crop application rates (Table 2.5). Deep drainage rates for dryland farming systems are included in Table 2.6 as constant rates (Wang, E. et al. (2005),Wang, E. et al. (2006)).

Table 2.3 Crop water application rates

Application Rates (mm)	
Citrus	**900**
Vines	**800**
Nuts	**1200**

Table 2.4 System and management efficiencies

Efficiency	
Furrow	**70%**
Sprinkler	**80%**
Drip	**85%**
Poor	**-10%**
Good	**7%**

Table 2.5 Combined efficiency for system type and management

Combined Efficiency		
Drip	**Poor**	**75%**
Drip	**Good**	**92%**
Sprinkler	**Poor**	**70%**
Sprinkler	**Good**	**87%**
Furrow	**Poor**	**60%**
Furrow	**Good**	**77%**

Table 2.6 Deep drainage rates for crop type, system type and management

Land Use Combination	**DD (mm)**
Dryland - Trees	**1**
Dryland - Perennial	**5**
Dryland - Annual	**10**
Vines - Drip - Good	**64**
Vines - Drip - Poor	**200**
Vines - Sprinkler - Good	**104**
Vines - Sprinkler - Poor	**240**
Vines - Furrow - Good	**184**
Vines - Furrow - Poor	**320**
Nuts - Drip - Good	**96**
Nuts - Drip - Poor	**300**
Nuts - Sprinkler - Good	**156**
Nuts - Sprinkler - Poor	**360**
Nuts - Furrow - Good	**276**
Nuts - Furrow - Poor	**480**
Citrus - Drip - Good	**72**
Citrus - Drip - Poor	**225**
Citrus - Sprinkler - Good	**117**
Citrus - Sprinkler - Poor	**270**
Citrus - Furrow - Good	**207**
Citrus - Furrow - Poor	**360**
Other	**0.1**

Resulting deep drainage rates for various land use combinations are shown in Figure 2.15. The assumed deep drainage rates indicate that generally drip irrigation has a higher realised efficiency than sprinklers, which have a higher realised efficiency than furrow systems. A well managed sprinkler system, however, will have lower deep drainage rates than a poorly managed drip system. Deep drainage under nuts is higher than citrus and vines due to higher water requirements.

Note that this method of assigning rates of deep drainage is very broad and deals with bulked parameters. Not all processes driving irrigation efficiency and deep drainage have been included. This conceptual model is not intended to replace detailed studies, but to provide a method of determining deep drainage rates from a limited number of key factors. It is intended to improve on approximating deep drainage from simply crop type alone.

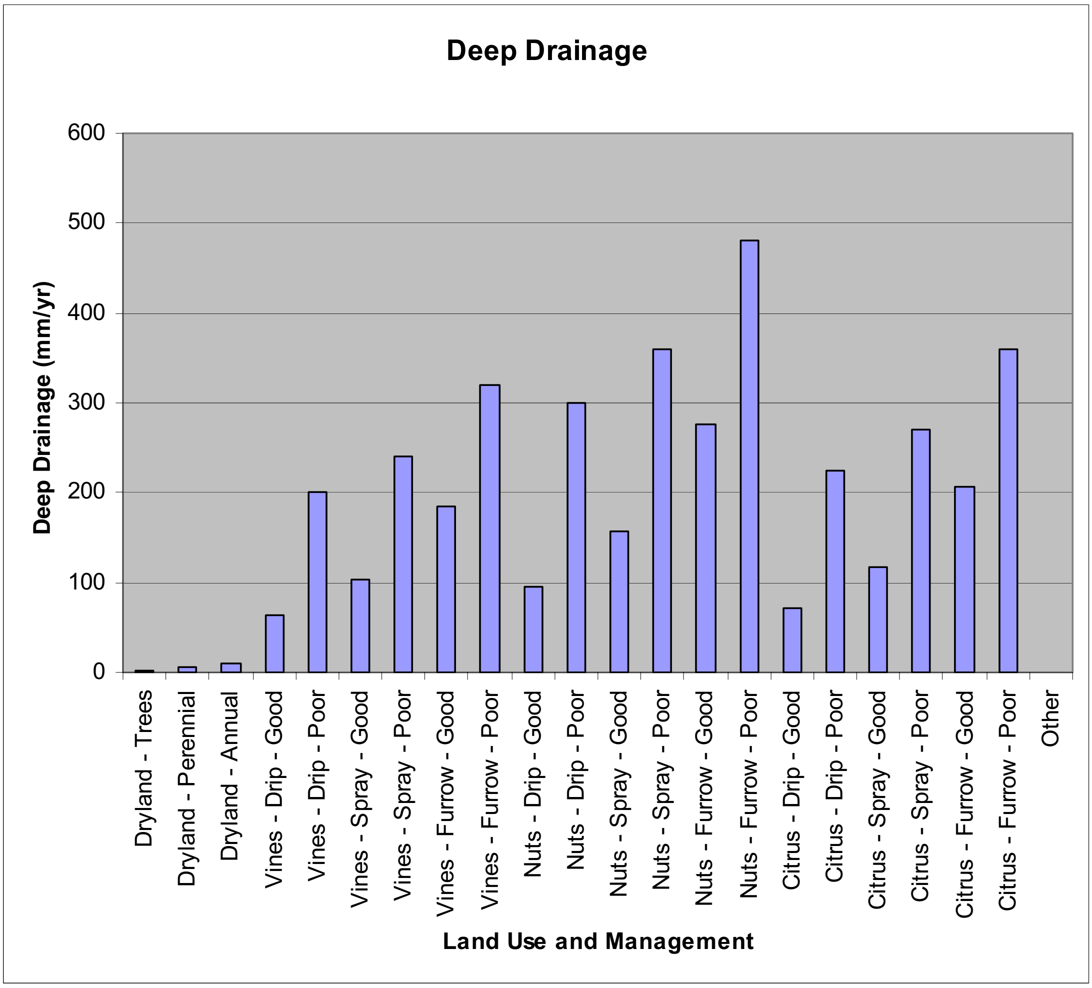

Figure 2.15 Assumed deep drainage rates for land use combinations.

Jeff Connor is in the final stages of preparing a regression analysis relating crop management with deep drainage rates. This will be available in December 2006.

Legacy of History

In order to compare modelled EC at Morgan with the resource condition target, it was necessary to estimate the potential increase in salt loads to the river from current irrigation developments, above which future changes in land use and land management practices will have an impact. This data, known as 'legacy of history' was estimated by running a historical development analysis using SIMPACT.

Vegetation clearance was defined specifically as clearance of native mallee vegetation communities. It is these communities that utilised virtually 100% of available rainfall. So when cleared and converted to dryland cropping, such areas were sources of increased root zone drainage (Holland et al. 2005). Due to a lack of spatial information detailing the timing of vegetation clearance, a conservative assumption that all clearance occurred in 1920 was made.

The approximate era of irrigation commencement was defined for each irrigation area from a combination of local knowledge and historical documents. Several areas where selected for more intense date mapping from historical aerial photography. These areas include Moorook, Waikerie, Qualco, Murtho and Bookpurnong. Some of these were included in case study investigations during validation/accreditation stages of the SIMRAT project ({MDBC 2005 #24318}).

Root zone drainage rates under irrigated crops have changed over time with improvements in irrigation technology and management techniques. Table 2.7 shows the rates used for the different eras of irrigation development. Irrigation originally developed in the 1880s was assumed to have improved from 300 mm yr^{-1} to 160 mm yr^{-1} in the 1980's.

Table 2.7 Root zone drainage rates applied depending on when the action started. These rates are kept constant for the duration of the analysis.

Era of Action	Long Term Drainage Rates
1880's - 1970's irrigation	300 mm yr^{-1} with reduction to 160 mm yr^{-1} after 1970
1980's irrigation	160 mm yr^{-1}
1990's - 2000's irrigation	120 mm yr^{-1}
1920 mallee clearance	1 – 16 mm yr^{-1} spatially varying

Four SIMPACT2 runs were performed that modelled each of the above root zone drainage rates: '300 mm yr^{-1}', '160 mm yr^{-1}', '120 mm yr^{-1}', and the 'mallee clearance' grid. In addition, a fifth run which modelled the decrease in root zone drainage from 300 mm yr^{-1} to 160 mm yr^{-1} was carried out. These runs were added by superposition to create groundwater inflows and salt loads to the river for 2000, 2020, 2050 and 2100 from each of the Land and Water Management Plan regions (Table 2.8,Table 2.9).

Table 2.8 Salt loads to the river valley (tonnes/day)

	Pre-Irrigation/ Clearance	2000	2020	2050	2100
Berri-Barmera	1246	7426	9108	12359	12766
Bookpurnong-Lock4	1496	2476	3076	4008	6453
Gurra Gurra Lakes	805	4715	5102	5354	7187
Loxton	1021	5896	6333	8803	11976
Merriti	4716	5085	5129	5193	5471
Murtho	-20	2225	3487	6766	12686
Pike River	580	6516	7359	8386	13947
Ral Ral	1176	7084	7517	8320	9921
Cadell	40	1977	2082	4449	4882
Blanchetown	8104	10575	11769	14326	22102
Pyap-Kingston	831	5205	5678	6503	9546
Qualco/Sunlands	38	4710	4646	6476	10902
Riverland North	1764	2446	3378	5123	8120
Taylorville North	388	5121	5581	7967	11903
Waikerie	380	3325	2154	3236	3268
Woolpunda	5208	664	713	746	1144
Total	**27774**	**75444**	**83112**	**108017**	**152274**

Table 2.9 Groundwater inflows to the river valley (ML/day)

	Pre-Irrigation/ Clearance	2000	2020	2050	2100
Berri-Barmera	33	192	237	319	327
Bookpurnong-Lock4	47	77	95	123	198
Gurra Gurra Lakes	22	100	110	117	160
Loxton	27	161	173	241	328
Merriti	129	143	145	147	157
Murtho	10	70	103	191	352
Pike River	20	194	221	255	441
Ral Ral	38	203	215	239	284
Cadell	1	40	42	91	99
Blanchetown	61	73	79	93	132
Pyap-Kingston	14	99	108	123	182
Qualco/Sunlands	2	74	73	101	169
Riverland North	25	32	40	54	80
Taylorville North	7	88	96	139	206
Waikerie	6	51	33	49	50
Woolpunda	109	14	15	15	24
Total	**550**	**1609**	**1783**	**2298**	**3189**

SIMPACT2 predicts the groundwater flux to the floodplain that occurs as a result of irrigation development and clearing of native vegetation for dryland agriculture. In addition to these are the natural inflows that occur as a result of the lower River Murray being one of the main discharge locations for the saline regional groundwater systems of the western Murray Basin. The natural pre-irrigation/clearance inflows to the floodplain from the regional aquifers beneath the highland were calculated for each FIPRU using the unconfined highland aquifer transmissivity and the interpolated pre-irrigation/clearance highland groundwater surface using Darcy's Law. To calculate the groundwater gradient into the floodplain, the river level was set to the river height at entitlement flow. Because of the great uncertainty in these approximate estimates they were further adjusted during model testing based on estimates from previous studies such as the Regional Saline Water Disposal Strategy (AWE (2003)) and ensuring that no seepage areas were predicted. The final adopted pre-irrigation/clearing groundwater fluxes to the river valley are summarised by Land and Water Management Plan (LWMP) area in Table 2.8 and Table 2.9.

A more detailed description of the calculation of Legacy of History flows is found in Holland, K.L. et al. (2005).

2.6. Linking policies and drivers to on-ground action

This section of the report outlines the structure of the model, including timescales of analysis, baseline 'status quo' data used and its sources, and the methods and assumptions used to generate the scenario builder for the model.

2.6.1. Model Structure

Timelines

The trajectory modelling used to indicate future resource condition impacts was based on two distinct time periods: a short period in which development and land use change was assumed to occur, and a longer period following this to estimate the riverine impacts into the future, of the order of 100 years. The development period is nominally 10 years for the analysis of regional plans, which fits within the timeframe of most of the NRM plans, and although longer than the planning timeframe of most irrigators, is long enough to capture some major changes such as changes in crop types or system replacement. For the analysis of future scenarios in year 3 of the LMLF project, a 50 year timeframe for development will be used.

The 10 year time period for development is commensurate with the timing for the next round of NAP funding.

In the third year of the project, for the development of the future scenarios, the potential for running the model as a series of time steps will be evaluated. These time steps would consist of implementing policy and actions, response in land use change and environmental response, and will be applied in series for the duration of the analysis. This will allow land use and land management decisions in the future to respond to environmental changes as they occur.

Baseline data

Baseline changes in land use and management combinations were estimated from the changes in crop type, system type and management that occurred between 1988 to 2003 in South Australia, and 1997 and 2003 for Victoria. These change rates were linearly scaled to reflect an average change in land use over the 10 year development period.

This baseline data was used as a first approximation to predict future irrigation development. Development under a 'do nothing' scenario was assumed to follow this same pattern after 2003. This assumption is obviously limited in predicting both the spatial distribution and crop types used in future irrigation, and as such is only a starting point for the model. Information on prior commitment to irrigate before 2003 in South Australia was compared with the baseline data to ensure that the spatial discretisation and total development areas were similar.

Data sources for the baseline data are discussed in Section 2.6.3.

Information for the volumes of water committed to irrigation prior to 2003 obtained from DEH are used to confirm baseline growth rates.

2.6.2. List of Scenario Builder options

The options for building scenarios were developed in consultation with the Project Steering Committee, the members of the Scenario Development Workshops, and various stakeholders who have been consulted separately. Options for scenario development are separated into those that are regionally applied, such as zoning policy, and those that are applied locally and therefore require a map to select specific SAUs. These options are shown in Table 2.10.

Table 2.10 List of options for the Scenario Builder

Regionally applied	***Measure***	***Data sets modified***
New development*	Area (ha)	% Dryland → Irrigation
Zoning policy	% level of achievement (SA), Levies for trading into regions (Vic)	% Dryland → Irrigation
Irrigation system improvement factor	x times rate of current upgrades	% Furrow → Sprinkler % Furrow → Drip % Sprinkler → Drip
Management improvement factor	x times rate of current management improvement	% Poor → Good Management
Deep drainage increase due to salinisation	add x% to current low DD rates	% increase/ threshold in DD values
Revegetation (weighted across region)*	Area (ha)	% Dryland → Other
Increase trees in dryland agriculture	x times rate of current shift to tree based dryland agriculture	% Annual → Tree % Perennial → Tree
Increase perennial dryland agriculture	x times rate of current shift to tree based dryland agriculture	% Annual → Perennial
Crop market prices	Market price	% Change between crop types Proportions of new crop types
Locally applied (using maps)		
New development*	Area (ha)	% Dryland → Irrigation
Build SIS	location, year, capacity, disposal links	Zero salt to river if behind an interception scheme
Build salt disposal capacity	SIS links, year, capacity	Allows more SIS to be built
Build tile drains	location, %DD reduction, disposal links	% reduction/ threshold in DD values
Revegetation*	Area (ha) locally	% Dryland → Other
Investment in infrastructure	Resulting area (ha) of new development IN ADDITION to regional rates	% Dryland → Irrigation
Retirement of irrigation	% of existing irrigation retired from each SAU	% Irrigation → Dryland % Irrigation → Other
Increased urban development	x times current rate	% Irrigation → Other % Dryland → Other

*Revegetation may be applied either locally or regionally, as can new development.

Building tile drains and an increase in deep drainage are applied directly to the deep drainage rates. Crop market price changes will be included in the model with the integration of the economic modelling in 2006.

Victorian levees have not yet been included, as these are specific to the incorporation of the economic models.

An example screen capture of the Scenario Builder Wizard screen is shown in Figure 2.16. This illustrates the capacity to apply actions to the entire region, or to individual SAUs or selections of SAUs.

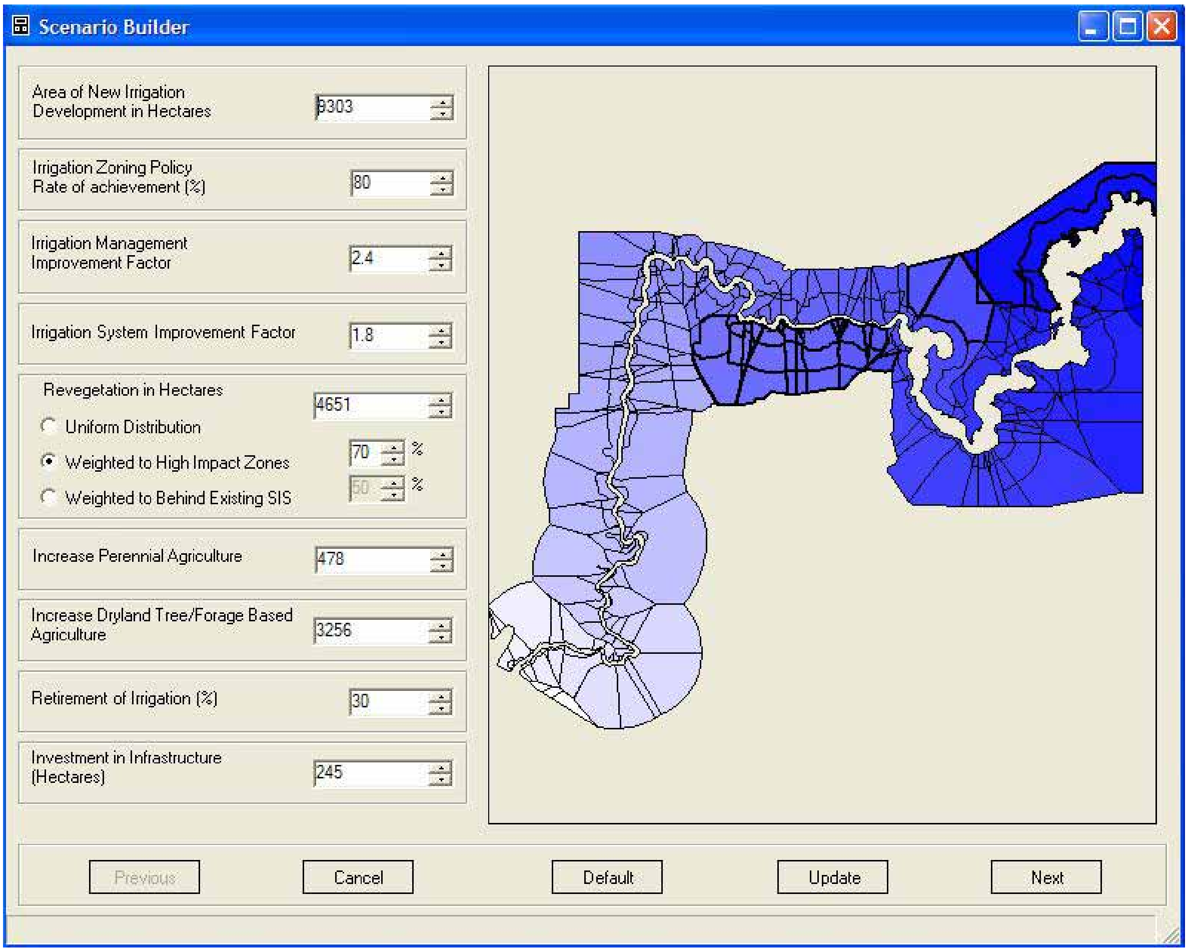

Figure 2.16 Screen capture of the Scenario Builder Wizard

Salt Interception Schemes and Disposal Rules

Rules and data for the function of salt interception schemes (SISs) and disposal capacity:

- if a SAU is within the capture zone of a salt interception scheme, the salt and groundwater inflows from that SAU will be zero until the combined inflows from the SAUs behind the SIS exceed the pumping capacity of the SIS

- if the combined inflows from the SAUs behind the SIS exceed the pumping capacity of the SIS, then any excess groundwater inflows and salt loads will occur according to their relative contribution
- any groundwater inflow intercepted by the SIS is accumulated for all SAUs, and all SISs that discharge into the same disposal basin
- if the sum of groundwater inflows to the disposal basin exceeds the capacity of the basin, the user will be notified, and the excess inflow will be returned to the river for each SAU, according to its relative contribution
- both SIS and disposal options have a build date, before which time, any groundwater inflows and salt loads will be discharged directly to the river
- each salt interception scheme and method of disposal have an installation cost, and an operating cost. These costs will be included in the economic analysis of the scenario.

The process followed and assumptions made in the calculation of the volumes of groundwater intercepted by salt interception schemes (SIS) or disposal basins are as follows:

where:

C_S = the capacity of the salt interception scheme

C_D = the capacity of the disposal option

GW_{SAU} = the groundwater inflows to the river from an individual SAU, including Legacy of History Flows.

GW_{SIS} = the potential groundwater inflows to a SIS, including Legacy of History flows

GW_{SIS-D} = the sum of all intercepted groundwater to be disposed of by a particular disposal option.

GW_D = the potential groundwater inflows to a disposal scheme, the sum of inflows of all SAUs supported by that disposal option.

R_S = the residual groundwater flow to the river once the SIS capacity has been reached.

R_D = the residual groundwater flow to the river once the disposal option capacity has been reached.

- If an interception scheme is present and the date is after the scheme has been built, the groundwater inflows plus legacy of history flows from each SAU are aggregated up to the SIS level (GW_{SIS}).
- If $GW_{SAU} \leq C_S$, then the new groundwater flow and salt loads to the river are set to zero, and the volume requiring disposal is equal to GW_{SIS}.
- If $GW_{SAU} > C_S$, then the total volume requiring disposal is equal to C_S, and the remainder that is not intercepted is equal to $R_D = (1-C_S/GW_{SIS})*GW_{SAU}$. The salt load to the river is calculated in a similar manner.
- The total groundwater volume intercepted by an SIS is aggregated to the disposal level (GW_{SIS-D}).
- If $GW_{SIS-D} \leq C_D$, then the values are reported.

- If $GW_{SIS-D} > C_D$, then the total groundwater inflows from all SAUs serviced by a disposal option (GW_D) is aggregated. The residuals for each SAU is calculated from $R_D = (1-C_D/GW_D)*GW_{SAU}$.
- The final residual groundwater flow to the river is selected from the maximum of R_D and R_S.
- The SIS intercepted volumes and disposal volumes are aggregated again, using groundwater flow rates of ($GW_{SAU} - R_D$) and ($GW_{SAU} - R_S$).

The scenario builder screen for salt interception and disposal is shown in Figure 2.17.

New irrigation development

The methodology for assigning new irrigation development, rules and data includes:

- New irrigation development will not exceed the total area of a SAU, after accounting for the areas of existing irrigation, townships or native vegetation.
- New irrigation development is specified as an area of irrigation in hectares.
- New development may be specified for the region, and retain the distribution of the baseline data, or be specified for individual SAUs. If a number of SAUs are selected, the total area is again distributed according to the baseline data.
- Weighting between regions may be changed by selecting discrete areas for development, or changing irrigation areas by single SAU.
- If the area of irrigation specified for an SAU is greater than the total area of dryland agriculture that may be changed, the total area changing is set 100% of the potential area for change.
- Similarly, if the total change from dryland agriculture to irrigation development or revegetation is higher than 100%, then the total change is set to 100%, and the area of development and revegetation are reduced proportionally.
- The proportions of different crop types changing from dryland agriculture to irrigation is assumed to be the same as the existing proportion of annual, perennial and tree based land uses represented by the current dryland distribution. There is potential to change this in the future if required.
- The proportion of new irrigation crop types is specified by the ‘new’ crop type fields within the GIS polygon input.
- Investment in infrastructure has the same effect as increasing new development in a selection of SAUs, but there is a cost to institutions associated with the development that is accounted for in the economic analysis.

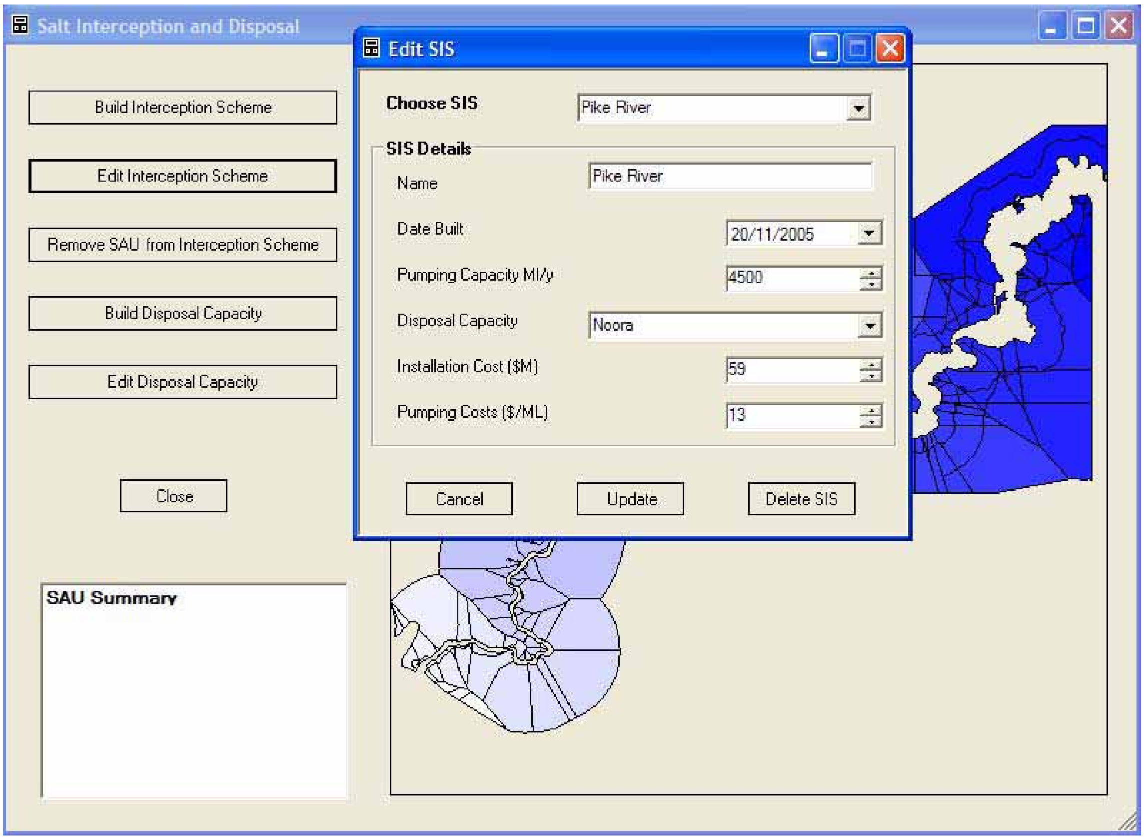

Figure 2.17 Screen capture of the salt interception scheme and disposal screen

Zoning Rules

Rules associated with zoning of new irrigation developments include:

- Irrigation zoning only applies to new irrigation developments, and represents irrigation that would be developed in areas of high salt impact under baseline conditions to be reassigned to low impact areas.
- When irrigation zoning is applied, the specified proportion of irrigation developments that would have occurred in high impact areas under a 'do nothing' scenario will be shifted to the nearest SAU in a low impact area.
- This proportion of irrigation being zoned to low irrigation areas represents the success rate of a zoning policy.
- If the area of the closest scenario unit available for irrigating is smaller than the area of irrigation being re-zoned, then the additional irrigation will spill over to the second and then third closest units.

Irrigation system and management improvement

Rules associated with irrigation system and management improvement include:

- Improvements in irrigation system or in irrigation management are specified by multiplying the baseline conditions with an improvement factor (nominally between 0 and 5), distributed in the same manner as the baseline data, but the maximum area of improvement will be limited to the total area of existing irrigation areas.

- Improvements in systems and management operate on existing irrigation only.
- Improvement in irrigation system is represented by a proportion of furrow irrigation changing to sprinkler or drip irrigation, and sprinkler irrigation changing to drip.
- Improvement in irrigation management is represented by a proportion of poorly managed irrigation systems improving to well managed systems.
- The maximum improvement of irrigation systems or management is limited to the total area of furrow, drip, sprinkler or poorly managed system. If the rate of improvement exceeds the area able to be improved, then the total change is set to a maximum of 100%.
- System and management improvement may be assigned locally to a selection of SAUs to represent intensive technology transfer or education in a single region.

Increasing perennial and tree based dryland agriculture

Rules pertaining to increasing of perennial and tree based agriculture include:

- Increases in trees and perennial land use in dryland agriculture is specified using an area, retaining the distribution of the baseline data.
- The maximum area changing to trees or perennial dryland agriculture is limited by the total areas of perennial and annual agriculture in the SAU.
- If the area changing to perennial or tree based agriculture exceeds the dryland area available, it is reset to the total dryland area
- Increases to both perennial and tree based dryland agriculture are calculated for the region only rather than selections of SAUs.
- Similarly, if the total change from annual dryland agriculture to perennial or tree based land use is higher than 100%, then the total change is set to 100%, and the area of development and revegetation are reduced proportionally.

Revegetation

Rules pertaining to revegetation include:

- Revegetation is assumed to occur only on dryland agriculture land use, not currently irrigated areas.
- Revegetation may be applied to either local SAUs, or to the region, and includes the option of weighting revegetation to behind salt interception schemes, or to high salt impact areas.
- If revegetation is weighted to high impact zones or behind salt interception schemes, then the weighted percentage of revegetation area is distributed between the selected high impact SAUs according to the baseline distribution data, and the remainder of the revegetated

area is weighted to the low impact areas, again according to the baseline distribution information.
- If the baseline data shows zero revegetation in an SAU, revegetation may be assigned to that unit by selecting the single unit and specifying an area of revegetation.

Retirement of irrigation

- Retirement of irrigation operates only on the land use currently being irrigated.
- Retirement of irrigation is specified as a proportion of the existing irrigation in a SAU or selection of SAUs changing to dryland agricultural activities
- The proportions of different crop types changing from irrigation to dryland agriculture is assumed to be the same as the existing proportion of citrus, vines and nuts represented by current irrigation. There is potential to change this in the future if required.
- The proportion of dryland crop types that the retired irrigation becomes is specified by the 'new' crop type fields within the GIS polygon input.

2.6.3. Data sources

Irrigated Areas

The spatial data sets for cropped areas were derived from the 2003/04 baseline crops with permission from custodians:

- River Murray Catchment Water Management Board
- Central Irrigation Trust
- Renmark Irrigation Trust
- Renmark to Bordar Local Action Planning Group

Information for areas of native vegetation, evaporation basins, water bodies, built up areas and road reserves was sourced from the Department for Environment and Heritage.

This data was used to determine the current proportions of dryland agriculture (pO_Dry), irrigated agriculture (pO_Irrig) and other developments (pO_Other) for the SAUs in South Australia.

Irrigated crop type distributions were determined from the 2003/04 baseline crops data, grouping the crops into representative categories of vines, nuts and citrus.

Dryland Areas

Current dryland crop distribution from was obtained from the Murray Darling Basin Land Use Mapping data for 2003, available from the Department for Environment and Heritage. The crop types were aggregated from this data as follows:

- *Annual* = Cereals, Oil seeds & oleaginous fruit

- *Perennial* = Cattle, Dairy, Grassland, Grazing modified pastures, Intensive animal production, Native/Exotic pasture mosaic
- *Trees/Forage* = grazing natural vegetation, irrigated hardwood production, irrigated plantation forestry, plantation forestry, woody fodder plants.

Changes in dryland crop types from 1996/97 – 2000/01 were obtained from the land use change report by {Bryan & Marvanek 2004 #24328}.

Irrigation System Type

Information on the distribution of system types within SA was obtained from the 2002-2003 Riverland Crop Surveys Data Report (RMCWMB (2005)), compiled on behalf of the Riverland Local Action Planning Associations. The system types were aggregated as:

- *Drip irrigation* = drip irrigation, micro sprinklers
- *Sprinkler irrigation* = Overhead sprinklers, under canopy sprinklers and pivot sprinklers
- *Furrow Irrigation* = Flood irrigation, other irrigation

Irrigation Management

Management types data was also taken from the 2002-2003 Riverland Crop Surveys Data Report (RMCWMB (2005)), and assumed in this first instance by whether or not a method for determining irrigation scheduling was recorded:

- *Good management* = Shovel or auger only, experience only, Soil water monitoring only, combination of, or other methods
- *Poor management* = No scheduling method recorded.

There are numerous methods of calculating good or poor management. It is acknowledged that this is the weakest data set used, and future work should target improving our understanding of irrigation management and its impact on deep drainage.

2.6.4. Probability Matrices

The distribution of land use combinations for each SAU is represented by a matrix of probability $[P_O]$, which describes the proportion of a land use likely to be found within that area. The probability matrix for the current state, $[P_O]$, is calculated from current land use data described in Section 6.3.

The second state land use distribution $[P_N]$, in this example at 2015, is defined by:

$[P_N] = [C].[P_O]$

where the change matrix [C] consists of the proportion of area changing from one land use to another. Examples of the $[P_N]$ and $[P_O]$ matrices are shown in Table 2.11.

Table 2.11 Example matrices showing the probability of a land use change occurring within a scenario analysis unit at state 1, 2005 (P_O) and state 2, 2015 (P_N)

P_o

Dryland - Trees	3.5%
Dryland - Perennial	49.0%
Dryland - Annual	17.5%
Vines - Drip - Good	2.13%
Vines - Drip - Poor	0.53%
Vines - Sprinkler - Good	3.36%
Vines - Sprinkler - Poor	0.84%
Vines - Furrow - Good	0.11%
Vines - Furrow - Poor	0.03%
Nuts - Drip - Good	0.46%
Nuts - Drip - Poor	0.11%
Nuts – Sprinkler - Good	0.72%
Nuts – Sprinkler - Poor	0.18%
Nuts - Furrow - Good	0.02%
Nuts - Furrow - Poor	0.01%
Citrus - Drip - Good	0.46%
Citrus - Drip - Poor	0.11%
Citrus - Sprinkler - Good	0.72%
Citrus - Sprinkler - Poor	0.18%
Citrus - Furrow - Good	0.02%
Citrus - Furrow - Poor	0.01%
Other	20.00%

P_N

Dryland - Trees	3.89%
Dryland - Perennial	44.74%
Dryland - Annual	19.47%
Vines - Drip - Good	2.92%
Vines - Drip - Poor	0.47%
Vines - Spray - Good	2.91%
Vines - Spray - Poor	0.54%
Vines - Furrow - Good	0.09%
Vines - Furrow - Poor	0.02%
Nuts - Drip - Good	1.45%
Nuts - Drip - Poor	0.19%
Nuts - Spray - Good	1.11%
Nuts - Spray - Poor	0.20%
Nuts - Furrow - Good	0.03%
Nuts - Furrow - Poor	0.01%
Citrus - Drip - Good	0.46%
Citrus - Drip - Poor	0.09%
Citrus - Spray - Good	0.57%
Citrus - Spray - Poor	0.11%
Citrus - Furrow - Good	0.02%
Citrus - Furrow - Poor	0.00%
Other	20.70%

Table 2.12 Example Change Matrix, with proportion of land moving from the horizontal row of land use combinations to the vertical column of combinations

	Agriculture - Trees/Forage	Agriculture - Perennial	Agriculture - Annual	Vines - Drip - Corporate	Vines - Drip - Private	Vines - Spray - Corporate	Vines - Spray - Private	Vines - Furrow - Corporate	Vines - Furrow - Private	Nuts - Drip - Corporate	Nuts - Drip - Private	Nuts - Spray - Corporate	Nuts - Spray - Private	Nuts - Furrow - Corporate	Nuts - Furrow - Private	Citrus - Drip - Corporate	Citrus - Drip - Private	Citrus - Spray - Corporate	Citrus - Spray - Private	Citrus - Furrow - Corporate	Citrus - Furrow - Private	Other
Agriculture - Trees/Forage	0.97	0.01	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
Agriculture - Perennial	0	0.91	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Agriculture - Annual	0	0.05	0.97	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
Vines - Drip - Corporate	0.0086	0.0086	0.0086	0.882	0.176	0.088	0.018	0.088	0.018	0	0	0	0	0	0	0.049	0.010	0.005	0.001	0.005	0.001	0
Vines - Drip - Private	0.0005	0.0005	0.0005	0	0.706	0	0.071	0	0.071	0	0	0	0	0	0	0	0.039	0	0.004	0	0.004	0
Vines - Spray - Corporate	0.0010	0.0010	0.0010	0	0	0.794	0.159	0.044	0.009	0	0	0	0	0	0	0	0	0.044	0.009	0.002	0.000	0
Vines - Spray - Private	0.0001	0.0001	0.0001	0	0	0	0.635	0	0.035	0	0	0	0	0	0	0	0	0	0.035	0	0.002	0
Vines - Furrow - Corporate	0	0	0	0	0	0	0	0.750	0.150	0	0	0	0	0	0	0	0	0	0	0.042	0.008	0
Vines - Furrow - Private	0	0	0	0	0	0	0	0	0.600	0	0	0	0	0	0	0	0	0	0	0	0.033	0
Nuts - Drip - Corporate	0.0086	0.0086	0.0086	0.098	0.020	0.010	0.002	0.010	0.002	0.98	0.196	0.098	0.020	0.098	0.020	0.098	0.020	0.010	0.002	0.0098	0.002	0
Nuts - Drip - Private	0.0005	0.0005	0.0005	0	0.078	0	0.008	0	0.008	0	0.784	0	0.078	0	0.078	0	0.078	0	0.008	0	0.008	0
Nuts - Spray - Corporate	0.0010	0.0010	0.0010	0	0	0.088	0.018	0.005	0.001	0	0	0.882	0.176	0.049	0.010	0	0	0.088	0.018	0.005	0.001	0
Nuts - Spray - Private	0.0001	0.0001	0.0001	0	0	0	0.071	0	0.004	0	0	0	0.706	0	0.039	0	0	0	0.071	0	0.004	0
Nuts - Furrow - Corporate	0	0	0	0	0	0	0	0.083	0.017	0	0	0	0	0.833	0.167	0	0	0	0	0.083	0.017	0
Nuts - Furrow - Private	0	0	0	0	0	0	0	0	0.067	0	0	0	0	0	0.666	0	0	0	0	0	0.067	0
Citrus - Drip - Corporate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.833	0.167	0.083	0.017	0.083	0.017	0
Citrus - Drip - Private	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.666	0	0.067	0	0.067	0
Citrus - Spray - Corporate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.750	0.150	0.042	0.008	0
Citrus - Spray - Private	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.600	0	0.033	0
Citrus - Furrow - Corporate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.708	0.142	0
Citrus - Furrow - Private	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.566	0
Other	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

The change matrix [C] is constructed from an understanding of the rate of change from each land use component to another. For example, if the rate of change from 2005 to 2015 for:

- citrus to vines is 5%
- sprinkler irrigation to drip irrigation is 10%
- poor management to good management is 20%

Then the probability of change from citrus under poorly managed sprinkler irrigation to vines under well managed drip irrigation is 0.1%. Whilst this is a small value, the combination of 22 different land use categories potentially changing to vines under well managed drip irrigation may add up to be significant. The rates of change from one state to another were estimated from land use change data outlined in Section 6.3. An example change matrix for one SAU is shown in Table 2.12.

The change matrix forms the vehicle for land management decisions to effect future land use distributions. Policy and economic levers alter the change matrix by varying the magnitude of change for land use (dryland, irrigated, other) crop type, irrigation system and management. The individual effects of NRM actions from the Scenario Builder on land use change components are outlined in Table 2.10.

2.6.5. Description of model outputs

Outputs from the River Murray Corridor Systems Model include:

- 'Salt load to river' (tonnes d^{-1})
- 'EC at Morgan' (dS cm^{-1}), calculated from the salt load in tonnes d^{-1} and converted to EC using the MDBC ready reckoner.
- 'Equivalent EC' calculated from the salt load in tonnes d^{-1} and converted using the MDBC ready reckoner.
- 'Groundwater inflows' (ML d^{-1}) the volume of water entering the river valley as groundwater. This does not include attenuation of groundwater flow by floodplains.
- 'Floodplain vegetation and wetland risk area' (ha) the area of floodplain vegetation and wetlands at risk of salinisation under a given scenario, as defined by the FRM model (Holland *et al.* 2005).
- 'Disposal volume' (ML d^{-1}) the volume of groundwater inflow intercepted by salt interception schemes which requires disposal through evaporation from highland basins, or other disposal schemes.
- 'Deep drainage' (mm a^{-1}) the rate of drainage of water below the root zone of vegetation, that eventually becomes groundwater recharge. Regional estimates of deep drainage are calculated from the total applied irrigation and rainfall, multiplied by one minus the water use efficiency.
- 'Profit' ($) total profits from land use activities in the river corridor.

2.6.6. Model calibration

Components of the model, including SIMPACT and the FIP model have previously been calibrated against current field measurements of river salt loads and floodplain salinisation ((2001b), (2004), (2003)). Whilst full calibration of an integrated land management model that includes biophysical and socio-economic functions to predict future environmental impacts is impossible, results from the L2R model will be compared with historical development patterns to validate the assumptions made in translating policy to land use change, and that the spatial realisation of development is within a range appropriate for the intended use of the model. The model is designed to indicate the magnitude of impact on resource condition targets from land use change and provide a means of comparing methods of management rather than providing exact predictions of salt loads at 100 years into the future. Data available for validation includes spatial maps of irrigation development in Victoria following implementation of a zoning policy, and in South Australia following installation of salt interception schemes. A study of the propagation of uncertainty through the model will be undertaken.

2.7. Economic impacts and irrigation response function

This report section outlines economic decision making and impact modelling components of the integrated biophysical-economic model focussed on irrigation in the Lower Murray region of South Australia and Victoria. The scope of economic decision making and economic impact modelling methodologies, and data are described.

The model describes is designed to estimate South Australian and Victorian River Murray irrigator development, technology, and management and irrigation drainage responses to changes in regional economic, policy and natural conditions. Economic impacts of changes in irrigation management on the regional irrigated agricultural sector are estimated.

The model simulates key irrigator responses and follow-on consequences including:

- irrigation development levels and locations,
- choices of irrigation technology and management,
- irrigation economic activity levels and profits from irrigation.
- irrigation application rates and drainage levels by location (a key input into the linked biophysical salt and water process models that will be used to predict salinity state of the river, and floodplain ecological health).
- The cost to governments (or irrigators, depending on assumed policy) of investment in salt interception and drainage disposal to meet MDBC salinity targets

The response models will be built to be capable of predicting irrigator response to changes in:

- economic conditions (e.g. commodity prices, production costs)
- policy (e.g. irrigation land use zoning, or salinity charges)
- biophysical system state (e.g. salinity of irrigation water, climate influence on crop ET and water availability).

The irrigator and policy decision making models will provide economic impact assessments and be integrated with water and salt biophysical process models to provide salinity impact assessments. As discussed in more detail below an ongoing focus of this modelling effort will be improved integration across related CMA, states, university and other CSIRO projects.

2.7.1. Scenario modelling

Agreed scenarios representing future conditions in the region will be the focus of analysis for exploring Lower Murray landscape futures with modelling. Conceptually, scenario modelling can take one of two forms.

1. <u>Action scenario modelling</u> – In this type of modelling, scenarios are assumptions about levels of actions that are the key drivers of regional economic health, river salinity and floodplain health conditions. For example scenarios can represent assumptions about:

   1. New irrigation development levels and locations
   2. Level of water use efficiency (and drainage) on existing and new irrigation developments

3. Levels and locations of salt interception scheme and drainage disposal investments

2. Policy scenario modelling – In this type of modelling, irrigator response to economic, policy and biophysical system state are modelled as levers that influence decisions by irrigators including decisions to locate new irrigation development or decisions to implement more efficient irrigation management. Irrigators are modelled as though they wished to increase economic returns to irrigation and scenarios are represented as combination of policies (e.g. land use policy), biophysical system conditions (e.g. river salinity, or climate), and economic conditions (e.g. commodity prices) that restrict behavioural choices or have incentive effects that influence behaviour.

Policy scenario modelling will result in estimates of choice levels of actions that irrigators would take for a given set of policy, economic, natural system conditions. Policy scenario modelling provides a coherent approach to investigation of effectiveness of regional policy at inducing actions under alternative assumption about external drivers such as commodity prices, and climate conditions.

In policy scenario modelling, each scenario is defined as a specific set of assumptions about:

- conditions determined largely outside of the region that influence LMLF including:
    - economic conditions (e.g. commodity prices, or production costs)
    - biophysical system states (e.g. climate state)
    - conditions upstream of the region (e.g. level of water withdraws, salt loading upstream)
    - policy and investment decisions made outside of the region (e.g. MDBC policy rules governing level and location of salt interception, drainage disposal investment)
- conditions in the region that influence LMLF including:
    - regional land and water use policy (e.g. irrigation zoning, practice requirements, incentives for efficiency, salinity charges)
- conditions influenced by conditions both within and outside the region
    - water trade trends influencing regional irrigation development (e.g. supply available from outside region, demand within region under various assumptions about trends influencing each)

Through a stakeholder interaction process 5 to 6 scenarios will be chosen for testing of the River systems model working with an appropriate subset of project steering committee members.

The economic decision making model will be used some what differently in policy and action scenario analysis. In policy scenario analysis level and location of irrigation development choice of irrigation technology and management and water application will be modelled as the highest profit options among feasible responses given scenario economic, policy, or biophysical system state conditions. In action scenario analyses, changes in level and location of irrigation development, irrigation technology and management, water application and drainage will simply be assumed and the economic impact model will be used to estimate costs of actions.

2.7.2. Integrating irrigator response and salt and water process models

One of the important objectives of the LMLF project is understand tradeoffs between economic and salinity management goals in managing irrigation in the region. A modelling challenge arises in integrated economic response and salinity process models because changes in irrigation practice and consequent economic impacts occur in much shorter time frames than salinity impacts.

The time required for water to travel through the unsaturated zone and groundwater, mean that changes in irrigation in the Lower Murray lead to changed saline groundwater base flow to the river many years later. Delays between irrigation changes and onset of salinity impacts are estimated to vary from less than one decade to more than a century depending on depth to water table, distance to the river and aquifer transmissivity at the location of irrigation (Miles et al). The hydrogeology model that will be used to assess salinity impact of irrigation (Miles et al) assumes a constant repeated annual pattern of irrigation drainage across the corridor for several decades in predicting changes in 20, 50 and 100 years to groundwater base flow, and river salt load. In contrast significant irrigation practice changes typically take place in a few years to a decade and consequent economic impact result follow-on within a matter of months to perhaps a few years.

For modelling tractability, in integration of irrigation practice change and salinity impact that take place on very different time scales, scenarios are modelled as consisting of two distinct time periods. The first is a period of change (typically a decade or more) in which economic, policy or biophysical system state changes result in changes in irrigation. The second period is the salinity impact assessment period, where salinity impacts that would follow-on from changes in the period of change in 20, 50 and 100 years are assessed. In salinity impact assessment it is assumed that changes in irrigation assumed in change period persist for the entire 100 year salinity impact assessment period.

2.7.3. Integrating social survey information in irrigator response model

In initial model development, economic rationalism (profit maximisation) subject to costs and returns to choices and policy restriction on actions will be assumed to be the primary determinant of irrigator responses. In successive iterations of the model specification this assumption will be modified to better represent constraints and preference that may result in deviation from pure economic rationalism in irrigator decision making. This will be accomplished through cooperation with the CSIRO ARCWIS group who will do work to shed light on the feasibility of the irrigator management actions and potential impediments to various approaches actually being adopted and implemented. This could include key informant interviews or other appropriate methods.

2.7.4. Irrigator response model functional specification

The proposed approach is to build a model to represent the way that irrigators are likely to choose among a range of strategies open to them. In the first instance it will be assumed that irrigators choose options to maximise profits (given limits such as available technology, information, management capacity or capital limits). Most past modeling of similar issues has used either optimization techniques (e.g. McCarl et al, 1999; Booker et al, 2005; Rosegrant et al, 2002) or systems dynamics simulations.

The intent is to model a period of change (a decade or more) in which economic, policy or biophysical system state changes result in changes long-run irrigation, land and horticultural/vine stock and permanent water allocation capital investments. To capture the way that decision making is likely to vary depending on capital asset condition, three separate but related models will be used to distinct irrigator sub-populations:

1. **The re-development model** will represent decision making by irrigators who own capital assets such as irrigation systems and permanent planting (e.g. vines or orchards) nearing the end of their useful life.. For this model it will be assumed that each year over a change period the irrigation equipment and permanent plantings for a portion of the irrigator population becomes fully depreciated. Thus these irrigators face the decision of whether to and if so where to re-invest in irrigation and what type of irrigation to invest in.

The location of development (distance from the river and lift above the river) are key determinant of salinity impact and significant determinants of irrigation development cost as well. For this reason, an algorithm that simulates how irrigators would choose among potential sites for development based on water delivery infrastructure and power costs will be developed for this part of the modeling. This will involve GIS based information about distance to river, depth to groundwater on land available for irrigation development, and engineering costs estimation procedure building on estimates that have already been developed by PIRSA (2004), Connor (2003). Development zoning policy will be modeled as restrictions on choice of development site to areas zoned low salinity impact.

2. **The new irrigation development model** has some similarities to the redevelopment model in that capital asset decisions must be considered it deciding to develop new irrigation. The key difference is that availability of water on the market from out of region is treated as the factor limiting rate of new development. In addition, each year an amount of permanent water will be assumed available on the market from out of the region, and if profitable opportunities exist, irrigators will invest in additional development.

3. **The existing irrigator model** represents the decision making process of irrigators who have develop irrigation for a particular crop at a particular location and are not considering relocation or switching crops. In this model irrigators consider only irrigation management decisions including level of irrigation to provide and type of system to invest in.

2.7.5. Modeling long run decisions

The goal is to model significant irrigated agricultural sector change in response to policy, economic and biophysical system state changes. This involves decisions on investments in land, permanent water rights, vine and horticultural stock and irrigation equipment, all assets with expected economic lives of 15 years or more. Following Dantzig (1955) such investment can be thought of as involving a two stage process. The first stage is upfront investments such as planting of vines or horticultural stock. Costs of such investments are borne upfront when the investments are made regardless of uncertain outcomes of the investments.

The second stage is the annual management decisions like irrigation water application rate (this is the only relevant stage in the existing irrigator model). These decisions depend on levels of variables determining profit that vary stochastically from year to year such as weather conditions, commodity and temporary market water prices. The first stage decision must be made based on some expectation of the probability of factors such as future weather and prices that are determined stochastically in the second stage of the investment. Second stage decision must be made given that capital assets chosen in the first stage can not be varied from year to year.

To model this two stage investment decision we intend to use the Dantzig (1955) two stage investment optimization process that has been successfully applied by McCarl (1999) to a related US problem but not yet in Australia to our knowledge.

2.7.6. Which modeling scenarios

There are a large number of potential scenarios, each a set of assumptions about:

- conditions determined largely outside of the region that influence LMLF including:
    - economic conditions (e.g. commodity prices, or production costs)
    - biophysical system states (e.g. climate state)
    - conditions upstream of the region (e.g. level of water withdraws, salt loading upstream)
    - policy and investment determined outside of the region (e.g. MDBC policy rules governing level and location of salt interception, drainage disposal investment)
- conditions in the region that influence LMLF including:
    - regional land and water use policy (e.g. irrigation zoning, practice requirements, incentives for efficiency, salinity charges)
- conditions influenced by conditions both within and outside the region
    - water trade trends influencing regional irrigation development (e.g. supply available from outside region, demand within region under various assumptions about trends influencing each)

While the exact detail of scenarios that will be modelled will be determined in an interactive process working with a project reference group of regional experts, in broad terms base on input to date five scenarios that will be considered are:

- Status Quo
    - Current rate of expansion, no attempt at reducing river or floodplain impacts
- Pro-Development
    - Development in accordance with the State Strategic plan, river and floodplain targets not of high importance
- Sustainable Development
    - Status quo development plus compliance with the RCTs using zoning and initiatives for satellite developments further from river. Incentives for WUE improvement
- Engineering Solutions

    - Status quo development plus compliance with the RCTs using predominantly SIS and disposal.
- Environmental Protection
    - Reduced rate of development with WUE policy, zoning, and protection of significant floodplains
- Impact Offsets
    - Irrigator pays for EC impacts, SIS and disposal of salt.
- The intent is conduct sensitivity analysis for all scenario modelling to assess sensitivity of result to assumption about variations in levels of external drivers including:
    - Climatic variation
    - Water availability
    - Upstream EC
    - Crop value/demand changes

2.8. Scenarios and Results

The sections below describe the development of scenarios for testing the current NRM plans using the River Murray Corridor Systems Model and the results from the modelling.

2.8.1. Scenarios developed from current NRM plans

The requirement for modelling in year 2 of the project was to test the effects of each individual NRM action, to compare their impacts, and then identify the combined effects of a suite of actions. The NRM actions from the current plans that were tested include:

- Construction of new salt interception schemes
- Implementation of an irrigation zoning policy
- Improvements in WUE due to system upgrades and management improvement
- Revegetation of dryland areas
- Changes in dryland crop type from annual crops to lucerne or trees

These actions are discussed in more detail below.

The timescale for the development change is 10 years, being short enough for reasonable confidence in the land management outcomes, and long enough to show some evidence of change. The period of change is assumed to occur over this 10 year period, and the impacts of the change are traced for up to 100 years in the future.

Area of new irrigation developed

Baseline irrigation development was calculated to be approximately 15500 hectares based on the change in irrigated area between 1997 and 2005, weighted to a 10 year development period. The model was run for situations reflecting zero growth (no new development), baseline development rate, half current rate (7750 ha), 1.5 times the current rate of development (23250 ha) and double current rate (31000 ha). These variable rates of development reflect different limitations to water availability and environments that may encourage or dissuade further irrigation development.

SIS construction

In South Australia, Bookpurnong and Loxton interception schemes have recently started pumping, while Pike River and Murtho are the next interception schemes due to be completed. The model is tested with and without the impacts of Bookpurnong and Loxton schemes, and with the addition of Pike River and Murtho schemes, and Chowilla and Pyap-Kingston. The extension of scheme at Woolpunda-Cadell has not been modelled.

In Victoria, current interception schemes include Buronga (1979 with upgrade in 1988), Rufus River (1984), Mildura-Murbein (1981, upgraded in 1990) and Mallee Cliffs (1994). [These schemes are used to intercept groundwater flow from floodplain evaporation basins rather than intercept regional groundwater. New groundwater interception schemes are planned for Pyramid Creek and

Glen Villa, an upgrade to the Buronga scheme, Mildura-Redcliffs, and extensions to the Murbein and Nangiloc-Colignan schemes.

The schemes that are likely to be completed within 10 years include Pike River and Murtho in South Australia, and Pyramid Creek and Glen Villa in Victoria. Whilst the timescale for development has been set at 10 years for these scenarios, the implementation of interception schemes is assumed to occur at regular intervals from the start of the modelling.

Systems runs include, for South Australia:

- Bookpurnong-Lock 4 and Loxton schemes;
- Bookpurnong-Lock 4, Loxton, Pike River;
- Bookpurnong-Lock 4, Loxton, Pike River and Murtho;
- Bookpurnong-Lock 4, Loxton, Pike River, Murtho and Chowilla; and
- Bookpurnong-Lock 4, Loxton, Pike River, Murtho, Chowilla and Pyap schemes

and for Victoria:

- Pyramid Creek and Glen Villa;
- Pyramid Creek, Glen Villa and Mildura-Red Cliffs;
- Pyramid Creek, Glen Villa, Mildura-Red Cliffs and Merbein (groundwater interception);
- Pyramid Creek, Glen Villa, Mildura-Red Cliffs and Merbein and Karadoc; and
- Pyramid Creek, Glen Villa, Mildura-Red Cliffs and Merbein, Karadoc and Nangiloc-Colignan.

Additional model runs with alternative salt interception schemes may be done as required by stakeholders.

Capacities and year of construction are shown in Table 2.13. The effective build date for schemes built before the start date of the mode is set at 2000.

Table 2.13 Salt interception schemes used in the analysis, their pumping capacity and effective build date.

Scheme	Capacity (ML/a)	Effective Build Date
Woolpunda_S	2101	2000
Woolpunda_N	3152	2000
Waikerie	4344	2000
Qualco	3600	2000
Bookpurnong	1980	2000
Loxton	4024	2000
Pike River	5041	2015
Murtho	756	2020
Chowilla	3806	2028
Pyap-Kingston	893	2040

Irrigation zoning policy

Zoning Policy is currently in place in Victoria, and is being phased in, in South Australia. Victorian scenarios will be run with the zoning policy assuming that the implementation of policy has 100% effectiveness. South Australian model runs will include zoning policy with uptake rates of 100%, 90% and 80%.

The impact of multiple impact zones in Victoria is accounted for in the economic analysis.

Technology transfer for WUE improvement

Improvement in irrigation systems in Victoria and South Australia through technology transfer and improvement in management is possible, and is indicated as priorities in the NRM plans.

System runs will include:

- Accelerated uptake of system improvement at 0, 1, 2 and 3 times the current rate.
- Accelerated management improvement at 0, 1, 2 and 3 times the current rate.

The current rate of system improvement assumes that 10% of furrow irrigation systems and 10% of sprinkler systems upgrade to drip irrigation, and 5% of furrow irrigation systems are improved to sprinklers within the given period of 10 years. Similarly, 20% of poorly managed irrigation systems are assumed to improve to well managed in the period of study.

It is estimated from current irrigation system and management information that 72% of the irrigated area (28 500 ha) is not being irrigated at optimal rates, through either little or no irrigation scheduling or monitoring, or furrow or sprinkler irrigation systems. There is, therefore, the theoretical potential to improve water use efficiency through changing system type or management practices. This rate of change is limited by the profitability of changing systems, overall cost of changing systems, and reluctance to change by irrigators. Although there is a large potential to improve water use efficiency, the actual rate of improvement will be limited. The current rate of improvement equates to 10% of the total irrigated area.

Whilst in this study drip irrigation (and micro-sprinklers) have been used to represent best practice, drip irrigation may not be suitable for all crop types. Similarly, irrigation at high efficiency rates may exacerbate accumulation of salt in the soil.

Revegetation

Revegetation of the entire river corridor is unlikely. Areas of potential revegetation were taken from the analysis of regional NRM plans (Walker *et al.* 2005) and Wang, E. et al. (2005) and Bryan, B. et al. (2005) for the South Australian River Murray Corridor. Bryan et al. (2005) suggest that the majority of salinity benefit in the river corridor can be achieved by revegetating an area of 10 000 hectares.

System runs to be tested by the model include:

- 1000 hectares of revegetation, distributed uniformly
- 5000 hectares of revegetation, distributed uniformly
- 10 000 hectares of revegetation in dryland areas, distributed uniformly
- Revegetation of 5000 hectares, but weighted toward the high impact zones
- Revegetation of 5000 hectares, but weighted in areas not protected by interception schemes.
- Revegetation of 5000 hectares, but weighted in areas with current or to be built interception schemes.

Dryland crops

Dryland crop change to perennial crops (such as lucerne) or tree based forage may occur in the next 5 years. Current areas of perennial and tree based agriculture are close to zero (Bryan, B. and Marvanek, S. (2004)). The growth in perennial agriculture is currently unknown, but expected to be low for a 10 year planning framework as technology is slow to uptake and profit remains marginal.

Levels of dryland crop change to be tested include:

- Area of lucerne plantings increased by 1000 hectares
- Area of lucerne plantings increased by 10 000 hectares
- Area of lucerne plantings increased by 100 000 hectares

Further investigation of revegetation and dryland crop change will be undertaken in the future scenario modelling in the third year of the project.

Combinations

Scenarios were developed from combinations of actions possible within a 10 year framework. These scenarios assumed different levels of salt interception, WUE improvement, revegetation and dryland crop change. Irrigation zoning was applied for all scenarios, as it is currently in the process of being implemented in South Australia, and has been in place in Victoria since 1993.

Three different levels of salt interception are assumed, and three different levels of WUE improvement, revegetation and dryland crop change (Table 2.14.

Table 2.14 Current NRM Plan analysis scenarios

Components	Scenario 1 (minimal change)	Scenario 2 (moderate change)	Scenario 3 (maximum change)	Scenario 4 (pro-development)	Scenario 5 (best practice)
Development	half current rate	current rate	double current rate	double current rate	current rate
Salt interception	Bookpurnong, Loxton	Bookpurnong, Loxton, Pike and Murtho	Bookpurnong, Loxton, Murtho, Pike River, Chowilla and Pyap	Bookpurnong, Loxton, Murtho, Pike River, Chowilla and Pyap	Bookpurnong, Loxton
Zoning	90% effectiveness	90% effectiveness	90% effectiveness	60% effectiveness	100% effectiveness
WUE improvement	1.5 times current rate	2 times current rate	3 times current rate	0.5 times current rate	100% operating at optimal management and optimal system
Revegetation	0 hectares	1000 hectares	5000 hectares	0 hectares	1000 hectares
Dryland crop change	0 hectares plantings	5000 hectares plantings	10 000 hectares plantings	0 hectares plantings	10000 hectares plantings
Irrigation crop change	10% change from vines to nuts	20% change from vines to nuts	30% change from vines to nuts	30% change from vines to nuts	20% change from vines to nuts

Market price variation and climate are being addressed in the future scenario modelling in year 3 of the project.

2.8.2. Results

Figures 2.18 to 2.23 show the variability of salt loads to the river, groundwater flow intercepted by salt interception schemes that requires disposal and proportion of floodplain impacted by salinity. The results are presented on a whole of region basis for the South Australian section of the Lower River Murray Corridor. Data for the Victorian region have been collated, but analysis of this region has been delayed by the availability of outputs from the Mallee Audit including updated SIMPACT input layers Legacy of History information and floodplain impacts. Victorian model runs will be undertaken as soon as these data sets become available. Economic analysis of the scenarios is currently being completed.

The model is also able to present salt impacts, groundwater flow and floodplain impacts on a sub-regional basis such as Land and Water Management Areas. These individual regions, however, are not shown in this report.

Figures 2.18 to 2.22 show the sensitivity of the model to the levers such as change in area of development, irrigation system and management improvement, irrigation zoning, installation of salt interception schemes, increases in perennial agriculture and changes in trends in crop change to nuts such as almonds. For each of these situations, the baseline rates of change are held constant, while the selected input is varied.

The curves on the graphs are labelled in the following manner:

- Area of development: 0, 0.5, 1 (baseline), 1.5 and 2 times the current rate of development;
- System / Management improvement: 0, 1 (baseline), 2 and 3 times the current rate of system improvement, 0, 1 (baseline), 2 and 3 times the rate of current management improvement, and 0, 1 (baseline), 2 and 3 times the rate of simultaneous system *and* management improvement;
- Zoning new irrigation development: No irrigation zoning (baseline), 80%, 90% and 100% effective zoning policy;
- Salt Interception Schemes: Pre- Bookpurnong and Loxton schemes, with Bookpurnong and Loxton (baseline), plus additional schemes as described
- Perennial crop change: 0 (baseline), 1000 ha, 10 000 ha, 100 000 ha of lucerne planting in dryland areas;
- Crop change trends to nuts; 10% (baseline), 20% and 30% of vines being replaced with nuts, with commensurate increasing proportions of new crops being plantings of nuts;
- Combinations of the above in 5 scenarios, described in Table 2.14.

In Figure 2.24, five different scenarios are compared against each other to distinguish the variation in salt and floodplain impacts and groundwater disposal capacity required. Results are still of a preliminary nature, and are currently being validated.

Changes in perennial vegetation and revegetation of dryland regions had very little impact on ultimate salt loads to the river (Figure 24a) at this time scale. The ultimate difference in salt load to the river varied by less than 0.1%, even with 100 000 hectares of perennial vegetation or 5000 hectares of revegetation. This small variation is likely caused by a combination of the very small change in deep drainage (10 mm/a to 5 mm/a, compared with 120 mm/a or more in irrigated crops) and the generally distant proximity of dryland cropping areas from the river compared with irrigated areas.

Both system and management improvement and new irrigation zoning had small effects on salt loads to the river as they were varied about the baseline (up to 6% and 8% respectively) (Figures 21a and 22a). The influence of a zoning policy is limited by the area of new development, and improving water use efficiency may be limited by salinisation of irrigated soils, economic and social factors.

The timing of the benefits from improving current systems and management was found to be earlier than that of zoning. This is thought to be because improvements in efficiency occur in existing irrigation systems and are therefore more likely to be found closer to the river, thereby having a more rapid impact. In addition to this, reductions in deep drainage modelled by SIMPACT propagate through an already wetted unsaturated zone more quickly than it this zone able to be wet by new irrigation developments.

The salt impacts from varying areas of development occur later in the modelled period, and affect the ultimate salt load to the river at 2100 by up to 19%. Similarly, increases in the trend of planting almonds may increase salt loads to the river at 2100 by up to 11% of the baseline.

Overall, the model outputs suggest that in South Australia, the land management practices for a ten year period of change are significantly outweighed by the still-increasing impacts of historical irrigation developments. Whilst in many scenarios, reducing the deep drainage from existing crops will create a salt benefit that may be used to offset new development; this benefit is consumed by the increased salt loads from the legacy of historical development at all points in time. The impact of historical development is an obvious issue for river and land managers.

The only river corridor management action that allows river salt loads to remain at the year 2000 level, at least until 2040, is the installation of additional groundwater interception schemes (Figure 2.21a). The interception schemes cause an obvious reduction in salt loads and also a potential improvement in floodplain salinity impact (Figure 2.23c), but this comes with a significant cost of mitigation and almost doubled requirement for disposal of intercepted saline groundwater (Figure 2.21b). The interception scheme at Chowilla was found to have a proportionally larger positive impact on the proportion of floodplain at risk of salinity than it had on salt loads to the river (Figures 2,21a and 2.21c). This is thought to be due to the absence of a groundwater mound behind the floodplain which would tend to hold groundwater heads high within the floodplain. This demonstrates that the characteristics of the floodplains are represented in the River Murray Corridor Systems Model in the same way as the Floodplain Impacts Model intended.

The results from modelling the 5 scenarios confirm the results from the sensitivity analysis, and allow aggregated actions to be combined in a non-linear and unintuitive manner (Figure 2.23a,b). This allows environmental impacts from the combined management actions to be compared against each other. They indicate that the installation of interception schemes will (in this case) offset increased rates of irrigation development. Comparing Scenarios 3 and 4 suggests that while interception schemes have the dominant impact, improvement in water use efficiency and zoning will significantly slow the rate of salt impacts.

Scenario 5 was constructed with the intent of showing the impact on salt loads from improving the water use efficiency to the point that all irrigation districts are operating at optimal management using an optimal system. Although this level of improvement is not practically possible in the 10 year timeframe being analysed, it does indicate the capacity of the system for improvement, and that should this level of improvement be achieved, the salt benefits would be equivalent to approximately two major interception schemes, with the volume of saline water requiring disposal remaining at or less than the volume in 2000. The equivalent water use efficiency associated with this best practice scenario is greater then 90%. At current river water salinity levels, irrigation at this efficiency would just begin to accumulate salt within the soils and lead to crop yield reductions.

In each of the graphs showing the volume of groundwater intercepted, the initial reduction in flows in is caused by an initial reduction in groundwater inflows in the Waikerie district Legacy of History data, and is exacerbated by the effects of improving water use efficiency, which impacts before additional regional development. Updated Legacy of History data is currently being sourced from the South Australian Department for Environment and Heritage.

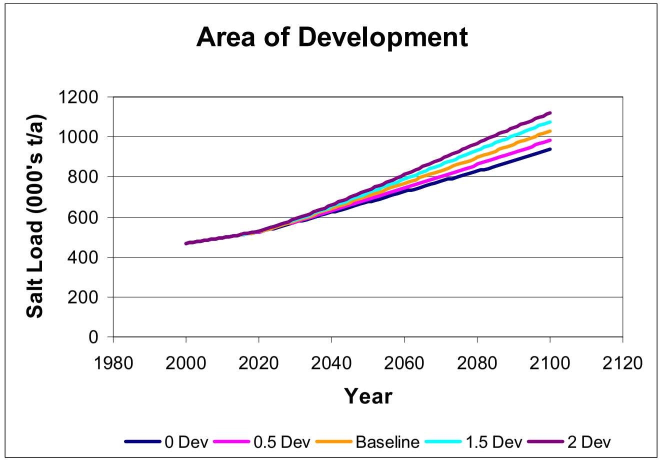

Figure 2.18a. Changes in salt loads to the river with varying areas of new irrigation development.

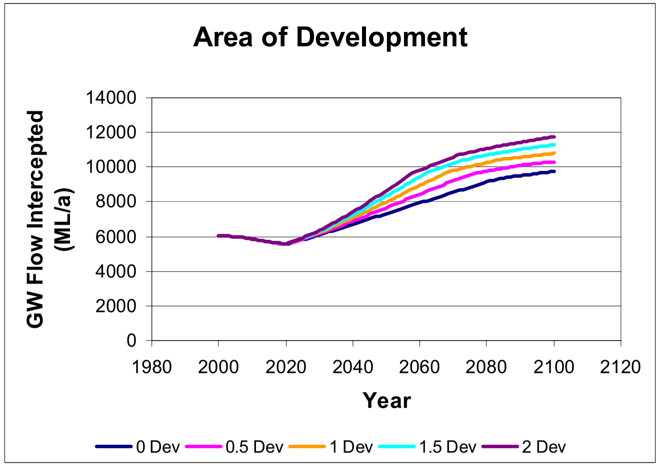

Figure 2.18b. Changes in volume of groundwater requiring disposal with varying areas of new irrigation development.

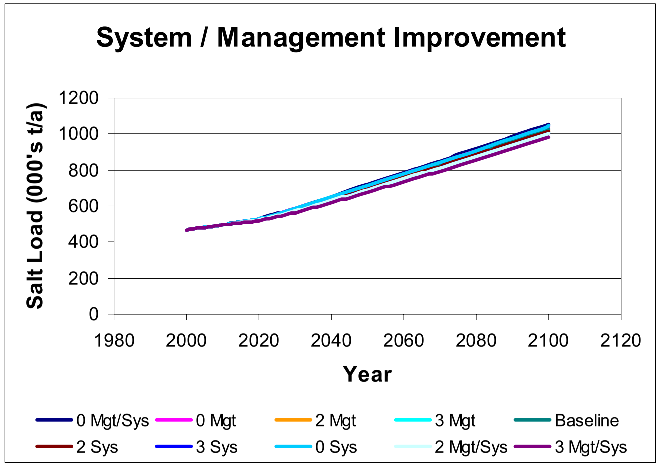

Figure 2.19a. Changes in salt loads to the river with improvements in irrigation management and systems x times current rates.

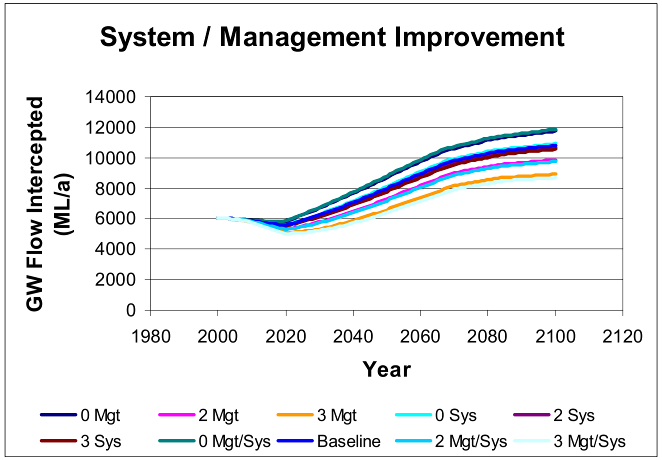

Figure 2.19b. Changes in volume of groundwater requiring disposal with improvements in irrigation management and systems x times current rates.

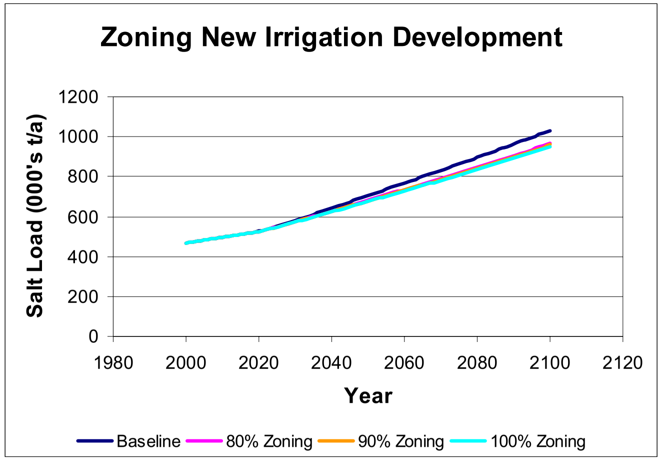

Figure 2.20a. Changes in salt loads to the river with varying achievement of policy to zone new irrigation development to low impact areas.

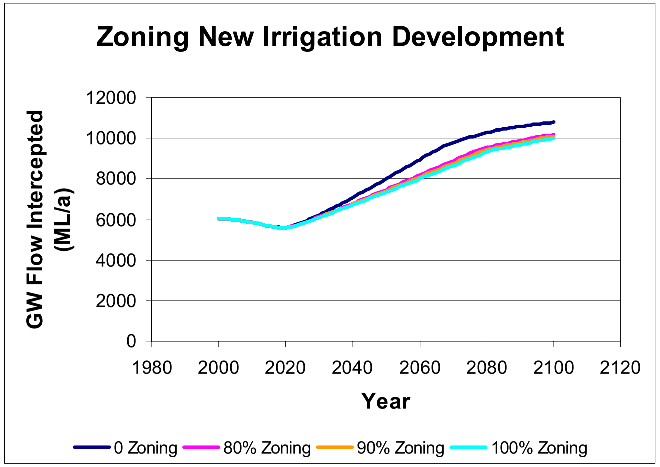

Figure 2.20b. Changes in volume of groundwater requiring disposal with varying achievement of policy to zone new irrigation development to low impact areas.

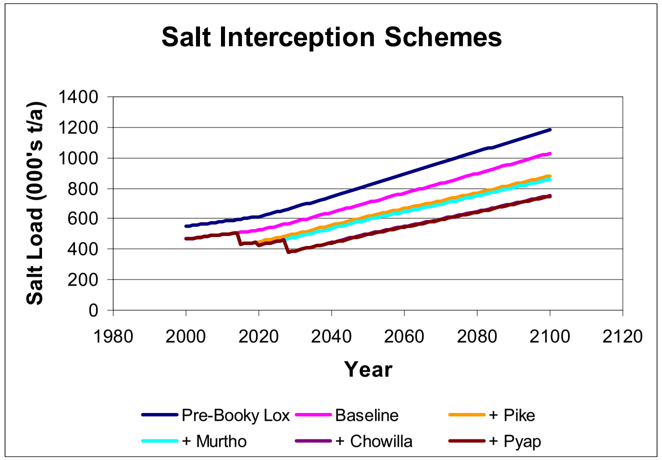

Figure 2.21a. Changes in salt loads to the river with additional salt interception schemes installed.

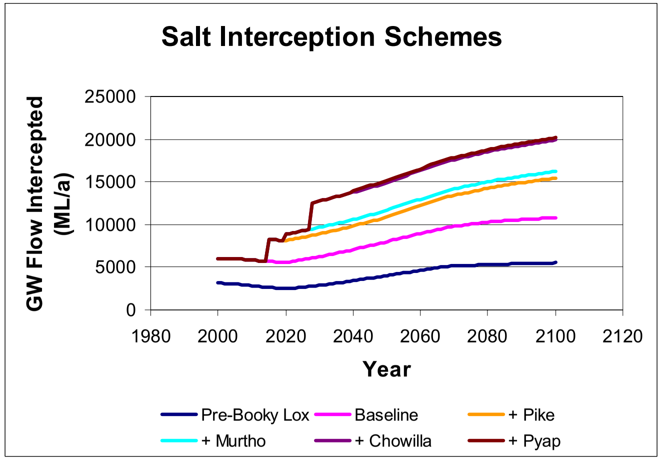

Figure 2.21b. Changes in volume of groundwater requiring disposal with additional salt interception schemes installed.

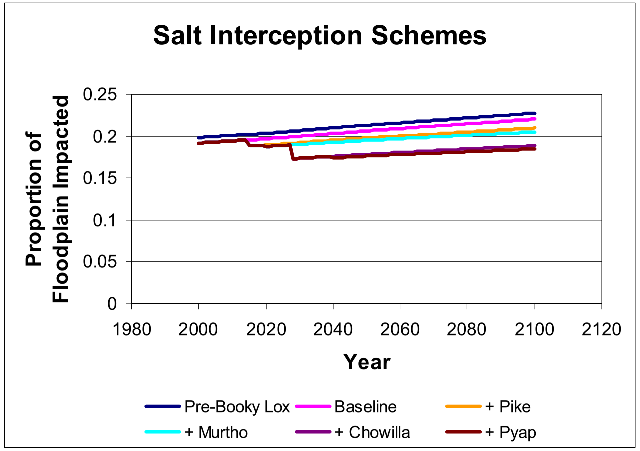

Figure 2.21c. Changes in proportion of floodplain impacted by salinity with additional salt interception schemes installed.

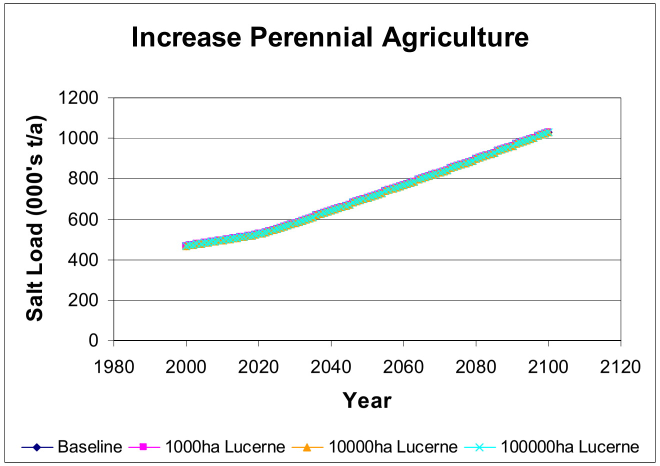

Figure 2.22a. Changes in salt loads to the river with increased areas of perennial agriculture (eg. lucerne) in dryland regions.

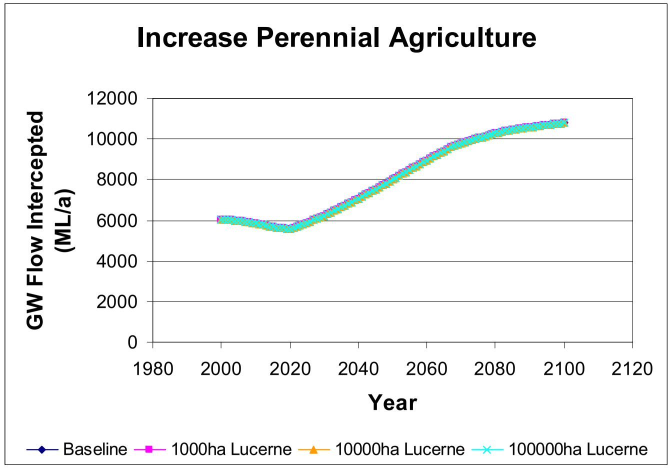

Figure 2.22b. Changes in volume of groundwater requiring disposal with increased areas of perennial agriculture (eg. lucerne) in dryland regions.

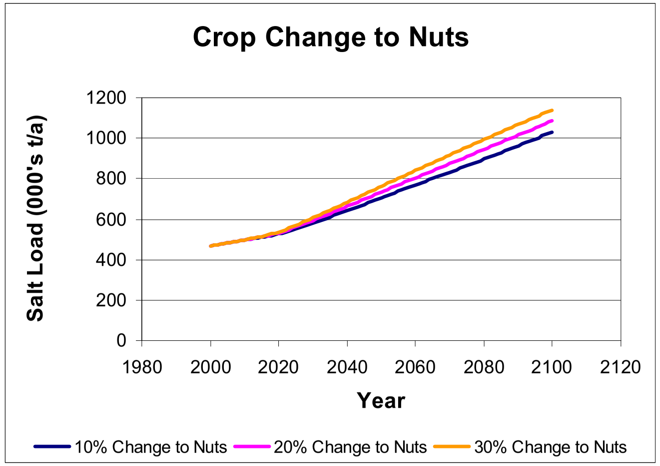

Figure 2.23a. Changes in salt loads to the river with increases in the crop change trend toward nuts (eg. almonds).

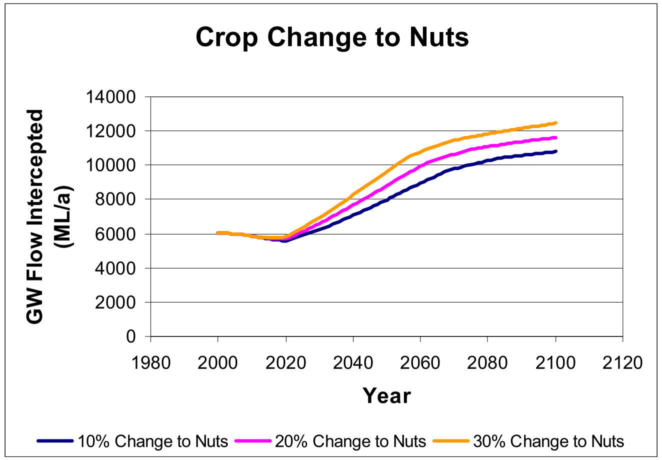

Figure 2.22b. Changes in volume of groundwater requiring disposal with increases in the crop change trend toward nuts (eg. almonds).

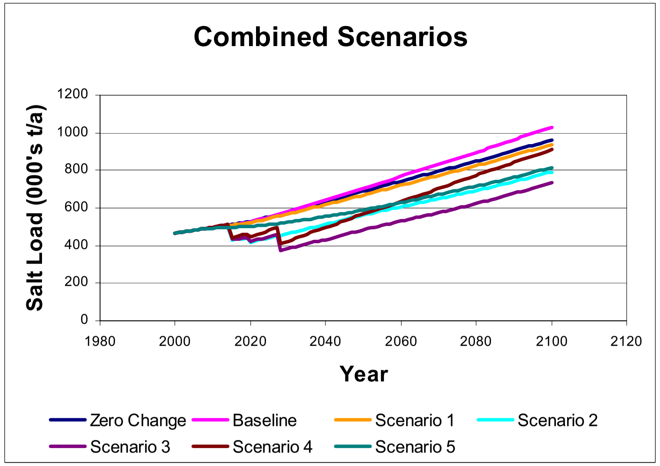

Figure 2.23a. Changes in salt loads to the river with various scenarios combining the variables above. Scenario details are discussed in the text.

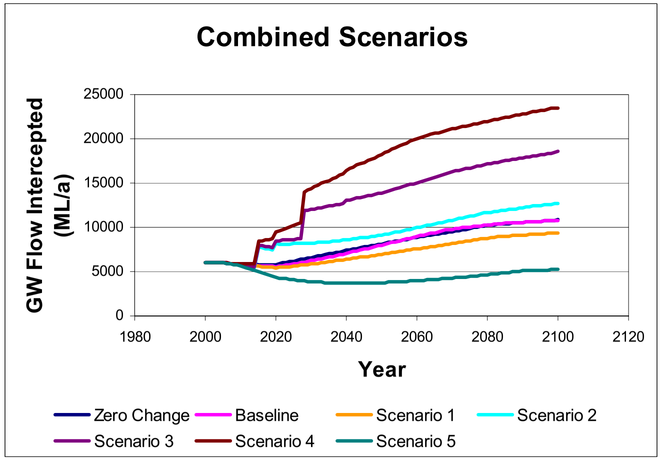

Figure 2.23b. Changes in volume of groundwater requiring disposal with various scenarios combining the variables above. Scenario details are discussed in the text.

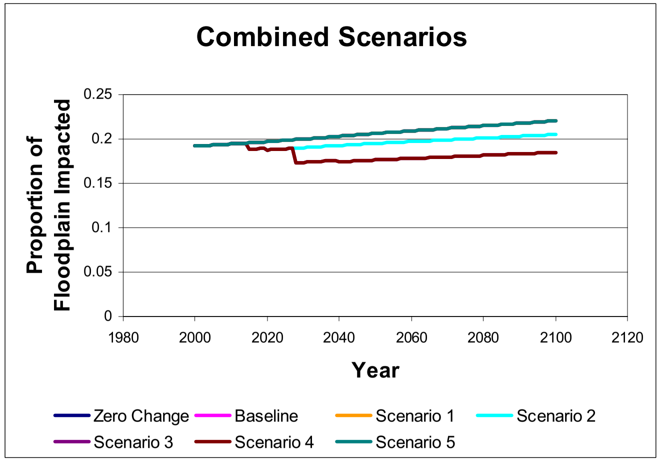

Figure 2.23c. Changes in proportion of floodplain impacted by salinity with various scenarios combining the variables above.

2.9. Discussion

The Lower Murray Landscape Futures Project set out to analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to social, economic and environmental outcomes, and to explore future options and scenarios for the Lower Murray in partnership with stakeholders in the region.

The River Murray Corridor Systems Model has been developed in order to address these project goals, to provide a framework for analysing the combined impacts of natural resource management actions. This report addresses the achievement of the first objective, analysis of existing plans. The third year of the project will be focused on the completion of objective two, exploration of future scenarios.

The aspirational goals of the LMLF project are shown below, with discussion of how the river corridor model enables these to be achieved.

Enabling regional bodies to evaluate the potential implications of regional plans and investment strategies, particularly the ability to achieve regional targets;

The River Murray Corridor Systems Model has been designed as a tool to enable stakeholders to evaluate the impacts of regional plans on biophysical and socioeconomic indicators. Analysis of regional plans with the model will assist in evaluating potential implications, on the proviso that the socioeconomic research is integrated with the biophysical modelling. Results from the model will indicate the likelihood of regional targets being achieved. Due to the complex nature of the resource condition targets, which are also governed by processes outside of the scope of the LMLF project such as flow manipulation, the model uses river salt loads and floodplain salinity risk as a best approximation or proxy for the temporal targets. The model is not intended to predict targets with high certainty due to the long time lags involved and uncertainty in land owner decision making that drives land use change.

Establishing a mechanism to enable regional bodies in the Lower Murray NAP Region to evaluate the impacts of the Regional Investment Strategies across the whole region;

The River Murray Corridor Systems Model is a starting point for modelling the whole region using the same assumptions and conceptual model. Provision of more detailed geologic and hydrologic data in Victoria will increase the level of confidence in this area.

Analysing existing regional plans and strategies for their likely impact on the landscape and community well being over the next 5 to 30 years for the Lower Murray NAP region;

Analysis of the existing regional plans and strategies is difficult due to the qualitative nature of many of the targets and actions. The river corridor section of the LMLF project addresses the integrated impacts of aggregated land use and management actions, by allowing users to test the future impacts of various combinations of NRM actions. Due to the qualitative nature of the plans, however, the uncertainty of these impacts remains high.

The model provides an indication of the future impacts of the plans on salt loads to the river, floodplain salinisation risk and costs associated with the strategies. The socioeconomic research component of the project is currently developing social indicators of community well-being, which will be incorporated into the RMCSM in year 3 of the project.

Empowering stakeholders in the region to explore and test alternative "future scenarios", without spending 20 years of trial and error;

The River Murray Corridor Systems Model is designed to be operated in a workshop environment, to enable stakeholders to test alternative future scenarios as they are conceived. Feedback from stakeholders has been used to develop the scenario generator module of the model, with some additional functionality to test future scenario options. Analysis of future scenarios will be undertaken in the third year of the project.

Exploring what are the landscapes that maximise community well-being;

The RMCSM has been designed with the capability of estimating economic benefits of various land uses and the economic impacts of NRM actions. Linking of socioeconomic outcomes and development of indicators in task C is required to understand the impacts of various landscapes on community well-being.

Creating a new standard for bringing together scientific rigour and community aspirations;

The RMCSM is a means of presenting many years of background scientific research in a way that is accessible to the community. Results from models such as SIMPACT, the Floodplain Wetland Impacts Model and an economic analysis are presented in a robust, simple to use framework that allows engagement of community in NRM planning.

Creating plans and strategies for solutions that address numerous issues in an integrated manner.

Whilst the river corridor section of the LMLF project assesses NRM plans and options for future landscape management in a top-down, integrated manner, it does not create new plans and strategies for the region. However, the RMCSM may be used to test combinations of land management and mitigation options in the initial stages of formulating future plans.

The South Australian and Victorian NAP milestones and whether they are met are discussed in Table 2.15. The majority of milestones have been met, with the exception of a higher resolution study for the riverine corridor which was agreed to not to be undertaken in the June 2005 PSC meeting. The milestones regarding completion of the final report, RMCS model and interactive demonstration have been changed to February 2006.

Table 2.15 South Australian and Victorian NAP milestones for year 2 of the LMLF project, with comments regarding whether they were achieved

SA and Victorian NAP Milestone	Achieved?
V1: LMLF Phase 2 research workplan and schedules developed and documented, covering environmental, social and economic analyses of Lower Murray landscape futures in the Mallee region, and the Wimmera region.	**Yes**
V2: LMLF Phase 2 research workplan presented to, and signed off by, Steering Committee at March 2005 Steering Committee meeting.	**Yes**
V3: Regional workshop of research team and regional stakeholders held in Mildura to develop landscape futures modelling scenarios for Mallee region.	**Yes**
V4: Regional workshop of research team and regional stakeholders held in Horsham to develop landscape futures modelling scenarios for Wimmera region.	**Yes**
S4: Engagement with regional stakeholders (PSC meeting at 3 monthly intervals, phone hook-ups and ad hoc visits between; workshops to develop scenarios and testing model.	**Yes**
V5: Interim Year 2 Progress Report charting modelling and scenario testing progress. Prepared as a written report submitted to SC and Vic NAP Office, and Presented to SC at June SC meeting.	**Yes**
V6, S5: Completion of Final Yr 2 Report, and its submission to Steering Committee at Dec 05 meeting, and to Vic NAP Office.	**Yes**
V7: Interactive demonstration of completed Yr 2 landscape futures analyses at appropriate regional stakeholder forum.	**Yes, additional presentation in April 2006**
S2: Completion of riverine corridor model with respect to all 4 resource condition targets. • Inclusion of all 4 resource targets • Inclusion of Victorian Mallee • Inclusion of higher resolution study site.	**In part, see below[1]**
S3: Completion of broader modelling area, as developed in consultation with stakeholders. • Model specification • Model completion.	**Discussed in dryland report section.**
S1: Progress of socio-economic component as outlined in the Year 1 report.	**Yes**
S6: Project management.	**Yes**

[1]The riverine corridor model has been completed, with respect to the two resource condition targets relevant to the region, river salt loads and floodplain salinity impacts. The remaining two targets are covered by the dryland modelling section of the project. The RMCSM showed that dryland processes

had an almost negligible effect on either river salinity or floodplain salinisation risk. Higher resolution data has been included in the preparation of input data sets for the model. It was decided by the project steering committee in June 2005 that a higher resolution study was no longer required for the project. As previously stated, data for the inclusion of the Victorian Mallee region has been collated, and model outputs are waiting only on the outputs from the Mallee Audit, including SIMPACT input layers and Legacy of History data, and floodplain impacts modelling results.

2.9.1. Understanding gained from modelling

The River Murray Corridor Systems Model has enabled the aggregated impacts of multiple policy and land management actions to be evaluated against the environmental targets of river salt loads and floodplain salt impacts. It has enabled the results from various combinations of different land management actions to be combined in a way that was not intuitive. The model therefore advances our understanding of the Lower Murray Region as a system.

The results from modelling have shown that:

- There is very little impact from changes in dryland processes such as revegetation and increasing perennial crops relative to actions that are applied to irrigation regions
- The impact from historical developments far surpasses the impacts from change in the next 10 years.
- Out of the land management actions that are applied to the irrigation regions directly, interception of salt through groundwater pumping has the largest benefit to river salt loads and floodplain salinity risk.
- There is still a large capacity to improve water use efficiency, particularly through system improvement. Whilst the theoretical capacity to improve efficiency is high, the practical ability to improve is reduced by the cost of changing systems and management and the timeframe required, depending on the age and lifespan of the current systems. Improving efficiency needs to be weighed up against the salt impacts on crops.
- Zoning policies for new irrigation developments and encouraging best practice management do have an appreciable benefit on river salt loads, and may reduce groundwater disposal requirements.

In systems models, the uncertainty in results is a function of the uncertainty in input data and sensitivity of the result to that data. In the River Murray Corridor Systems Model, areas of uncertainty are identified as:

- Legacy of History Data for South Australia. Although this input data has been generated from SIMPACT, a model that uses the same algorithms as SIMRAT, which has been accredited by the MDBC as fit for purpose for calculating the impacts of water trades, it has the highest impact on modelled salt loads to the river. Small changes in Legacy of History data will have observable impacts on environmental targets. Validation of the Legacy of History data against MODFLOW model outputs is currently being undertaken.
- Deep drainage from different irrigation systems and management. Deep drainage inputs will effect the change in salt loads to the river from

new irrigation and improvements in irrigation efficiency. Although this has a smaller impact on final salt load and floodplain salinity outputs than Legacy of History, accurate quantification is required. The model currently uses the best available data. Field based research to quantify changes in deep drainage for different management, irrigation systems and crop types is required, and results used to update the RMCSM input data as it becomes available.

- Current rates of change of crop types and irrigation systems and management are used to define the baseline scenario. Whilst current proportions of different types of systems and management is possible using crop surveys, the confidence in the rate of change of systems is decreased by a lack of information over a longer period of time.

The areas of uncertainty discussed highlight the intent of the RMCSM as a regional planning tool rather than a method of accounting salt impacts. It provides a means of comparing actions or combinations of actions, and identifying land management combinations with the highest potential to address river and floodplain impacts. Once identified, these actions should go through further more detailed analysis before implementation.

The first aim of the LMLF project is to analyse the existing NRM plans, and determine whether the resource targets that they set are achievable through the actions specified. It is difficult to discern the success of the plans in their current form of specifying qualitative actions without strict quantification of the levels of application.

While the target of 800 EC at Morgan 95% of the time is only able to be evaluated with the inclusion of a stochastic flow component within the model, conceptually it may be achieved if the salt loads to the river remain within a comparable level of the current salt loads. If the plans do achieve the targets, it will be primarily through optimally applied salt interception schemes, with the additional benefits from actions targeting irrigation areas directly, such as technology transfer to improve water use efficiency and zoning policies. Both river salt loads and floodplain salinity are only able to be kept at current levels through the use of salt interception schemes.

Whether the NRM targets are met also depends on external drivers such as the incoming EC upstream of the region and the magnitude and frequency of flows through the modelled reach. It should be noted that the modelling was undertaken for a single ten year period of development, therefore the results represent the minimum salt loads to be expected. If the rate of development continued indefinitely, the environmental impacts would be increased.

2.10. Conclusions

The objectives of the LMLF Project are to analyse the impact of existing regional plans and investment strategies on natural resources, with consideration given to community well-being, and to explore future options and scenarios for the Lower Murray in partnership with stakeholders in the region. This report represents the achievement of the first objective, analysing the impacts of the existing regional plans and investment strategies.

The River Murray Corridor Systems Model provides a method of assessing the integrated impacts of aggregated land management and salt mitigation actions on a number of resource condition targets, and forms a means of relating impacts with lag times that may exceed 100 years, with land management decisions being made today. The model integrates a number of existing biophysical and economic models including SIMPACT, the Floodplain and Wetland Impacts Model and aggregates potential future land management actions using a scenario builder module. Outputs from the model include EC impacts, change in salt loads to the river, floodplain vegetation and wetland salinisation risk, profits from crops and cost of mitigation. The model does not yet have socioeconomic indicators integrated. This is expected to be included as the socioeconomic research in Task C is finalised.

Scientifically, the River Murray Corridor Systems Model forms a first attempt to integrate hydrological processes with social and economic processes in order to understand the complex farming landscape system of the Lower River Murray Mallee. It has been designed to analyse the relative impacts of various land management and salt load mitigation combinations on multiple resource condition targets. The aggregated impacts of land management actions are not intuitive, and not calculable by superposition of individual effects due to non linear interactions between land use change, interception schemes and irrigation zoning, plus limits on development and irrigation efficiency improvement.

On inspection of the results, the development of salt interception schemes has the most rapid impact on river salt loads and floodplain vegetation health, but at a great cost. The volumes of water requiring disposal from existing schemes already exceeds the current disposal capacity, therefore further investment in disposal is required. Irrigation zoning reduces the ultimate salt load impacts at 2100 slightly more than improving water use efficiency, but the effects of improving WUE are seen earlier. This is thought to be a result of the large area of current irrigation and the closer proximity to the river than zoned new developments. Any action involving management of irrigation has a significantly greater impact on river salt loads than managing dryland farming practices. The impact of dryland farming management on floodplain salinisation and riparian vegetation health is negligible in 100 years.

Management implications from this study include:

- The impact from historical developments far surpasses the impacts from change in the next 10 years.

- Out of the land management actions that are applied to the irrigation regions directly, interception of salt through groundwater pumping has the largest benefit to river salt loads and floodplain salinity risk.
- Zoning policies for new irrigation developments and encouraging best practice management do have an appreciable benefit on river salt loads, and may reduce groundwater disposal requirements.
- The ultimate salt load reduction from zoning at 100% efficiency after 100 years was found to be slightly greater than the effects from changing water use efficiency, but the improvement of irrigation systems and management had a more rapid impact on salt loads to the river.
- There is still a large capacity to improve water use efficiency, particularly through system improvement. This is limited by the timing of this change and crop yield reduction associated with too high a water use efficiency.
- There is very little impact from changes in dryland processes such as revegetation and increasing perennial crops relative to actions that are applied to irrigation regions at this timescale
- The Floodplain Impacts Model indicated that floodplain salinity risk was minimally affected by changes in deep drainage from landscape management practices. Interception of groundwater through groundwater pumping was the major driver for improvements in floodplain salinity risk.

The River Murray Corridor Systems Model is designed to be operated in a workshop environment, to enable stakeholders to test alternative future scenarios as they are conceived. Analysis of future scenarios will be undertaken in the third year of the project.

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3. Lower MurrayLandscapesMurray Landscape Futures – Dryland Component

3.1. Introduction

3.1.1. Scope

This activity complements River Corridor Modelling (Task A) as it targets the dryland areas across the broader region. The rationale for this separation is that the riverine corridor has much stronger drivers (irrigation development, agreements on river salinity and environmental flows) and levers (zoning, engineering works, riverine management) than the larger area away from the river and the separation of tasks provides sufficient focus on both areas, given the key differences. Clearly, there is an interaction between these tasks within the riverine corridor.

One of the key principles for the Lower Murray Landscape Futures project was the need to provide an integrated analysis of the plans. For areas away from the river, this implies we consider together the themes of terrestrial biodiversity and dryland farming systems, while in the riverine corridor; all 4 themes need to be considered together.

3.1.2. Geographical Focus

This project will cover the entire region covered by the Lower Murray Landscape Futures project. That is, it will include:

- The dryland area covered by the SA MDB INRM Group
- The dryland area in the Victorian Mallee CMA and the Wimmera CMA

There is some sense in taking a bioregional perspective. However, there are 6 or 7 bioregions that overlap with the SA MDB, Wimmera and Mallee CMAs.

The geographic bioregion that largely coincides with the CMAs is the Murray Darling Depression within the study area. This bioregion covers most of the 3 CMAs, but avoids the hard rock areas of the SA and southern Wimmera. It also includes substantial parts of NSW.

The MDD includes the areas most at risk of wind erosion.

There is some advantage to consider ecological goals from a bioregional perspective. Much of the remnant native vegetation is in NSW MDD bioregion.

NRM targets refer to catchment management/INRM region boundaries not bioregions.

Biodiversity layers and analysis will also need to consider linkages to floodplain ecosystems.

3.1.3. Aims

The aims of this project are to:

1. Assess the impact of existing NRM plans for the dryland areas of the Mallee bioregion (Murray Darling Depression) on selected resource condition targets (terrestrial biodiversity, wind erosion) and socio-economic indicators.
2. Assess the impacts of these plans under alternative scenarios based on the outcomes of the analysis of the existing plans and input from stakeholders.

3.1.4. Milestones and Outputs

3.1.5. Structure of the Report

Aim 1 of the study involves the assessment of the impact of NRM plans on RCTs and socio-economic indicators. This will be delivered by March 06. Hence, this report focuses on:

1. Preliminary model construction that consists of two modules.
    a. The first is a Systematic Regional Planning (SRP; Bryan et al, 2005) model that examines spatial priorities for NRM based on selected targets in existing NRM plans of the dryland areas of the LMLF. The economic impact of implementing these priorities is also considered.
    b. The second is an individual behaviour model that examines landscape and land use change under scenario analyses for aim 2. Landowner decision making can be modelled and modified and the impact on landscapes can be examined.
2. Data compilation, audit and analysis.
    a. Compilation and auditing of spatial data is the first step in meeting aim 1. Examination of what data is available enables us to complete a preliminary examination of resource targets found in relevant plans.
    b. More detailed analysis that explicitly examines quantitative targets and the geographic requirements for meet those targets.
3. Preliminary SRP outputs.
    a. Geographic priorities for on-ground actions to meet resource condition targets contained in existing NRM plans.
    b. Estimate of the economic impact if on-ground priorities are implemented.

3.1.6. Approach

To achieve the above objectives and working within the above constraints, it is necessary for any approach to be:

1. spatially explicit
2. flexible enough to consider a range of actions
3. inclusive of alternative land uses incorporating perennials
4. able to assess impacts of land use and management on NRM outcomes of wind erosion, recharge and ecological outcomes
5. in the absence of spatially explicit actions being specified, needs to identify those areas most likely to achieve goals.

At the basis of this approach is the need for a GIS-based model that can analyse alternative scenarios for the whole bioregion. It is essential that a common framework is used across the entire area. Furthermore, the GIS-based models need to be supported by crop/land use models that can relate land use to wind erosion, deep drainage etc as well as spatial datasets on soils and climate.

The limited funding for the project means that any approach needs to be based on existing models that are used in the region rather than the development of any new models or extensive calibration of models not previously used in the area. The 4 components suggested are:

1. Systematic Regional Planning (SRP) model as the GIS-based model
2. APSIM as the crop/land use model
3. Climate scenarios from CAR and from interactions with Peter Hayman (SARDI)
4. Outputs from PIRVic work with Victorian Mallee

To assess the feasibility of meeting NRM targets and to provide some idea of the nature and magnitude of the actions required, Bryan et al. (2005) developed the concept of Systematic Regional Planning (SRP) for NRM and demonstrated its application in the SA River Murray Corridor. We recommend that this approach be applied to the broader region. SRP uses a decision theory framework to identify geographic priorities for actions such as vegetation management and revegetation of perennials for cost-effectively achieving multiple NRM objectives (e.g. salinity, wind erosion, biodiversity) and meeting regional NRM targets. The key benefit of SRP lies in the use of smart geographic targeting of NRM actions to achieve multiple NRM benefits at minimal extra cost. SRP enables assessment of the cost and impact of achieving salinity, wind erosion and biodiversity targets including quantification of the ability of various market-based economic drivers (e.g. biomass industries, carbon credits, fodder crops) for encouraging NRM actions. SRP also provides spatially explicit options and future scenarios for the region under NRM and assesses the impact.

Whilst Bryan et al. (2005) implemented SRP in the River Murray Corridor, comprehensive NRM planning requires a whole-of-region perspective and this project proposes the extension of SRP for NRM in the Murray Darling Depression

(MDD) bioregion in the study region. This project also extends the SRP techniques to include consideration of the impacts of climate change on NRM.

Climate change presents a major challenge to the continued biophysical, economic and social viability of the region. Planning for NRM needs to identify options that provide the greatest biophysical benefits and maximise the resilience of regional biophysical, economic and social systems to climate change.

3.1.7. SRP modelling framework

Planning (SRP) for multiple objectives Natural Resource Management in the Murray Darling Depression bioregion within Lower Murray study area. SRP will identify geographic priorities for NRM actions that most cost effectively meet NRM targets identified in regional plans given the uncertainty involved in future climate change. NRM targets and priorities will be synthesised and integrated into a comprehensive set of bioregional priorities and targets. The cost of achieving these targets will be assessed along with the biophysical, economic and social impact and future options for NRM will be developed. Future options include quantifying landscape scenarios for vegetation management and revegetation actions which meet NRM targets, maximise the effectiveness of these actions and minimise economic and social impacts. Conducting a comprehensive SRP analysis requires the development of a number of data layers. Each of these forms a separate component of this project, and will require input from the different agencies working in the region. These could potentially include:

- identifying geographic priorities for biodiversity enhancement
- update and improve geographic priorities for river salinity mitigation
- identifying geographic priorities for dryland salinity mitigation
- quantifying the impact of NRM actions on river flow
- identifying geographic priorities for wind erosion mitigation
- quantifying the distribution of agriculture and economic returns
- quantifying the spatial distribution of potential economic returns to biomass production This project aims to develop further the concept of Systematic Regional
- quantifying the spatial distribution of potential economic returns to carbon trading
- quantifying the spatial distribution of social impacts of large scale NRM actions

(Please note -we would expect the different state agencies involved in NRM to contribute to in developing these data layers)

A major aspect of this project also involves quantification of the risk and uncertainty surrounding each of these layers with respect to the impacts of climate change.

3.1.8. Objectives

General

- Review the NRM plans of the Victorian Mallee, Wimmera, the NSW Lower Murray Darling Basin and the SA Murray Darling Basin and synthesise a set of NRM targets for the entire MDD bioregion.
- Assemble, create and integrate a variety of spatial biophysical, ecological, administrative, social and economic data layers describing relevant elements of the biophysical, economic and social environments of the MDD bioregion.

Climate Change

- Assemble estimates of changes in rainfall, precipitation and CO2 from GCMs and prepare for input into other models which may require downscaling, stochastic weather generators etc.

Biodiversity

- Analyse existing regional plans from a perspective of how biodiversity targets may be achieved for the whole region taking a short, medium and long term view
- Create a series of spatial data layers quantifying geographic priorities for biodiversity actions according to landscape ecological and conservation planning principles given the impacts of climate change
- Quantify the cost and feasibility of achieving regional biodiversity targets and the impact on regional landscape structure and function including economic and social impacts

River Salinity

- Use modified SIMPACT model to enable better assessment of the salinity benefits of revegetation of deep-rooted perennials including improved wetting and drying algorithms
- Experiment with time horizons in salinity modelling to make a comprehensive assessment of the river salinity benefits of revegetation in the MDD
- Quantify the impact of climate change on salinity benefits of revegetation

Dryland Salinity

- Assemble data and create model to identify geographic priorities for revegetation to mitigate dryland salinity considering the likely impacts of climate change

Wind Erosion

- Enhance wind erosion mapping using new data from DWLBC and others
- Estimate the impacts of climate change on wind erosion and set geographic priorities for NRM actions to meet wind erosion targets given the uncertainty of climate change estimates

Agricultural Economics

- Quantify and map the distribution of agriculture in the MDD and quantify the economic returns to agriculture
- Assess the impact of climate change on land use in the MDD using outputs from climate change models and established crop models such as APSIM.
- Identify future options for the distribution of agriculture in the region that is most resilient to variations in climate will provide a basis for NRM in the region

Biomass Production

- Quantify the spatial distribution of biomass productivity using the latest data from the FloraSearch project
- Calculate the economic viability of biomass production for Integrated Tree Processing across the MDD. Identify the best sites for ITP plant location.
- Conduct a sensitivity analysis of biomass production to variation in biomass prices and costs given uncertainty of climate change
- Provide an indication of NRM benefits and future landscape character under different biomass production scenarios

Carbon Trading

- Provide a regional spatially explicit assessment of the carbon sequestration potential under biomass production, high productivity mallee species and biodiversity species
- Assess the profitability of carbon trading and quantify the costs and NRM benefits

Social Impacts

- Quantify the social impacts of various NRM scenarios in terms of impacts on population, services, economics and sustainability
- Use an input-output or Computable General Equilibrium model to calculate the likely ripple effects of NRM actions and impacts
- Quantify the spatial distribution of social resilience to changes in land use required by NRM and climate change

3.1.9. Methodology

- Create future options and scenarios for NRM actions for the MDD bioregion in the Lower Murray study area using Systematic Regional Planning that meet multiple objective regional targets. This will involve identifying sites for NRM actions such as vegetation management and restoration that maximise the effectiveness of these actions and minimise the impact of achieving targets on regional economies and communities. (to de done in consultation with parties involved and CMA's)
- SRP will use spatial optimisation techniques within Spatial Multi-Criteria Decision Analysis to identify geographic priorities for NRM actions that cost-effectively meet regional targets based on biophysical and economic principles.

- Geographic priorities for NRM actions will also maximise the resilience of regional biophysical, economic and social systems to the potential impacts of climate change in the light of significant uncertainty

3.1.10. Alternative Scenarios

While alternative scenarios are to be developed next year, the long lead time to develop an analytical capability for these scenarios means they need to be considered upfront. From discussions so far, we have made the 'straw man' assumption that alternative scenarios of interest include the impacts of climate change and the use of different economic incentives for encouraging large scale NRM actions. The drier conditions being predicted for the region may itself cause large changes in land management due to the decreasing viability of existing annual crops and pastures. The project will link with the Mallee Sustainable Farming (MSF) systems project to include the latest farming system developments in the analysis proposed. It is essential that in analysing the robustness of current NRM plans, that various climate change scenarios are considered.

The natural resource management outcomes distilled in the resource condition targets include:

- Reductions in recharge and river salinity,
- Reductions in wind erosion and
- Improvements in biodiversity conservation.

Reaching resource condition targets will involve widespread actions by landholders that include vegetation management, revegetation, and changes in agricultural practices. The most likely options are perennial plantings for biomass industries, perennial grasses and fodder crops (e.g lucerne, old man saltbush), and local native species for carbon trading, and the widespread adoption of conservation farming systems (eg MSF). Recent work has suggested that plantings for a biomass industry and carbon trading may be viable for the SA mallee region and this forms a good basis for analysis (Bryan et al. 2005).

Thus, the proposed approach involves modelling the spatial distribution of NRM actions (e.g. revegetation of biomass species, vegetation management etc.) that most cost effectively meet RCTs using the economic drivers of biomass, fodder crops, carbon trading, and sustainable farming. This will be done under various climate change scenarios. Based on these findings, the impact of NRM plans on the resilience of biophysical, economic and social systems can be assessed.

3.1.11. Objectives

The three objectives below outline the approach taken in this project:

Create a consistent set of RCTs: Based on available science and related policy, refine existing RCTs such that they are specific, measurable using existing data, consistent and detailed enough to enable spatial prioritisation for investment in NRM using available data sources.

Analyse the impact of existing plans on RCTs: Assess the impact of natural resource management actions as specified in regional plans on the achievement of RCTs, and assess the economic and social impact of these actions.

Analyse the impact of existing plans on RCTs under future scenarios: Assess the impact of natural resource management actions on the achievement of RCTs under different future changes in external drivers (e.g. changes in commodity prices, climate, technology, social structures and attitudes), and under different policy options. What are the likely economic and social impacts of natural resource management actions under the future scenarios? (see figure below).

3.2. The Targets

The LMLF Phase One Report (Walker et al 2005) presented the results of the analysis of regional plans. The methodology consisted of collating the major state and catchment and natural resource management plans and investment strategies for the Lower Murray region; defining categories for the main aspirations, targets and actions within these plans and strategies; dividing into broad natural resource condition areas, and; choosing key resource condition targets with which to assess the plans and strategies.

A total of 15 plans/strategies were reviewed. The review documented 173 aspirations, 252 targets and 1252 actions. These aspirations, targets and actions were binned into the four natural resource themes of salinity and water allocations; aquatic biodiversity; terrestrial biodiversity, and; dryland farming systems. We are interested only in the last two themes for the dryland component, namely terrestrial biodiversity and dryland farming systems.

To meet the first aim of the dryland component of the LMLF [*Assess the impact of existing NRM plans for the dryland areas of the Mallee bioregion (Murray Darling Depression) on selected resource condition targets (terrestrial biodiversity, wind erosion) and socio-economic* indicators] we need to synthesise the aspirations and targets into a set of tight quantifiable targets. Many of the existing aspirations and targets are qualitative and therefore cannot be closely examined for their ability to improve natural resource condition. Furthermore, their qualitative nature precludes them for use in a land use change model. The following sections report on the target and action synthesis and quantification outcomes for the two themes.

3.2.1. Existing targets

Terrestrial biodiversity

Appendix 1 list the full set of terrestrial biodiversity aspirations, resource condition targets and action targets extracted from the 15 plans/strategies reviewed in Walker et al (2005). Walker et al (2005) also produced a qualitative summarised list of actions from the full set of terrestrial biodiversity-related targets and actions. We have revised this list and included it in Table 3.16. For this study we are particularly interested in native vegetation management and revegetation on private lands, and biodiversity management on public lands elements in Table 3.16.

Table 3.16 Summary of actions drawn from the 62 terrestrial biodiversity actions and targets compiled in year one. See Appendix 1 for more detail.

Action	**Description**
Data collection	Complete surveying and mapping of vegetation classes, biological surveys, habitat assessment.
Native vegetation management and revegetation on private lands	Set native vegetation targets, implement revegetation strategies, maintain, improve and reconstruct natural habitat, revegetation of threatened habitat areas, revegetate buffer areas, link blocks of remnant vegetation and encourage natural regeneration of degraded areas. Increase the area of priority native vegetation retained and restored on farms under Heritage Agreements, sanctuaries and covenants, etc.
Biodiversity management on public lands	Implement revegetation and biodiversity action plans. Priority reserves covered by management plans. Increase the area of priority native vegetation retained and restored in reserves.
Pest species management	Implement plans to manage invasive plant and animal species that threaten biological diversity, particular for priority areas.
Threatened species and habitat recovery planning	Implement multi-species coordinated conservation and recovery plans. Protect and manage critical habitat and key threats for species of conservation significance through the development and implementation of recovery plans. Identify species, ecosystems, parks or reserves that require recovery plans and further actions. Develop resource database for threatened species habitat for long term conservation planning.
Policy development	Assist in the development of land use and catchment biodiversity policy at State and Basin-wide levels.
Effective management	Establish procedures/mechanisms between local municipalities and State Government to assist with land clearing issues. Develop effective management agreements for native vegetation held under Heritage Agreements.
Incentives	Establish market-based incentives to maintain and rehabilitate biodiversity on private land.
Research	Improve understanding of ecosystem services. Investigate and gain knowledge of the recovery of threatened ecological communities and species to target future investment. Undertake research into farming to improve land capability in dryland areas.
Awareness raising	Increase awareness in the community about the role and value of native vegetation and biodiversity issues. Improve accessibility to information regarding habitat values and protection for landholders.

We set about synthesising the 62 aspirations and targets into a set of quantifiable targets for assessment and modelling. Many aspirations and targets are qualitative in nature and therefore have no use in a modelling and systematic planning sense. For example, all the aspiration targets relating to terrestrial biodiversity (Appendix 1) cannot be explicitly modelled. While they act as overarching goals, or guiding principles (e.g. *To bring about a significant improvement in the condition and health of the native vegetation and* *biodiversity within the catchment*, or *Habitat protection and recovery to improve biodiversity and protect areas of conservation significance*), they contain limited, if any, tangible or explicit information about how much, where, and by when the natural resource is managed. Therefore the first task was to extract the quantitative targets. The quantitative targets are listed in Table 3.2.

Table 3.17. Description of quantifiable biodiversity targets (RCTs and MATs). All vegetation is native vegetation remnants or indigenous plantings unless otherwise stated.

Region	Revegetation	Protect vegetation	Improve vegetation condition
Mallee	• Increase cover of each EVC to **15%** of pre-Euro extent.[1] • **30%** cover across each bioregion.[1]		• Improve condition of **20%** across all conservation significance levels.[1]
Wimmera	• **Net gain** of extent and quality of vegetation through revegetation, **2012**.[2] • **750ha** per year revegetation of priority EVCs.[2]	• **Net gain** in condition and extent of vegetation through protecting remnants, **2012**.[2] • **750ha** of high quality remnants protected per year.[2] • **500ha** of low-medium quality remnants protected per year.[2]	• **Net gain** in condition and extent of vegetation through enhancing remnants, **2012**.[2]
SAMDB	• Increase cover by **1%** in agricultural region, **2020**.[4] • Re-establish **950ha** of vegetation to provide links in priority areas, **2006**.[4]	• Protect and enhance **10,000ha** of vegetation, **2006/07**.[5] • **50%** of 6 specific threatened communities protected, **2006**.[3] • Increase area of priority vegetation protected to >**2,000ha**, **2006**.[3]	• Protect and enhance **10,000ha** of vegetation, **2006/07**.[5] • Improve condition of **50%** of vegetation on private land, **2020**.[4]

[1]Vic Mallee RCS

[2]Vic Wimmera RCS

[3]SAMDB INRM Plan

[4]SAMDB INRM Invest

[5]SAMDB CWMP

Dryland farming systems

Appendix 2 lists the full set of dryland farming aspirations, resource condition targets and action targets extracted from the 15 plans/strategies reviewed in Walker et al (2005). The quantitative targets extracted from Appendix 2 are listed in **Table** 3.18. Only a small number of targets relating to dryland farming systems can be used in a quantitative sense.

Table 3.18. Description of quantifiable dryland farming systems targets (RCTs and MATs).

Region	Dryland salinisation	Soil erosion	Soil health
Mallee	• Reduce land threatened by salinisation from **10%** to **8%** of total land surface.[1] • **20%** reduction in groundwater recharge from farming systems.[1]	• Negligible erosion **6** out of **10** years.[1] • Confine eroding land to **3%** in dry years.[1]	
Wimmera		• *Reduction in wind and water soil erosion levels to be determined by* ***2004***.[2]	• **5%** increase in sustainable land management techniques (e.g. minimum tillage & stubble retention), **2007**.[2]
SAMDB	• Improve dryland WUE by **70%** by **2020**.[3] • Establish **25,000ha** of *perennial* vegetation, **2006/07**.[4] • Constrain salt affected land to **120,000ha**, **2020**.[3]	• Establish **25,000ha** of *perennial* vegetation, **2006/07**.[4] • **40%** reduction in agricultural land at risk of wind erosion in each June, **2020**.[3]	• **Increased trend** in soil carbon levels in cropping soils, **2020**.[3]

[1]Vic Mallee RCS

[2]Vic Wimmera RCS

[3]SAMDB INRM Invest

[4]SAMDB CWMP

3.2.2. New expanded targets

Looking at **Table** and **Table** 3.18 it is evident that only a small number of targets contain a quantifiable element. In all cases they describe either an areal or proportional goal. That is, an increase in existing areas of native vegetation protected/managed or increase in existing vegetation cover by some hectare amount or percentage, or some proportional/areal reduction in soil erosion attributes. These figures in themselves are laudable, however they are overly pithy and in total, have minimal consideration for broad ecological processes, conservation planning principles, and economic realities (see Bryan et al 2005; Crossman and Bryan, 2006). This demands a revised and expanded set of quantitative targets that contain both existing quantitative areal and proportional goals, as well as clearly defined ecological and conservation goals and explicit consideration to landowners' bottom line. Furthermore there is inconsistency between regions in the quantities highlighted in existing targets (Table and Table 3.18).

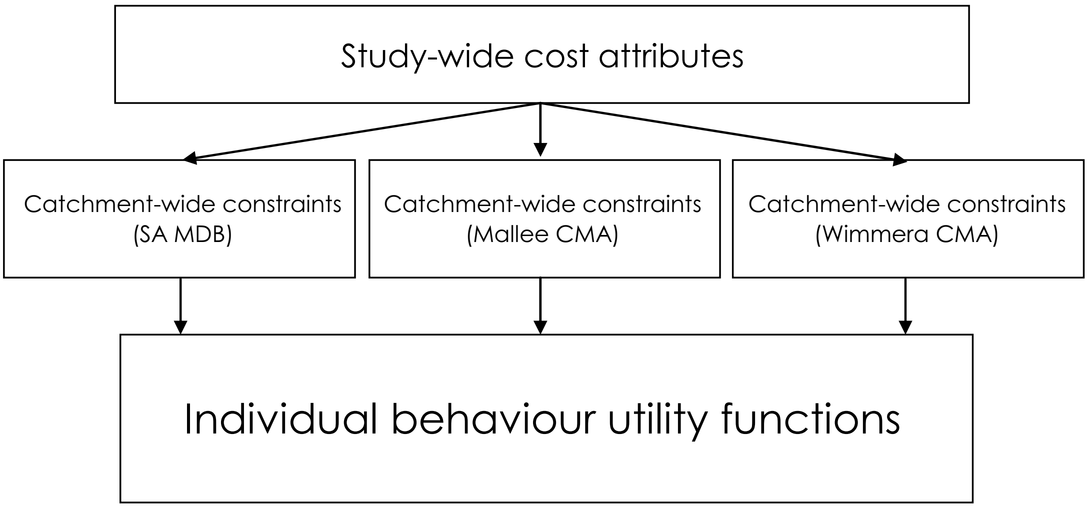

Figure 3.4. Flow chart depicting target hierarchy

This then poses the question of how to best model across the entire LMLF study area. To solve this dilemma we developed a hierarchical set of targets (

Figure 3.4). At the highest level are the LMLF-wide goals that universally apply to the study area. These goals are imposed on the model described in Section 2 through a set of attributes that drive model solutions toward lower cost alternatives. Cost in this case is a function of spatial and economic attributes. The second level of target hierarchy is the set of constraints imposed on the model that vary according to study area catchment. NRM plans and investment strategies for the three catchments in the study area (Figure 3.6) contain spatially disparate targets whose integrity must be maintained for meeting 'aim 1' of the project. The third level of target hierarchy is at the individual, or agent, level. Constraints and targets at this level directly influence and define individual behaviour.

The graphical representation of the target hierarchy in

Figure 3.4 was used as a base for specific target definition. The new targets for each of the actions in Figure 3.5 are listed in Table 3.19. The new targets contain the quantifiable elements of existing NRM targets in the LMLF, but have been expanded to include the conservation planning principle of representativeness (JANIS, 1997; Margules and Pressey, 2000; Groves 2001), measures of habitat size, shape and configuration (Diamond, 1975), economic estimates of opportunity cost and returns from alternative farming systems, and integration of other degrading processes. The new targets are an improvement on the existing set because there are now explicit goals of managing multiple natural resource problems, making this a multi-objective and integrative study (Bryan and Crossman, in prep a,b).

Table 3.19. New targets for actions specified in Figure 3.5.

Action	Study-wide cost attributes	Catchment-wide constraints (Note: Targets under group '1' are all existing targets)	Individual behaviour utility functions
Vegetation management	• Bigger patches are better • Simple shapes are better • Least fragmented are better • Further from patch edge better • Higher risk patches are better • Most important bird habitat patches are better • Lower opportunity cost better • Higher wind erosion potential better	<u>Short-term (by 2006-08):</u> 1. Protect and enhance **10,000ha** (including **50%** of **6** threatened communities) in the **SAMDB**; **750ha** of high quality and **500ha** of low-medium quality remnants in the **WimCMA**, and; **20%** of remnants in the **MalleeCMA**. 2. Must work toward a **30%** representative target of each EVC/Veg community, climate zone, and soil land system <u>Medium-term (by 2020):</u> 1. Protect and enhance **50%** of remnants on private land in the **SAMDB**, and **11,250ha** of high quality and **7,500ha** of low-medium quality remnants in the **WimCMA**. 2. Achieve a **30%** representative target of each EVC/Veg community, climate zone and soil land system.	
Revegetation with indigenous species	• Closer to remnant vegetation is better • Closer to higher risk patches are better • Closer to most important bird habitat patches are better • Lower opportunity cost better • Higher wind erosion potential better • Higher salinity risk better	<u>Short-term (by 2006-08):</u> 1. Establish **950ha** in the **SAMDB**; **750ha** in priority EVCs in the **WimCMA**, and; **30%** cover across each bioregion and **15%** cover in each pre-Euro EVC in the **MalleeCMA**. 2. Must work toward a **15%** representative target of each pre-Euro EVC/Veg community, climate zone, and soil land system. <u>Medium-term (by 2020):</u> 1. Increase cover by **1%** in agricultural region of **SAMDB**, and **11,250ha** in high priority EVCs in the **WimCMA**. 2. Achieve a **15%** representative target of each pre-Euro EVC/Veg community, climate zone, and soil land system.	

Alternative farming systems	• Higher wind erosion potential better
	• Higher salinity risk better
	• Higher economic returns better, potentially estimated from:
	  o Biomass supply
	  o Agro-forestry
	  o Carbon sequestration
	  o Salinity & wind erosion credits
		<u>Short-term (by 2006-08):</u>
		1. Reduce salinisation threat from **10%** to **8%** and confine eroding land to **3%** of total land surface in **MalleeCMA**, and establish **25,000ha** of perennial vegetation in the **SAMDB**.
		<u>Medium-term (by 2020):</u>
		1. Constrain salt affected land to **120,000ha**, improve dryland WUE by 70% and reduce wind erosion risk land by **40%** in the **SAMDB**.	

Sustainable farming	• Higher wind erosion potential better • More sandy soils better	<u>Short-term (by 2006-08):</u> 1. Confine eroding land to **3%** of total land surface in **MalleeCMA** <u>Medium-term (by 2020):</u> 1. Reduce wind erosion risk land by **40%** in the **SAMDB**.	

3.3. Agro-ecological Systems and NRM Linkages

The linkages between resource condition targets, on-ground management actions and economic drivers of change are complex. Different natural resource management actions address different resource condition targets (Error! Reference source not found.) and hence, different resource condition targets may be achieved through one or more NRM actions. Additionally, different economic drivers are needed to provide incentives for different natural resource management actions. Below we develop a conceptual model that captures the linkages between natural resource management objectives, management actions, and economic drivers that provides a basis for Systematic Regional Planning.

As discussed above, some of the highest priority regional natural resource management objectives include salinity, biodiversity, and wind erosion. Carbon sequestration is another high priority natural resource management objective at state government level. In the Corridor, the natural resource management actions include revegetation with fodder crops, biomass species, local native species, and the management of remnant native vegetation. These actions have been identified because they each have associated economic drivers to encourage their large scale adoption including livestock production, biomass enterprises, carbon trading, and public funding (Figure 3.2).

Revegetation of fodder crops involves the planting of deep-rooted perennial fodder species such as lucerne or old-man saltbush. Fodder crops can provide benefits for salinity through reduction in groundwater recharge and for wind erosion through the soil binding action of the roots and the attenuation of wind speeds by the standing biomass. Fodder crops provide economic benefits through livestock production and are known to be economically viable in the Corridor (Figure 3.2). Revegetation for biomass production involves the planting and short-rotation harvest of eucalypt species (i.e. Eucalyptus oleosa). Biomass plantings may reduce wind erosion and salinity, and potentially provide some carbon benefits, but will have limited biodiversity benefits because of the monoculturic nature of the crop. Biomass enterprises can provide an economic driver for biomass plantings and involve the processing of biomass primarily for renewable energy but also for oil and activated carbon. Trading of subsurface carbon sequestration or carbon offsets from renewable energy may also increase the economic incentive (Figure 3.2). Revegetation of local native species and remnant vegetation management can address all four objectives. Economic drivers for these actions include carbon trading and public funding. However, public funding is likely to be low and carbon trading has a fairly high risk associated with it given the failure of Australian government to ratify the Kyoto protocol. In this study we concentrate on the actions of revegetation of biomass species, revegetation of local native species, and remnant vegetation management to achieve natural resource management objectives (Figure 3.2).

Processes of environmental degradation operate heterogeneously across the landscape and actions located at different sites offer different levels of NRM benefit. For maximum benefit, actions need to be targeted in high priority locations. The benefit of vegetation management and revegetation actions for biodiversity depends on their location relative to the spatial arrangement of remnant habitat in the landscape context. The benefit of revegetation for salinity and wind erosion also depends on the spatial location of the plantings. Salinity benefits are dependant upon the geohydrologic and groundwater characteristics of the site of the plantings. The benefit of revegetation in wind erosion mitigation depends upon the location of revegetation and the susceptibility of soil to erosion. Economic processes also vary spatially. The profitability of biomass production varies spatially with productivity, opportunity and transport costs. Decisions need to be made about the location and types of management actions to invest in that most cost effectively achieve natural resource management objectives. The complexity that undermines these decisions requires a systematic and data-centric approach to planning based on an explicit multi-criteria decision analysis (MCDA) framework.

3.3.1. Actions

While actions are stated for each of the relevant plans, they are not always stated in a spatially explicit fashion. Where they are, the spatial modelling framework will define the impacts on selected resource condition targets and from there, an assessment of the regional social and economic impacts. Where actions are not explicitly defined, a range of options will be considered. If spatial data is not available, an approach similar to that developed by Bryan et al (2005) for the River Corridor will be used.

In summary, these actions relevant to the above RCTs can be summarised as:

1. Increase extent of native vegetation
2. Improve condition of existing vegetation
3. Enhance the management of remnant vegetation through reserve systems or through off-reserve measures
4. Encourage stubble retention and conservation farming
5. Explore alternative farming systems, incorporating perennials
6. Increase area of perennial vegetation.

3.3.2. Agricultural Land Management

A substantial element of the dryland landscape futures modelling depends on the agricultural land management decisions made by individual landholders. Decisions made by farmers affect levels of agricultural production, farm profit, and the environmental outcomes of deep drainage and wind erosion potential.

Analysis of these farming systems is conducted using APSIM. The outputs of this modelling are spatially-explicit information on crop production, deep drainage and wind erosion potential. These outputs are used as inputs into other components of the dryland modelling.

The land management actions available to farmers in continuous cropping systems are either traditional farming or the adoption of conservation farming techniques. The land management action available to graziers is the establishment of deep-rooted perennial species (e.g. lucerne, saltbush, etc.).

Grazing pressure in the pure grazing farming system is considered to be moderate as graziers strive for sustainable grazing levels when it is the main source of income for the farm.

The crop/pasture rotation system combines most of the characteristics of both of its component farming systems. The cropping phase can involve deep or shallow rooted crops and farmers can employ traditional or conservation farming land management actions. The grazing phase is characterised by shallow rooted annuals and farmers can plant deep rooted annuals as a land management action. Perennials are not considered in this farming system because of the temporary rotational nature of the pasture. Grazing pressure in crop/pasture rotation systems is expected to be high as grazing is used as a means of reducing biomass to complement the cropping system.

3.4. Analysis of NRM Plans

3.4.1. The top down module

We present a model that identifies broad geographic priorities for meeting resource condition targets contained in existing NRM plans – i.e. identifies options and cost-effective priorities for land use change. This module is a core component of meeting Aim 1.

The outputs may then be linked with the bottom-up farmer decision-making module or may simply become drivers of land use change. For example, only those farms identified by the top-down module are the focus of paddock-scale change as farmers maximise utility. Not quite sure how this will work yet but initial thinking suggests a marrying of the agent-based model with a systematic regional planning type model.

3.4.2. SRP for Multiple Objective NRM

- Create future options and scenarios for NRM actions for the MDD bioregion using Systematic Regional Planning that meet multiple objective regional targets. This will involve identifying sites for NRM actions such as vegetation management and restoration that maximise the effectiveness of these actions and minimise the impact of achieving targets on regional economies and communities.
- SRP will use spatial optimisation techniques within Spatial Multi-Criteria Decision Analysis to identify geographic priorities for NRM actions that cost-effectively meet regional targets based on biophysical and economic principles.
- Geographic priorities for NRM actions will also maximise the resilience of regional biophysical, economic and social systems to the potential impacts of climate change in the light of significant uncertainty

Model structure

Analysis of current NRM plans will involve an assessment of key biophysical, economic and social indicators.

A multitude of models will be run for each of the three catchments. The models are summarised in Table 3.20, Table 3.21 and Table 3.22.

Table 3.20. Spatial allocation models for revegetation using local native species.

Revegetation of Local Native Species

Targets	Spatial Allocation Models					
	Go Anywhere	**Cheapest**	**Best for Biodiversity**	**Best for INRM**	**Most Cost-Effective**	**Sustainability Ideal**
Mallee CMA Increase cover of each EVC to 15% of pre-Euro extent 30% cover across each bioregion **Wimmera CMA** Net gain of extent and quality of vegetation through revegetation 750ha per year revegetation of priority EVCs (11,250ha) **SAMDB INRM** Increase cover by 1% in agricultural region	Select random areas of cleared land for revegetation	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (pre-Euro communities) score • Conservation priority (bioregions) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (pre-Euro communities) score • Conservation priority (bioregions) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Opportunity cost • Establishment cost • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (pre-Euro communities) score • Conservation priority (bioregions) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Opportunity cost • Establishment cost ***Additional constraints***: • All high wind erosion risk areas revegetated • All high deep drainage risk areas revegetated • All river salinity contributing areas revegetated • Conservation status (pre-Euro communities) >= 1,000ha or 30% • Conservation status (climate zones) >= 1,000ha or 30% • Conservation status (soil classes) >= 1,000ha or 30% • Conservation status (bioregions) >= 1,000ha or 30%

Re-establish 950ha of vegetation to provide links in priority areas					
Mallee CMA Increase cover of each EVC to 15% of pre-Euro extent 30% cover across each bioregion	Select random areas of cleared land for revegetation	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Conservation priority (climate zones) score • Conservation priority (soil classes) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Opportunity cost • Establishment cost • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Conservation priority (climate zones) score • Conservation priority (soil classes) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Opportunity cost • Establishment cost ***Additional constraints***: • All high wind erosion risk areas revegetated • All high deep drainage risk areas revegetated • All river salinity contributing areas revegetated • Conservation status (pre-Euro communities) >= 1,000ha or 30% • Conservation status (climate zones) >= 1,000ha or 30% • Conservation status (soil classes) >= 1,000ha or 30% • Conservation status (bioregions) >= 1,000ha or 30%
Wimmera CMA Net gain of extent and quality of vegetation through revegetation 750ha per year revegetation of priority EVCs (11,250ha)	Select random areas of cleared land for revegetation	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Conservation priority (pre-Euro communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Opportunity cost • Establishment cost • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Conservation priority (pre-Euro communities) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Opportunity cost • Establishment cost ***Additional constraints***: • All high wind erosion risk areas revegetated

			• Conservation priority (bioregions) score	• Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	• All high deep drainage risk areas revegetated • All river salinity contributing areas revegetated • Conservation status (pre-Euro communities) >= 1,000ha or 30% • Conservation status (climate zones) >= 1,000ha or 30% • Conservation status (soil classes) >= 1,000ha or 30% • Conservation status (bioregions) >= 1,000ha or 30%
SAMDB INRM Increase cover by 1% in agricultural region Re-establish 950ha of vegetation to provide links in priority areas	Select random areas of cleared land for revegetation	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Conservation priority (pre-Euro communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Opportunity cost • Establishment cost • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Conservation priority (pre-Euro communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	***Minimise***: • Dist to remnant veg • Dist to high risk remnant veg • Fragmentation score • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Opportunity cost • Establishment cost ***Additional constraints***: • All high wind erosion risk areas revegetated • All high deep drainage risk areas revegetated • All river salinity contributing areas revegetated • Conservation status (pre-Euro communities) >= 1,000ha or 30% • Conservation status (climate zones) >= 1,000ha or 30% • Conservation status (soil classes) >= 1,000ha or 30% • Conservation status (bioregions) >= 1,000ha or 30%

Table 3.21. Spatial allocation models for protecting and improving remnant native vegetation.

Remnant Vegetation Protection and Enhancement					
Targets	Spatial Allocation Models				
	Go Anywhere	Cheapest	Best for Biodiversity	Most Cost-Effective	Sustainability Ideal
Mallee CMA Improve condition of 20% across all conservation significance levels	Select random areas of vegetation for protection and enhancement	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Remnant veg risk score • Fragmentation score • Conservation priority (veg communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	***Minimise***: • Remnant veg risk score • Fragmentation score • Opportunity cost • Establishment cost • Conservation priority (veg communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	***Minimise***: • Remnant veg risk score • Fragmentation score • Opportunity cost • Establishment cost ***Additional constraints***: • Conservation status (veg communities) >= 1,000ha or 50% • Conservation status (climate zones) >= 1,000ha or 50% • Conservation status (soil classes) >= 1,000ha or 50% • Conservation status (bioregions) >= 1,000ha or 50%
Wimmera CMA 750ha of high quality remnants protected per year (11,250 ha) 500ha of low-medium quality remnants protected per year (7,500 ha)	Select random areas of vegetation for protection and enhancement	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Remnant veg risk score • Fragmentation score • Conservation priority (veg communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	***Minimise***: • Remnant veg risk score • Fragmentation score • Opportunity cost • Establishment cost • Conservation priority (veg communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	***Minimise***: • Remnant veg risk score • Fragmentation score • Opportunity cost • Establishment cost ***Additional constraints***: • Conservation status (veg communities) >= 1,000ha or 50% • Conservation status (climate zones) >= 1,000ha or 50% • Conservation status (soil classes) >= 1,000ha or 50% • Conservation status (bioregions) >= 1,000ha or 50%

SAMDB INRM Improve condition of 50% of vegetation on private land Protect and enhance 10,000ha of vegetation 50% of 6 specific threatened communities protected Increase area of priority vegetation protected to >2,000ha	Select random areas of vegetation for protection and enhancement	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Remnant veg risk score • Fragmentation score • Conservation priority (veg communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	***Minimise***: • Remnant veg risk score • Fragmentation score • Opportunity cost • Establishment cost • Conservation priority (veg communities) score • Conservation priority (climate zones) score • Conservation priority (soil classes) score • Conservation priority (bioregions) score	***Minimise***: • Remnant veg risk score • Fragmentation score • Opportunity cost • Establishment cost ***Additional constraints***: • Conservation status (veg communities) >= 1,000ha or 50% • Conservation status (climate zones) >= 1,000ha or 50% • Conservation status (soil classes) >= 1,000ha or 50% • Conservation status (bioregions) >= 1,000ha or 50%

Table 3.22. Spatial allocation models for the adoption of sustainable farming techniques.

Adoption of Sustainable Farming Techniques

(conservation farming and deep-rooted perennial fodder)

Targets	Spatial Allocation Models				
	Go Anywhere	**Cheapest**	**Best for NRM**	**Most Cost-Effective**	**Sustainability Ideal**
Mallee CMA Reduce land threatened by salinisation from 10% to 8% of total land surface 20% reduction in groundwater recharge from farming systems Negligible erosion 6 out of 10 years Confine eroding land to 3% in dry years	Select random areas for conservation farming and deep-rooted perennials	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Wind erosion risk score • Deep drainage risk score • River salinity contribution	***Minimise***: • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Opportunity cost • Establishment cost	***Minimise***: • Wind erosion risk score • Deep drainage risk score • Opportunity cost • Establishment cost ***Additional constraints***: • All high wind erosion risk areas addressed • All high deep drainage risk areas addressed • All river salinity contributing areas addressed
Wimmera CMA Reduction in wind and water soil erosion levels to be determined by 2004 5% increase in sustainable land management techniques (e.g. minimum tillage & stubble retention)	Select random areas for conservation farming and deep-rooted perennials	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Wind erosion risk score • Deep drainage risk score • River salinity contribution	***Minimise***: • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Opportunity cost • Establishment cost	***Minimise***: • Wind erosion risk score • Deep drainage risk score • Opportunity cost • Establishment cost ***Additional constraints***: • All high wind erosion risk areas addressed • All high deep drainage risk areas addressed • All river salinity contributing areas addressed

SAMDB INRM Improve dryland WUE by 70% Establish 25,000ha of perennial vegetation Constrain salt affected land to 120,000ha 40% reduction in agricultural land at risk of wind erosion in each June Increased trend in soil carbon levels in cropping soils	Select random areas for conservation farming and deep-rooted perennials	***Minimise***: • Opportunity cost • Establishment cost	***Minimise***: • Wind erosion risk score • Deep drainage risk score • River salinity contribution	***Minimise***: • Wind erosion risk score • Deep drainage risk score • River salinity contribution • Opportunity cost • Establishment cost	***Minimise***: • Wind erosion risk score • Deep drainage risk score • Opportunity cost • Establishment cost ***Additional constraints***: • All high wind erosion risk areas addressed • All high deep drainage risk areas addressed • All river salinity contributing areas addressed

Data requirements

Data requirement for all models summarised in Table 3.20, Table 3.21 and Table 3.22 are listed in Table 3.23 and Table 3.24.

Table 3.23. Summary of performance indicators for all spatial allocation models.

Performance Indicators		
Revegetation of Local Native Species	**Remnant Vegetation Protection and Enhancement**	**Adoption of Sustainable Farming Techniques**
• Total area of revegetation • Average distance to remnant vegetation • Average distance to high risk remnant vegetation • Average fragmentation score • Average wind erosion risk score • Average deep drainage risk score • Total river salinity avoided • Total opportunity cost • Total establishment cost • % of high wind erosion risk areas revegetated • % of high deep drainage risk areas revegetated • % of pre-Euro veg communities > 30% cons status • % of climate zones > 30% cons status • % of soil classes > 30% cons status • % of bioregions > 30% cons status	• Total area of vegetation protection and enhancement • Average remnant veg risk score • Average fragmentation score • Total opportunity cost • Total establishment cost • % of veg communities > 30% cons status • % of climate zones > 30% cons status • % of soil classes > 30% cons status • % of bioregions > 30% cons status	• Total area of conservation farming • Total area of perennial fodder • Average wind erosion risk score • Average deep drainage risk score • % of high wind erosion risk areas revegetated • % of high deep drainage risk areas revegetated • Total river salinity avoided • Total opportunity cost • Total establishment cost

Table 3.24. Summary of data required for all spatial allocation models and performance indicators.

Data Required	Notes
Revegetation	
bioregions	Attach ID code and name
Pre-Euro communities	Make sure community ID codes match those of existing veg comm.
climate zones	Grid of IDs of 20-class climate zones
soil classes	Grid of soil classes
Dist to remnant veg	Negative exponential
Dist to high risk remnant veg	Create an index = distance x risk (where hi risk = low value)

	rescale to continuous 1 <= n <= 5
Fragmentation score (cleared areas)	Similar to Hobbs & McIntyre (2000) but continuous values not classified, rescale to continuous 1 <= n <= 5
Conservation priority (pre-Euro com) score	Proportion of each pre-Euro veg comm. Vegetated
Conservation priority (soil classes) score	Proportion of each soil class vegetated
Conservation priority (bioregions) score	Proportion of each climate zone (use 20-class climate classification) vegetated
Conservation priority (soil classes) score	Proportion of each soil class vegetated
Wind erosion risk score	To come from Jon Fawcett (PIRVic)
Deep drainage risk score	To come from Jon Fawcett (PIRVic)
River salinity contribution	To come from Matt Miles (SA DEH)
High Wind erosion risk areas	Binary grid To be created from Jon Fawcett data (PIRVic)
High Deep drainage risk areas	Binary grid To be created from Jon Fawcett data (PIRVic)
River salinity contributing areas	Binary grid To be created from Matt Miles data (SA DEH)
Vegetation Protection & Enhancement	
Remnant veg risk score	From Jo McNeill (PIRVic)
Fragmentation score (veg cells)	Similar to Hobbs and McIntyre (2000) but continuous values not classified, rescale to continuous 1 <= n <= 5
Conservation priority (remnant com) score	Proportion of each remnant veg comm. Protected
Conservation priority (bioregion) score	Proportion of each bioregion protected
Conservation priority (climate) score	Proportion of each climate zone (use 20-class climate classification) protected
Conservation priority (soil classes) score	Proportion of each soil class protected
Adoption of Sustainable Farming Techniques	
land threatened by salinisation	Maybe NLWRAudit?
salt affected land	Maybe same as above?

3.5. Landscape Futures Analysis

3.5.1. The bottom up module

The heart of this model is a land use change modelling engine. This takes the form of a farmer decision-making module. This is a futures model to meet Aim 2.

Hence, our model concentrates on private decision makers (farmers). However, we might want to consider what might happen on publicly owned cleared land. Perhaps give some rate of actions funded by public agencies under some scenarios?

The land use change model is based on the general problem structure illustrated in Figure 3.5.

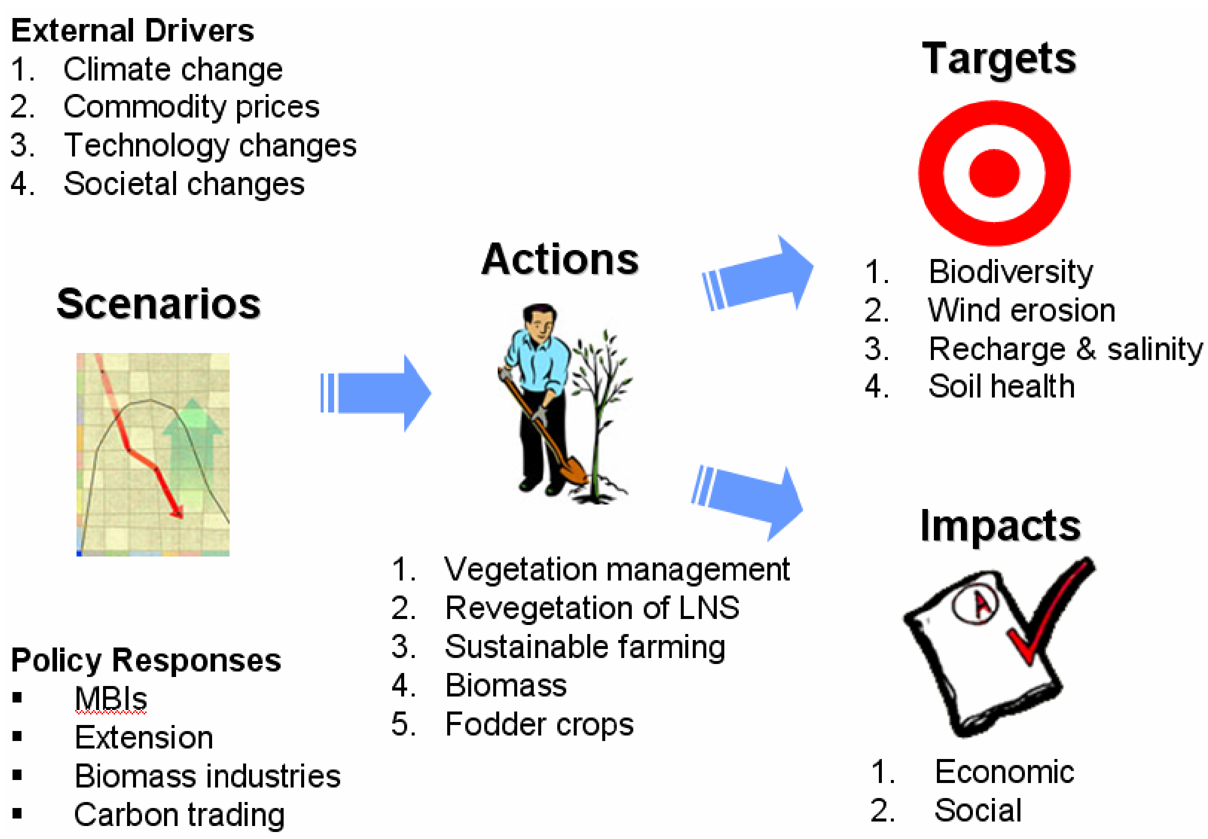

Figure 3.5. General problem structure where external drivers and policy institutions influence the level of uptake of natural resource management actions and land use change by landholders. The degree of achievement of NRM targets is then assessed and the social and economic impact of land use change is quantified.

Farmers are our fundamental decision makers and farms the decision making unit. Each farmer controls a number of grid cells in the farm. Grid cells may include areas of different ag landuse, veg, urban, waterbody etc. We are only interested in remnant vegetation and agricultural landuses. Vegetation can be grazed or ungrazed. We have no data on what areas are grazed. We need to make assumptions about this after talking to people about whether native vegetation is largely grazed or not in specific areas. As above, publicly owned vegetation can be assumed to be ungrazed.

The main ag. landuses are:

1. cereal/sheep
2. sheep grazing of cleared land
3. sheep grazing of native veg
4. Other broadacre crops (lucerne, canola, bean, peas etc.)

Once the above is quantified we then need to create our transition matrices. Potential future land uses or *actions* include:

1. Vegetation management
2. Revegetation of local native species for biodiversity
3. Sustainable farming
4. Agroforestry*
5. Fodder crops

* Agroforestry can be more than biomass. in the higher rainfall areas in the southern parts of the study area, forestry products of woodchip, timber, pulpwood etc. would almost certainly be more profitable and have more certain markets. We could use the results of Bennell et al. (2004) Florasearch to select the most profitable types of agroforestry!? Trevor Hobbs key contact here.

Each existing land use can be subjected to a specific subset of the actions above.

Cereal/Sheep -> 2, 3, 4, 5

Grazed cleared land -> 2, 3, 4, 5

Grazed remnant vegetation -> 1

The farmer decision engine will calculate which grid cells change land use at each iteration of the model. The decision of land use change at each cell will be based on marginal expected utility calculated using a multi-attribute utility function, where:

$$EU_{ij} = \sum_{k=1}^{n} f(w_k p_k u_k) \text{ for } i = 1, 2, ..., l, j = 1, 2, ..., m$$

where l = grid cells in farm

m = potential new land uses (vegetation management, revegetation,..)

n = attributes of utility

w = utility weighting weight for utility attribute k

p = probabilistic risk of utility attribute k

u = utility score of attribute k

Farmers have multiple (n) attributes of utility. First and foremost is the economic component. Existing land uses have an opportunity cost which needs to be quantified. Farmers then decide whether or not to change land use according to the marginal increase in EU resulting from change to one of the potential suite of possible new land uses. We can model this in one of 3 ways:

Deterministic, Utility Maximisation

In this simple model we assume that each farmer will change land use immediately and maximise their utility by selecting the land uses that offer gains in marginal expected utility over current land use. To calculate the marginal change in EU we first calculate the utility of the current land use of the cell. We then calculate the EU of all potential future land uses (m). To calculate the marginal change in EU resulting from changing to each potential future land use we subtract the utility of current land use from the EU of future land use. In a single GIS function (upos) we can select the land use that offers the greatest gain in marginal EU for all cells. This model is simple insofar as all inputs can be reduced to NPV and EAE figures thus avoiding the timestep problem.

Stochastic Land Use Change

We can specify a stochastic land use change condition to account for non-optimising behaviour commonly seen in the real world as landholders do not always behave the way economics predicts. We can do this by calculating probabilities of change based on EU. We calc the utility of current land use and the EUs of all potential future land uses and rescale such that the sum of utilities equals 1. Land use is then selected by calculating a random number. In this model the landholder is most likely to stay/change to land uses that offer the highest utilities but every so often may change to a low utility land use. This model can be run using a monte carlo framework to create frequency distributions and capture uncertainty. It also does not require time steps and can be done as a global function.

Temporal Agent-Based Model

This paradigm involves explicit use of a timestep iterative model. We might consider this because this kind of model is more extensible to transform into an agent-based model at a later date. The advantage of this kind of model is that we can incorporate temporal factors such as evolution of farmer knowledge, attitudes and behaviours resulting from policy changes, change in climate over time, price shocks, increased communication and networking, and farmers learning from their neighbours. We can also incorporate diminishing marginal returns in a temporal model that I cant think how to do in a global (single time step) model.

How might it work? At each timestep the farmer makes decision on what cells to change land use. There are questions about how to model **what** kind of land use changes occur. We can use methods described above. We could use a either a deterministic utility max algorithm or a stochastic algorithm. There are also unanswered questions about **when** farmers make land use changes. Note that this kind of model is not really a temporal model as such but more a heuristic model. It does not make sense to say that landholders change one hectare of land use per year.

Note that there are issues of how to model the economic components in a timestep model. Do we consider NPV? when and how? also changeover costs also apply which include the establishment costs and possibly opportunity costs of underutilised plant etc.

The utility function could incorporate aggregate measures such as the amount of land already under vegetation per farm, and use this to update the marginal utility of each cell. We could also use a greedy (richness) algorithm to select the cell (at timestep *t*) that complements most the existing landuses at timestep *t*-1 in terms of the utility function of the farmer.

3.5.2. Implementation

Step 1 – Quantify objective RCTs for the entire LMLF region i.e. manage 50% of each community type, revegetate 15% etc. Use existing targets as a foundation.

Step 2 – Undertake audit of existing data and estimate how existing targets contribute to natural resource management

Step 3 – Implement land use change model using newly quantified object RCTs from step 1.

3.6. The study area

The Lower Murray region of interest in this study is an area encompassing the South Australian Murray-Darling Basin INRM Region, and the Wimmera and Mallee Catchment Management Authorities (Figure 3.6). The dryland component of the Lower Murray Landscape Futures project excludes irrigated land uses and the River Murray floodplain from modelling, however these locations are considered in other parts of the this study, particularly in reference to remnant vegetation management and threat. The extent of the floodplain was derived from data from Ian Overton, CSIRO (unpublished data). The boundary has been constructed from a number of data sources including the 1956 flood boundary, on-ground data points, and the interpretation of vegetation using aerial photography. Irrigated areas were extracted from the 2003 snapshot land use mapping (Section 3.10.3).

The total area of the region is 11.87 million ha, and the total population is approximately 186,000. Table 3.25 lists the breakdown of area and population by each catchment. Population distribution of each catchment is clustered around the major urban centres and the River Murray corridor. The combined population of the major urban centres of Murray Bridge (13,000), Mt Barker (9,100) and Berri (4,200) is approximately one third of the SAMDB total (ABS, 2001). Similarly for the Victorian component of the study area, the population of Mildura (28,000) is nearly half the Mallee CMA total, and Horsham (13,200) and Stawell (6,100) contain nearly half of the Wimmera CMA total (ABS, 2001). Major land uses, tenure and biophysical features are discussed in Chapter 7.

Table 3.25. Catchment breakdown of area, land use and population totals for the Lower Murray study area.

		SAMDB[1]	Wimmera CMA[2]	Mallee CMA[3]	Total
Total Area	ha	5,601,800	2,343,900	3,925,600	11,871,300
	%	47.6	19.6	32.8	100
Irrigation	ha	102,284	10,779	74,512	187,575
	%	54.5	5.7	39.7	100
Vegetation	ha	3,045,810	450,373	1,789,740	5,285,923
	%	57.6	8.5	33.9	100
Floodplain	ha	110,266	0	120,566	230,832
	%	47.8	0.0	52.2	100
Population	Total	81,000	44,000	61,000	186,000
	%	43.5	23.7	32.8	100

[1]SA MDB CWMP
[2]Vic Wimmera RCS
[3]Vic Mallee RCS

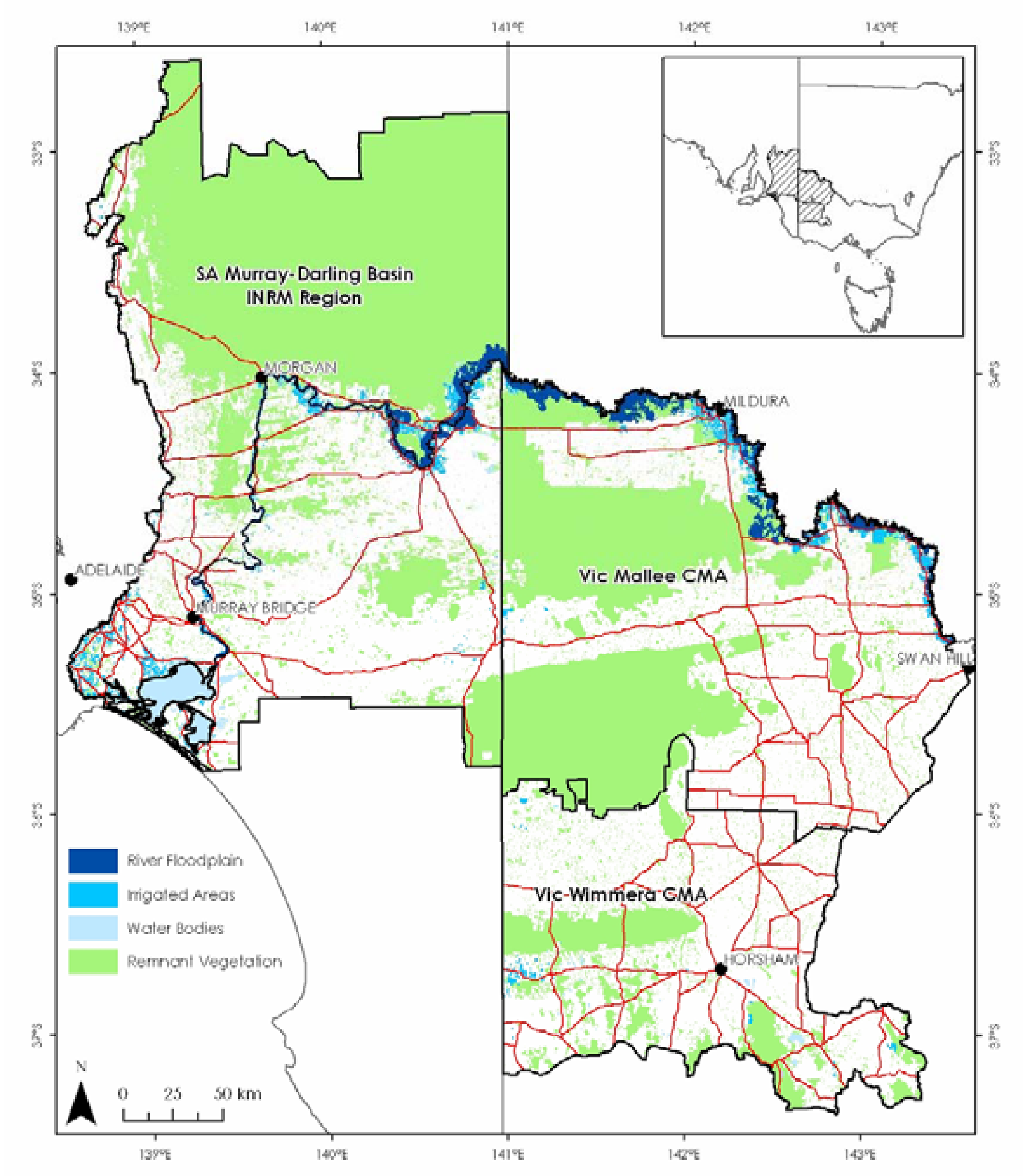

Figure 3.6. Study area of the Lower Murray Landscape Futures dryland component. Note that the blue areas are the River Murray floodplain and all land under irrigation. These areas are excluded from land use change modelling.

3.7. Spatial data

This chapter is divided into two components. The first and most lengthy section is an audit of relevant existing data required to meet existing NRM targets and a spatial quantification of natural resources. Many layers of data have been compiled and analysed for this project and a significant amount of modelling and data assembly are required for input into the SRP and individual-based land use change models. There have been several challenges in assembling data across state borders especially in relation to spatial accuracy, scale and attribute consistency. Some of these issues are discussed at the end of the chapter.

The second section of this chapter examines in more detail the distribution of natural resources of relevance to specific NRM targets and the areal extent of actions required to meet these targets.

3.7.1. Land tenure and use

Land use and tenure are derived from two sources. Land use for the LMLF is a dataset derived from the Australian Land Use and Management (ALUM) classification system version 5 (Commonwealth of Australia 2002). The ALUM classifications were mapped from a number of sources, namely fine-scale satellite imagery, vector-based cadastral databases from each state, other land use and cover databases and field data. In this study the land use database was built using 2001 data. Tenure was derived from cadastral and land management databases and is current as of mid 2005, the time of data supply.

Public and Private Land Management

It is necessary in this study to distinguish between land areas that are publically and privately managed. Public land is generally managed in a way that provides benefits for the community such as public amenity. Private land lmanagement is characterised by economic use such as agricultural production. Although there is no clear relationship between ownership and management style, land ownership and tenure data can be used to identify publically and privately managed land.

Land ownership and tenure data for the South Australian and Victorian components of the LMLF were derived from three sources: the fine-scale South Australian Digital Cadastral Database (DCDB) and the Victorian cadastral database VicMap Property, and a coarser scale Victorian database of public land management. The former datasets are the premier spatial layers of individual property distribution, title, ownership, tenure, and value.

In South Australia, tenure has been classified as freehold, crown lease or crown land. Freehold land is privately held and managed whilst crown land is publicly held and managed. Crown lease is publicly owned but is generally managed privately. Substantial checking and modification was made to the SA cadastral data to validate and correct the land tenure classification.

The Victorian land management database dichotomises land parcels into either freehold or publicly owned land, with the latter attribute subdivided into more detailed public management types. The public/private split is sufficient for the current purpose of presenting tenure in the LMLF region. To maintain consistent levels of boundary accuracy between the states, the Victorian land management database was spatially joined to that State's cadastre and the individual land parcels were allocated a private/public attribute.

Areal and proportional extent of each tenure type is listed in Table 3.26. Considerably larger proportions of the Victorian CMAs are under public tenure than in the SAMDB. In particular, 43% of the Mallee CMA is under public management.

Further detailed discussion of public tenure is found in section 0 through analysis of extent of remnant vegetation protection.

Table 3.26. Catchment breakdown of the areal and proportional extent of each tenure type within the Lower Murray study area.

	SAMDB		Wimmera CMA		Mallee CMA		Total	
	Area (km2)	%	Area (km2)	%	Area (km2)	%	Area (km2)	%
Freehold	50,011.8	89.3	19,626.2	83.8	22,369.7	57.0	92,007.7	77.5
Public land	5,981.9	10.7	3,804.5	16.2	16,876.3	43.0	26,662.7	22.5

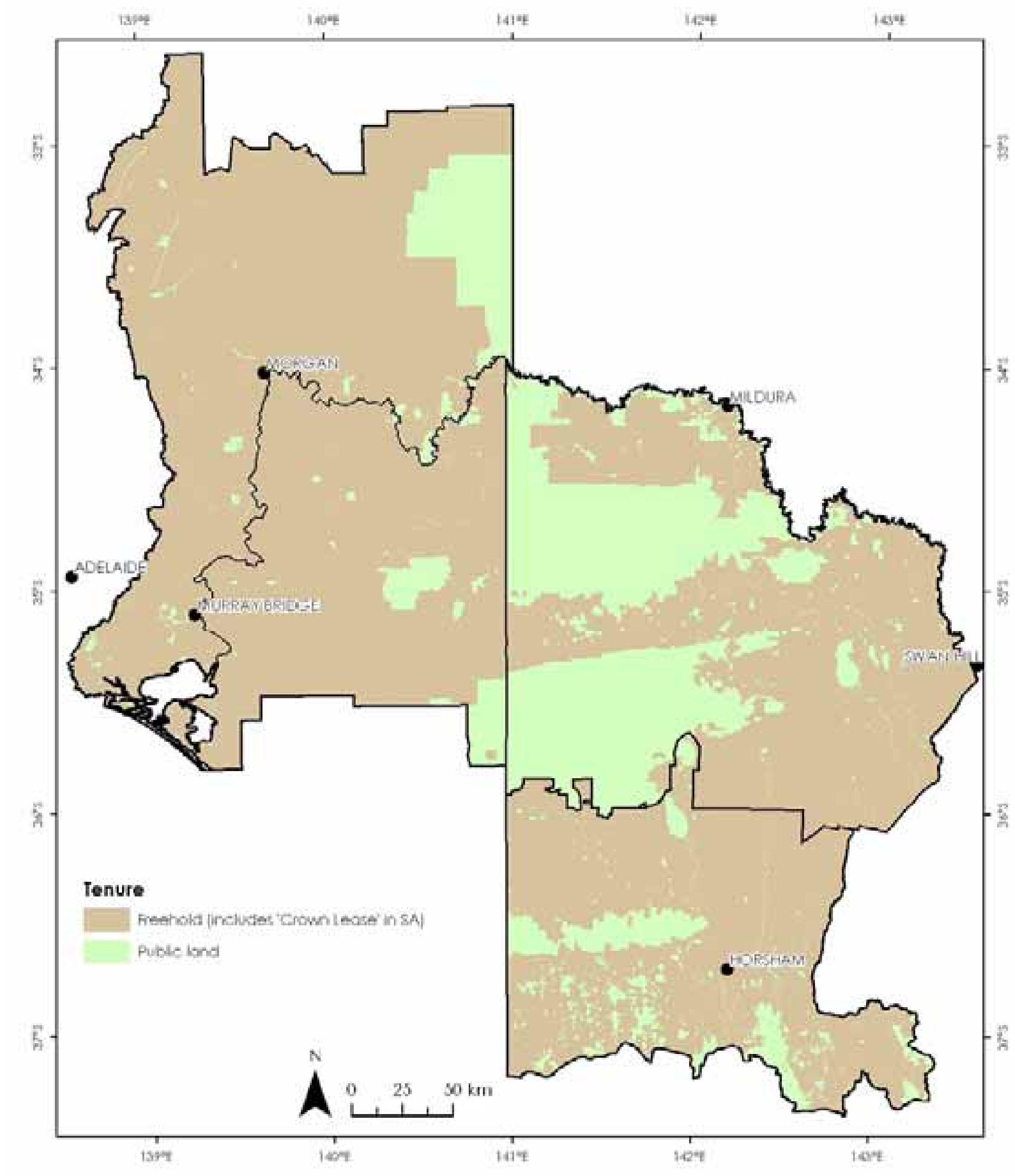

Figure 3.7. Land tenure and management in the LMLF study area.

Land Use

Land use in the Lower Murray is dominated by a handful of types. Figure 3.8 presents the spatial distribution of the main land uses in the region. Visually it is clear that the major intensive land uses are dryland cropping and grazing of modified pastures and native vegetation. Forestry is a significant land use, particularly in Victoria. However, much of this forestry is native vegetation under the stewardship of public forestry agencies. Land set aside for conservation and recreation is also dominant in the region. Irrigation, while not spatially extensive, is a significant land use along the River Murray, with other pockets of irrigated lands in the far southwest of the SAMDB and in the central western Wimmera CMA.

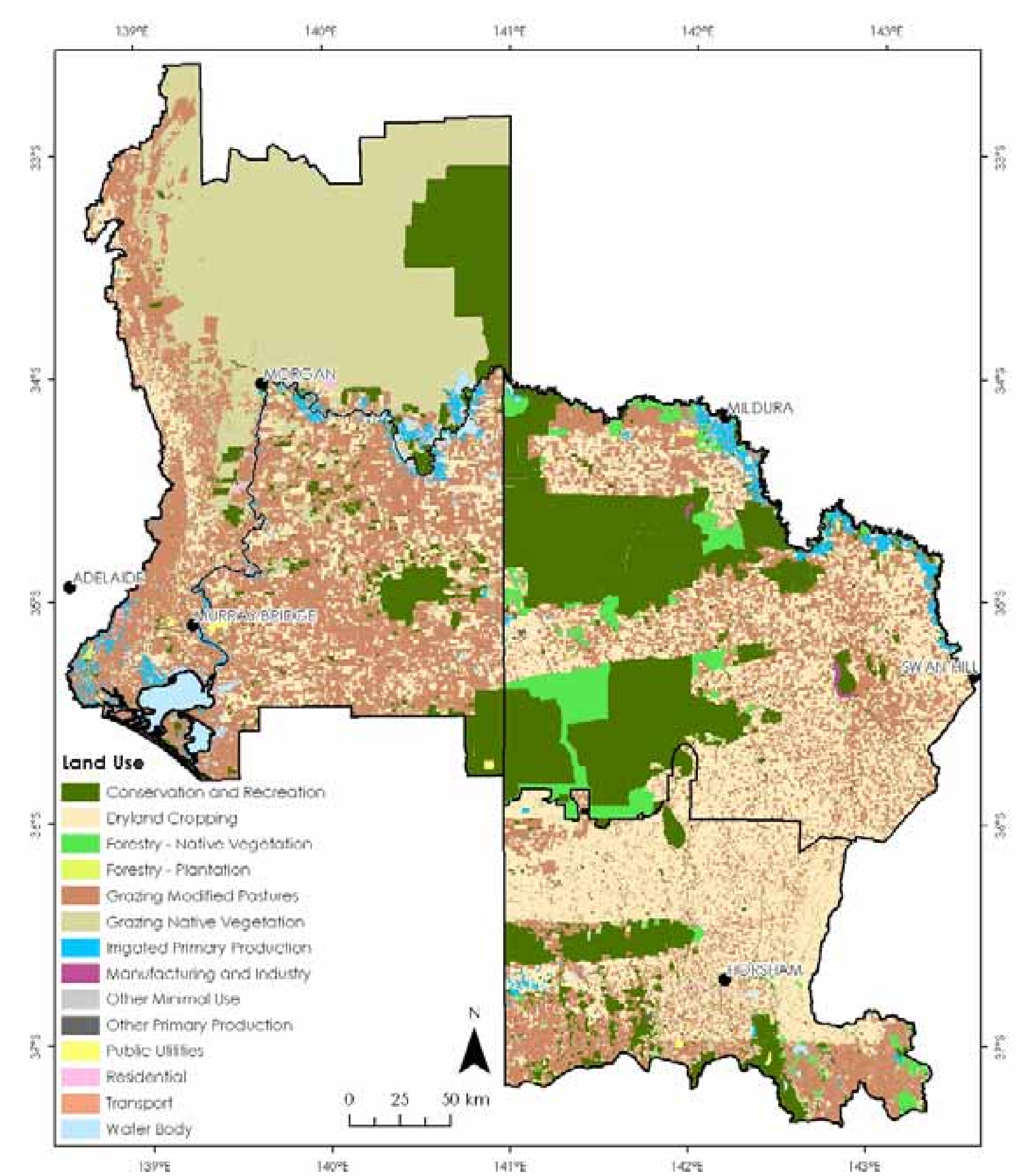

Figure 3.8. Dominant land uses in the LMLF study area.

Total area and proportions of each major land use type, and catchment breakdowns are listed in Table 3.27. Land under some form of protection for conservation accounts for nearly 20% of the study area. Over half of this land is in the Mallee CMA. Grazing of native vegetation, i.e. native vegetation under private tenure, also accounts for nearly 20% of the region. The bulk of this is in the north-western part of the study area. This land is predominantly nutrient-poor chenopod shrubland and open woodland leased from the Crown. Native vegetation grazed in the Mallee and Wimmera CMAs is made up of small remnant patches outside of formal protection.

Dryland cropping and grazing of modified pastures covers over 50%, with an approximately even split between the two land uses. On a catchment basis, nearly 80% of all dryland cropping in the Lower Murray study area occurs within the Victorian CMAs, even though the two areas account for just over 50% of the land mass. Grazing of modified pastures is more evenly distributed across the study area, with 55% of this land use occurring in the SAMDB. It is important to realise however, that the dryland cropping/grazing land use breakdown represents a single snapshot in time. In reality landowners switch between the two, making dryland cropping and grazing a dynamic land use. Section ?? explores this in more detail in an attempt to allocate probabilities of cropping and grazing in any particular year based on their geographic spread at the time of mapping (2001).

Table 3.27. Catchment breakdown of dominant land use area for the Lower Murray.

Land Use	**Area (ha)**				**% Total**
	SAMDB	**Mallee**	**Wimmera**	**Total**	**Study Area**
Conservation and Recreation	*668,281*	*1,335,307*	*350,035*	*2,353,623*	*19.8*
Habitat/species management area	0	0	4,022	4,022	0.0
Lake - conservation	0	19,448	26,593	46,041	0.4
Landscape	0	4	32	36	0.0
Managed resource protection	5,155	0	4,600	9,755	0.1
Marsh/wetland - conservation	0	21	1,135	1,156	0.0
National park	55	538,718	193,570	732,343	6.2
Natural feature protection	1	111,629	26,776	138,406	1.2
Nature conservation	647,428	1,641	0	649,069	5.5
Other conserved area	0	9,359	43,910	53,269	0.4
Protected landscape	0	0	194	194	0.0
Recreation and culture	0	3,628	3,785	7,413	0.1
Rehabilitation	2,917	394	103	3,414	0.0
Remnant native cover	12,113	8,986	30,658	51,757	0.4
Strict nature reserves	0	36,285	14,334	50,619	0.4
Wilderness area	612	605,194	323	606,129	5.1
Dryland Cropping	*638,831*	*1,222,986*	*1,143,789*	*3,005,606*	*25.3*
Cropping	638,831	1,219,195	1,117,698	2,975,724	25.1
Oil seeds	0	892	19,179	20,071	0.2
Oil seeds & oleaginous fruit	0	2,899	6,912	9,811	0.1
Forestry - Plantation	*3,080*	*1,048*	*2,687*	*6,815*	*0.1*

Land Use	Area (ha)				% Total Study Area
	SAMDB	Mallee	Wimmera	Total	
Hardwood plantation	0	0	1,352	1,352	0.0
Other forest production	0	333	0	333	0.0
Plantation forestry	3,080	715	996	4,791	0.0
Softwood plantation	0	0	339	339	0.0
Forestry - Native Vegetation	*72*	*296,947*	*42,547*	*339,566*	*2.9*
Production forestry	72	296,947	42,547	339,566	2.9
Grazing Modified Pastures	*1,850,469*	*851,000*	*610,447*	*3,311,916*	*27.9*
Grazing modified pastures	1,850,469	851,000	610,447	3,311,916	27.9
Grazing Native Vegetation	*2,110,038*	*20,356*	*76,411*	*2,206,805*	*18.6*
Grazing natural vegetation	2,110,038	0	31,554	2,141,592	18.0
Livestock grazing	0	20,356	44,857	65,213	0.5
Irrigated Primary Production	*102,104*	*74,608*	*10,794*	*187,506*	*1.6*
Horticulture infrastructure	0	7,915	0	7,915	0.1
Irrigated cropping	5,161	10,035	0	15,196	0.1
Irrigated flowers & bulbs	0	2	0	2	0.0
Irrigated hay & silage	0	9	0	9	0.0
Irrigated land in transition	0	28	0	28	0.0
Irrigated legume/grass mixtures	0	76	0	76	0.0
Irrigated modified pastures	32,844	454	187	33,485	0.3
Irrigated oleaginous fruits	0	699	0	699	0.0
Irrigated perennial horticulture	56,326	604	97	57,027	0.5
Irrigated plantation forestry	147	123	0	270	0.0
Irrigated seasonal horticulture	7,624	2	7,184	14,810	0.1
Irrigated tree fruits	0	9,152	1,700	10,852	0.1
Irrigated tree nuts	0	5,107	0	5,107	0.0
Irrigated vegetables & herbs	0	12,523	0	12,523	0.1
Irrigated vine fruits	0	26,672	1,626	28,298	0.2
Land in transition	0	1,207	0	1,207	0.0
Manufacturing and Industry	*2,104*	*10,304*	*2,350*	*14,758*	*0.1*
Commercial services	0	331	476	807	0.0
Manufacturing and industrial	505	1,321	705	2,531	0.0
Mining	1,599	2,548	424	4,571	0.0
Quarries	0	6,104	745	6,849	0.1
Other Minimal Use	*44,025*	*198*	*4,551*	*48,774*	*0.4*
Other minimal use	44,025	198	4,551	48,774	0.4
Other Primary Production	*1,333*	*1,398*	*947*	*3,678*	*0.0*
Intensive animal production	997	19	728	1,744	0.0
Intensive horticulture	214	0	0	214	0.0

Land Use	Area (ha)				% Total
	SAMDB	Mallee	Wimmera	Total	Study Area
Marsh/wetland - production	0	173	0	173	0.0
Perennial horticulture	122	0	0	122	0.0
Pigs	0	407	32	439	0.0
Poultry	0	799	187	986	0.0
Public Utilities	*13,098*	*7,211*	*6,614*	*26,923*	*0.2*
Defence	4,669	0	0	4,669	0.0
Electricity generation/transmission	0	15	12	27	0.0
Gas treatment, storage and transmission	0	0	1	1	0.0
Public services	0	1,832	1,254	3,086	0.0
Research facilities	0	0	23	23	0.0
Services	7,960	0	36	7,996	0.1
Sewage	0	562	251	813	0.0
Supply channel/aqueduct	16	1,913	1,903	3,832	0.0
Surface water supply	0	0	32	32	0.0
Utilities	89	2,655	125	2,869	0.0
Waste treatment and disposal	364	155	139	658	0.0
Water storage and treatment	0	79	2,838	2,917	0.0
Residential	*24,382*	*5,293*	*13,276*	*42,951*	*0.4*
Residential	24,382	40	32	24,454	0.2
Rural residential	0	1,961	9,705	11,666	0.1
Urban residential	0	3,292	3,539	6,831	0.1
Transport	*73,204*	*89,716*	*66,464*	*229,384*	*1.9*
Airports/aerodromes	0	697	344	1,041	0.0
Navigation and communication	0	19	0	19	0.0
Railways	0	4,913	2,076	6,989	0.1
Roads	1,024	84,084	64,009	149,117	1.3
Transport and communication	72,180	3	35	72,218	0.6
Water Bodies	*70,198*	*7,442*	*9,952*	*87,592*	*0.7*
Lake	4,108	4,965	9,428	18,501	0.2
Marsh/wetland	47,491	1,462	78	49,031	0.4
Reservoir	1,339	205	174	1,718	0.0
River	17,261	810	272	18,343	0.2

Farming Systems

Agriculture is the dominant land use in the Lower Murray study area and the distribution of different types of farming systems fundamentally drives the regional economy and impacts upon biophysical systems. The nature and distribution of farming systems is a key data input into various aspects of landscape futures modelling in this study including the quantification of opportunity costs of foregone production, and the impacts of land use on remnant ecosystems, dryland and river salinity, and wind erosion.

Farming systems in the Lower Murray vary greatly according to both environmental conditions such as climate and soils, but also socio-economic factors such as tradition, beliefs and attitudes. To quantify the distribution of farming systems we need to simplify the many different farming systems occurring in the Lower Murray region. Farming systems are classified according to land use type (cropping/grazing) and crop rooting depth.

Generally, farming systems in the Lower Murray involve some sort of cropping/grazing rotation ranging between continuous cropping right through to continuous livestock grazing. Cropping can involve crops of either medium or shallow rooting depth. Shallow rooted crops are legumes and include the ABS Level 3 commodity classes of chick peas, faba beans, field peas, lentils, lupins, mung beans, soybeans, vetches. Medium rooted crops are cereals and oilseeds (barley, oats, cereal rye, buckwheat, triticale, and wheat). The distinction is made because rooting depth of crops has an important influence on natural resource management outcomes, especially salinity. The grazing farming system is characterised by shallow rooted annual species grazed largely by sheep, but some beef cattle also occur in the SA MDB (Bryan and Marvanek 2004). Note that substantial areas of native vegetation are also grazed in the Lower Murray. For pragmatic reasons we consider that to be a vegetation management issue rather than a farming system.

Agricultural land management is dynamic and land use typically changes regularly from year to year depending on the type of rotation employed (Bryan and Marvanek 2004). As a result it makes little sense to map the distribution of grazing and cropping land uses using a snapshot database captured in a single year as land use in subsequent years is likely to change. Instead, we quantify the distribution of farming systems as a set of probabilities of occurrence of grazing, medium rooted, and shallow rooted crops that change continuously across the study area.

Quantifying the distribution of farming systems involved two steps. Firstly, the probabilities of grazing versus cropping were quantified. Secondly, the cropping probability was split up into the medium rooted and shallow rooted components.

To quantify the probabilities of grazing versus cropping for dryland agricultural areas of the Lower Murray, smooth surfaces characterising the density of cropping and grazing land uses within a neighbourhood were created. A moving window kernel density function was used to calculate the density surfaces based on the catchment scale land use mapping which broadly distinguishes grazing from cropping land use (see Section X). This technique calculates for each 1 ha grid cell the density per unit of area of cropping and grazing land uses within a specified radius (30 km) of the cell. The influence of areas of cropping/grazing in the neighbourhood of each cell is weighted using a smoothly curved quadratic kernel function (Silverman 1986, p. 76, equation 4.5) based on the distance from the cell. The influence is highest where areas of cropping/grazing are coincident with the grid cell and diminishes with increasing distance away, reaching 0 at the radius distance. The probability of grazing was then calculated for each grid cell by dividing the density of grazing by the density of grazing plus the density of cropping. The probability of cropping was calculated as one minus the probability of grazing:

$$p_g = d_g + d_c$$

and,

$$p_c = 1 - p_g$$

Where:

p_g = probability of grazing

p_c = probability of cropping

d_g = density of grazing

d_c = density of cropping

Decomposing the probability of medium rooted versus shallow rooted crops was done in a similar way agricultural production mapping by Bryan and Marvanek (2004). The Bryan and Marvanek (2004) data is of a coarser spatial resolution than the catchment scale land use mapping but captures a higher level of detail in mapping individual agricultural commodities which makes it suitable for distinguishing between crop types. Density surfaces for both medium rooted and shallow rooted crops were calculated based on the Bryan and Marvanek (2004) agricultural commodity mapping using a 100 km radius to cover differences in the focus areas of the 2 studies in the south western Wimmera. The ratio of medium rooted to shallow rooted crops was calculated using the density surfaces. The probability of medium rooted crops was calculated for each cell by multiplying the probability of cropping calculated earlier by the ratio of medium to shallow rooted crops:

$$p_{cm} = \frac{d_{cm}}{d_{cs}} \times p_c$$

and,

$$p_{cs} = p_c - p_{cm}$$

Where:

p_{cm} = probability of medium rooted cropping

p_{cs} = probability of shallow rooted cropping

d_{cm} = density of medium rooted cropping

d_{cs} = density of shallow rooted cropping

The result of this modelling is three grids displaying the probability of grazing, medium rooted, and shallow rooted crops (Figure 3.9). The three probabilities sum to one for each grid cell. Together these three grids quantify the likely farming systems operating in the Lower Murray according to the probability that these land uses occur in any given year. For example if a grid cell has a probability of grazing of 0.2, a probability of medium rooted crops of 0.6 and a probability of shallow rooted crops of 0.2 then we can estimate that on average the cell will be under medium rooted crops for 6 years in 10, shallow rooted crops for 2 years in 10, sheep grazing for 2 years in 10. The moving window approach is able to typify the nature of farming systems by quantifying the relative densities of different agricultural land uses in the local neighbourhood using snapshot data for a single year.

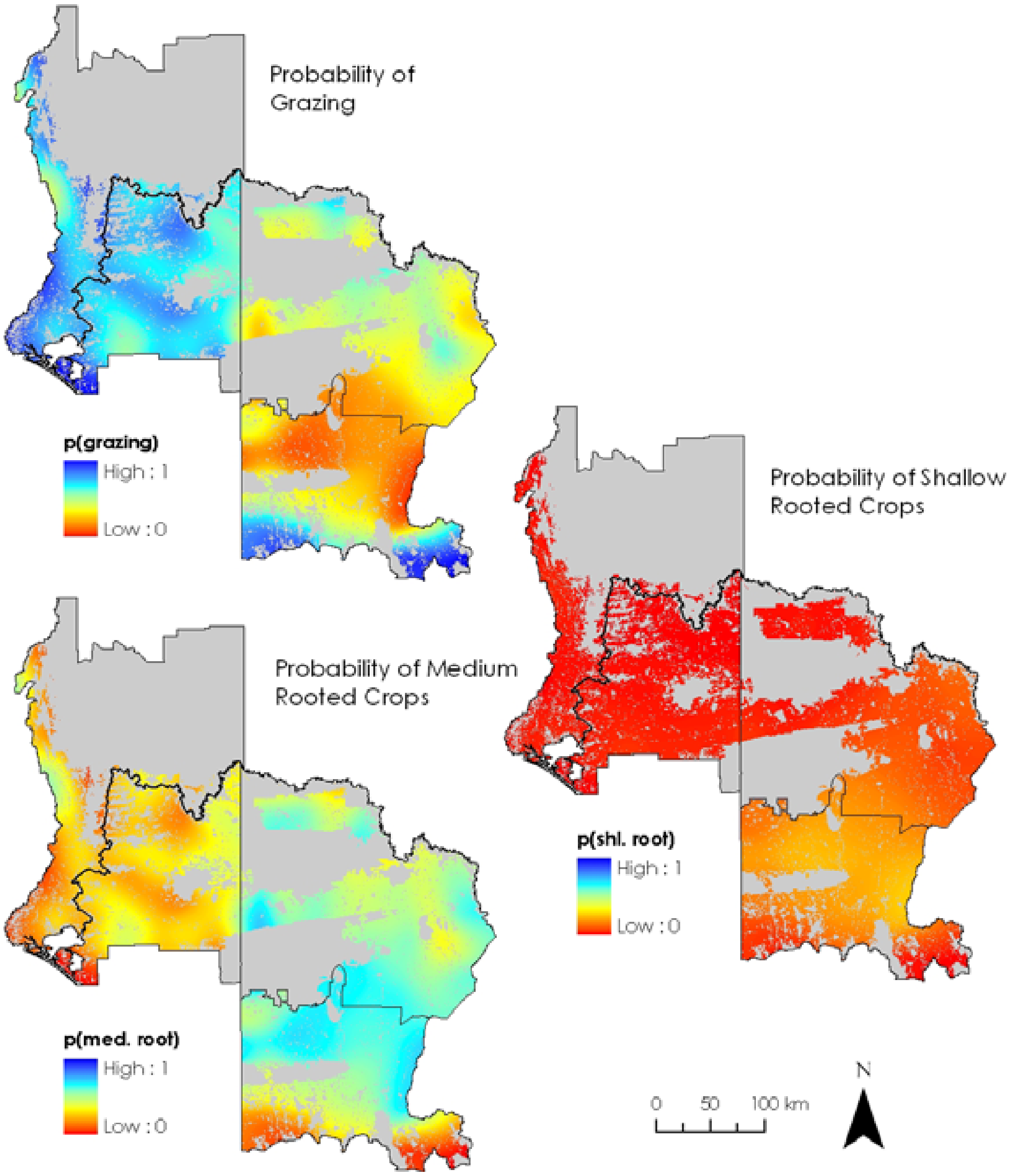

Figure 3.9. Derived surfaces showing probability of grazing, shallow rooted crops and medium rooted crops across the Lower Murray study area.

Opportunity cost

The opportunity costs of foregone agricultural production were estimated by integrating the farming system probability layers with the *profit at full equity* (PFE) surface developed by Bryan and Marvanek (2004) for the year 2001. In effect, the opportunity cost is calculated as a measure of expected return as it involves multiplying the likelihood of a land use occurring by the returns from the land use and is a reasonable indicator of the annual average profit at full equity from the farming system.

Calculating opportunity costs involves first estimating the profit at full equity for livestock grazing, medium rooted crops, and shallow rooted crops for all dryland agricultural areas. This was done by calculating for each grid cell the average PFE of all areas within an 80 km radius mapped as grazing by Bryan and Marvanek (2004) using a focalmean function. The same was done for medium and shallow rooted crops. In this way, surfaces of the average local PFE within for each of the three land uses were created.

To calculate the expected returns from agriculture the entire farming system was considered as described by the probabilities of occurrence of grazing, medium rooted and shallow rooted crops (see Section 3.10.4). For each cell the expected returns equals the sum of the probability of occurrence of each agricultural land use multiplied by the PFE from the land use.

$$c_o = p_g PFE_g + p_{cm} PFE_{cm} + p_{cs} PFE_{cs}$$

where:

c_o = opportunity cost of foregone agricultural production

PFE_g = Profit at full equity of grazing

PFE_g = Profit at full equity of grazing

PFE_g = Profit at full equity of grazing

Opportunity costs of foregone agricultural production vary from -6 $/ha to 280 $/ha in the Lower Murray study area. Opportunity costs are generally higher in the Victorian Mallee CMA than in the SAMDB and higher again in cropping areas of the Wimmera CMA (Figure 3.10) due to the more productive agricultural land in this area.

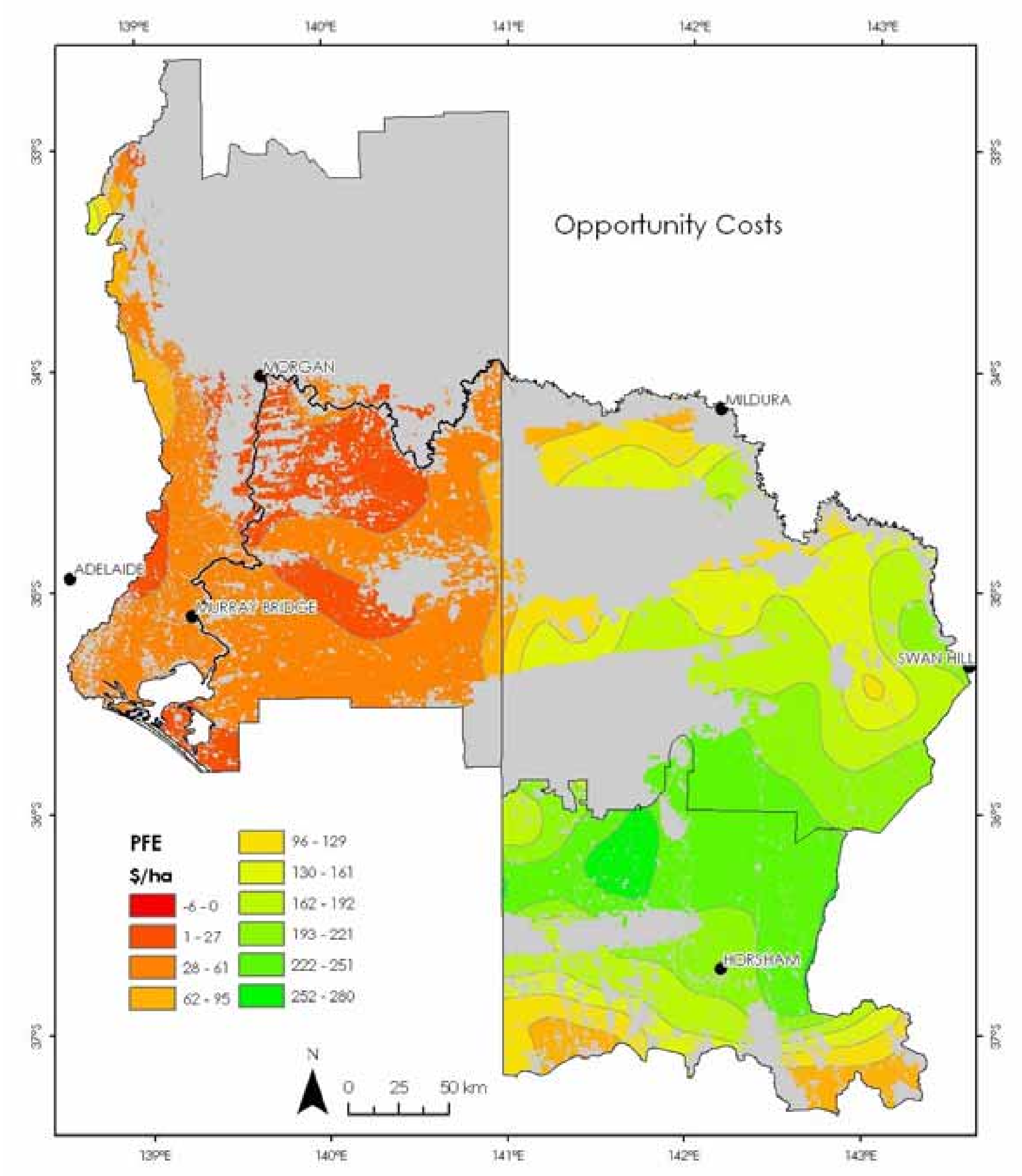

Figure 3.10. Opportunity cost of foregone agricultural production calculated as expected returns from the farming system.

Farms

The fundamental decision making unit of the agent-based model in this study is the farm property. Individual farmers are charged with the land use and management decisions and these decisions are applied over the geographical area of farm properties.

Farms were identified using the SA cadastral database (DCDB) and the VicMap Property database. Properties were identified by aggregating land parcels belonging to the same land title reference in SA. For Victoria, land parcels belonging to the same land title were already aggregated in the VicMap Property GIS database. Farms were identified by overlaying the properties data with areas mapped as dryland agriculture in the land use layer.

There are over 142,000 individual property titles in the Lower Murray region. The number of individual privately owned and managed properties identified in non-floodplain, non-irrigated areas engaged in dryland cropping, grazing and grazing native vegetation is 31,977. Farm properties identified in the GIS range in size from 1 ha to 236,000 ha (Figure 3.11). The spatial distribution of dryland farming properties is presented in Figure 3.12.

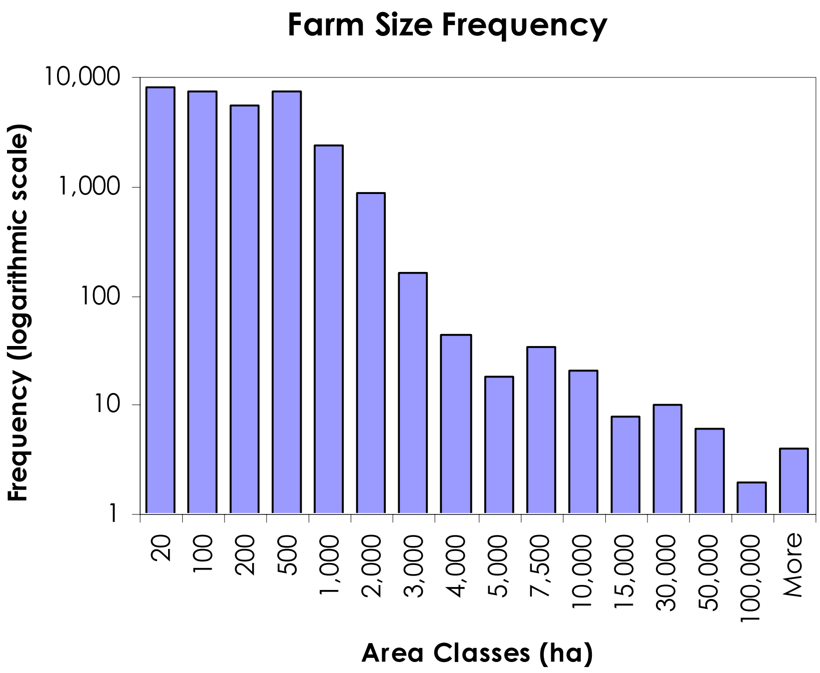

Figure 3.11. Histogram of farm size frequency in the Lower Murray.

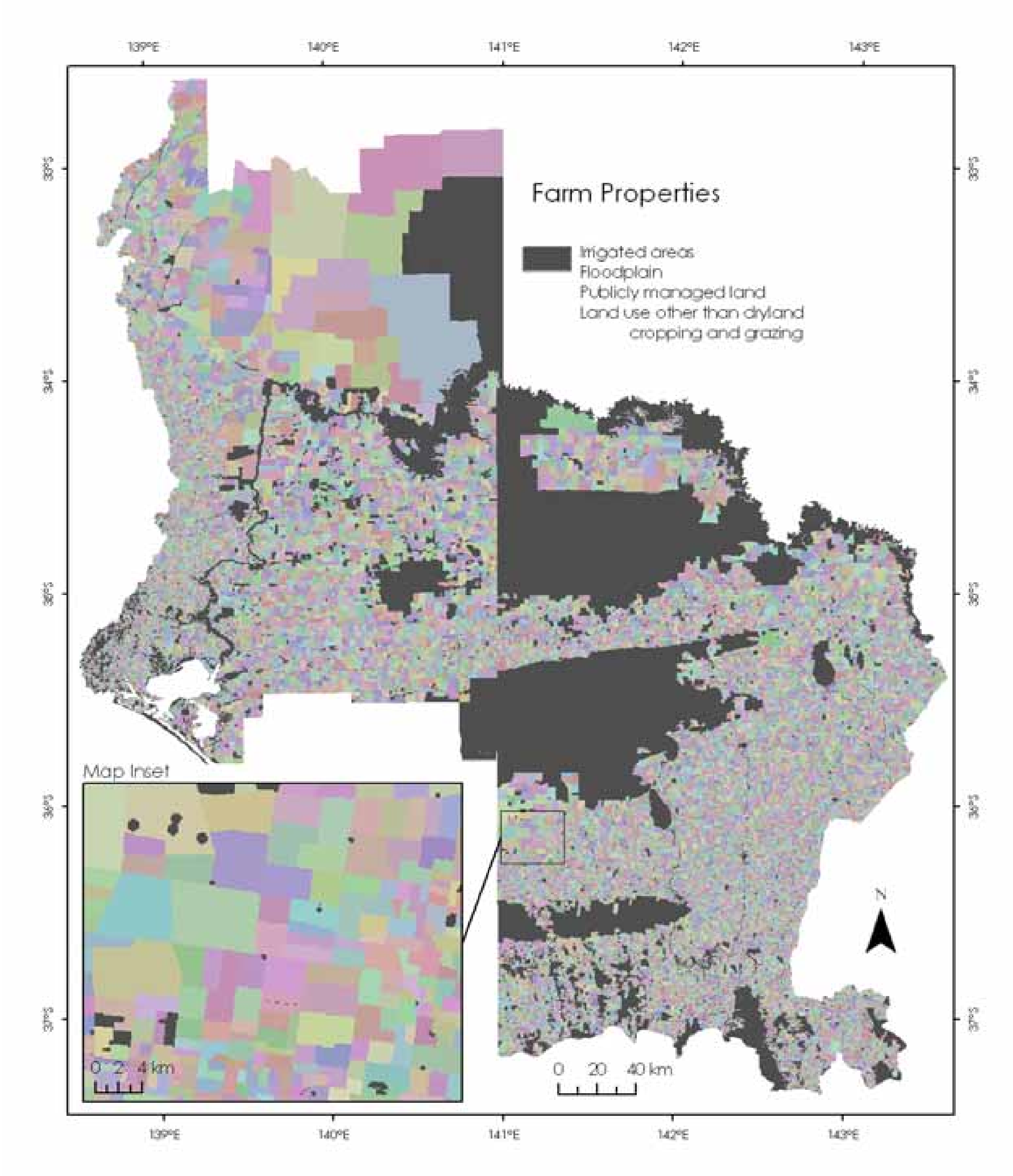

Figure 3.12. Individual dryland farming properties in the Lower Murray.

3.7.2. Biophysical attributes

Topography

Topography (Figure 3.13) of the Lower Murray study area is for the large part flat to gently undulating, with 90% of the region below 200m in elevation. Approximately

60% of the region is below 100m above sea level. The highest elevations are found in the south-eastern corner of the study area (the Grampians) and along the western fringe (Mt Lofty Ranges). Elevations extend above 1,000m in several locations in the Grampians, while in the Mt Lofty Ranges, maximums are in the 700-800m range.

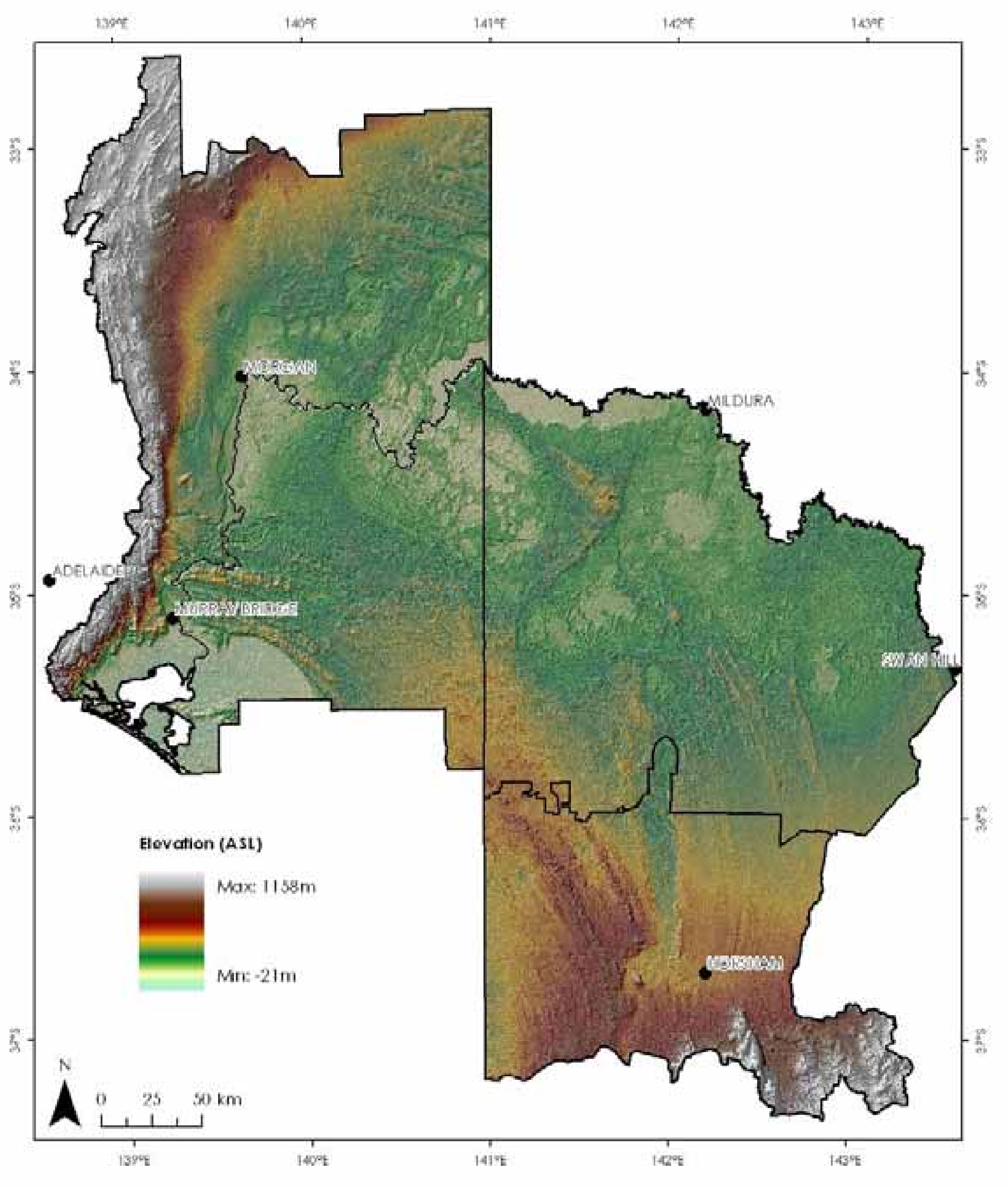

Figure 3.13. Topography of the study area.

Climate

Climate has a strong influence on the distribution of both biodiversity and agricultural production over regional scales. Climatic attributes such as rainfall and temperature have long been used as surrogates for characterising the distribution of biodiversity (Nix 1986) and are known to fundamentally affect crop yield and livestock vigour. Climate zones are characterised in this study for input into both the biodiversity and agricultural production analyses. With regard to biodiversity, climate is used to prioritise actions for conservation in climate zones that have been disproportionately cleared for agriculture. In addition, we can ensure that a certain proportion of each zone is protected and/or revegetated to represent the range of potential biodiversity occurring across zones. With regard to agricultural production, different model runs of the APSIM agricultural production simulator are conducted for each climate zone to capture climatically-driven differences in agricultural production.

Climate zones were created for the Lower Murray study area using a multivariate cluster analysis and maximum likelihood classification of three climatic variables on two scales. A very broad classification was created for use in modelling agricultural production using APSIM. For biodiversity, a finer classification was required that captures climatic patterns within the Lower Murray region that may influence the distribution of biodiversity on a broad scale. BIOCLIM (Busby 1991) was used to create surfaces characterising the spatial distribution of mean annual precipitation, mean annual temperature, and an annual moisture index (precipitation minus evapotranspiration). BIOCLIM interpolates point-based climatic data based on a topographic surface to create the data layers (Busby 1991). In this study, the Geoscience Australia 9 arc second Digital Elevation Model was used as the basis for BIOCLIM interpolation.

All of the climate surfaces display a strong relationship with latitude with the hotter, dryer climates occurring in the north (SA MDB and Mallee) grading through cooler, wetter climates to the southern Wimmera (Figure 3.14). There is some topographic attenuation of climate with the higher elevations in the southern Wimmera and the Mt. Lofty and southern Flinders Ranges in SA displaying cooler, moister climates. Mean annual temperature ranges from 7.9 to 17.4 $^{\circ}$C in the Lower Murray (Figure 3.14). Mean annual rainfall ranges from 200 mm/yr in the north of the SA MDB to 1,400 mm/yr in the southern Wimmera. Annual Moisture Index follows a similar geographic pattern.

A 16-class classification was selected as a reasonable climatic classification for biodiversity modelling using an iterative process of cluster analysis and inspection along the lines of Bryan (2006). An iterative k-means classification (ISOcluster) technique was used to identify clusters in the multivariate climate data (Figure 3.12) and a maximum likelihood classification algorithm was used to assign all cells to the nearest climate class. The 16-class classification was further generalised to a four class classification for use in agricultural production simulation in APSIM. Statistics of the classifications are described in Table 3.28 and presented graphically in Figure 3.16 and Figure 3.17.

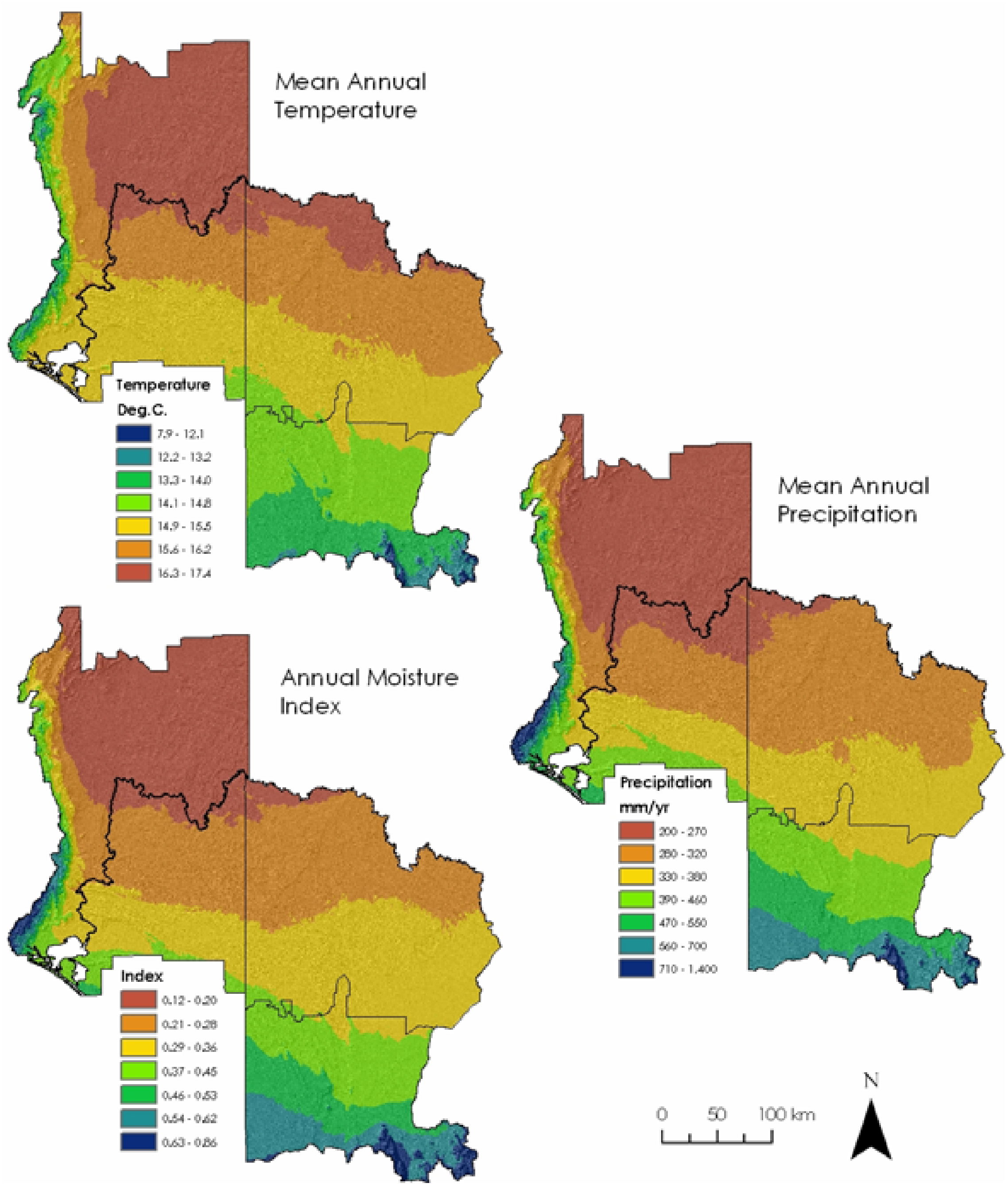

Figure 3.14. Climate layers modelled using BIOCLIM including mean annual temperature, mean annual precipitation, and annual moisture index

Table 3.28. Climate classification summary.

Class	Area (sq. km)	Temp (Mean)	Temp (StD)	Prec (Mean)	Prec (StD)	AMI (Mean)	AMI (StD)
4-class Climate Classification							
1	37,804	16.44	0.36	249.87	23.10	0.18	0.03
2	43,493	15.51	0.41	317.35	21.27	0.29	0.03
3	25,914	14.59	0.42	403.01	37.85	0.39	0.04
4	11,502	13.47	0.62	592.99	94.57	0.57	0.06
16-class Climate Classification							
1	10,995	16.20	0.18	273.20	10.36	0.22	0.01
2	2,029	14.49	0.42	304.17	35.35	0.24	0.04
3	3,861	15.89	0.34	229.53	15.73	0.16	0.02
4	11,032	16.82	0.20	227.02	12.93	0.15	0.01
5	10,439	16.56	0.15	251.16	8.88	0.18	0.01
6	10,252	15.71	0.16	290.81	9.60	0.25	0.01
7	9,396	16.05	0.15	310.92	7.84	0.27	0.01
8	10,988	15.48	0.20	320.44	9.06	0.29	0.01
9	13,510	15.19	0.17	343.31	10.83	0.32	0.01
10	9,900	14.90	0.19	370.93	15.82	0.35	0.01
11	6,970	14.38	0.23	400.30	15.41	0.40	0.02
12	6,040	14.08	0.24	454.01	21.51	0.45	0.02
13	2,119	14.97	0.14	450.17	28.72	0.42	0.03
14	5,671	13.75	0.21	532.31	24.74	0.54	0.02
15	3,942	13.36	0.34	610.01	32.57	0.60	0.02
16	1,570	12.53	0.96	787.30	84.92	0.67	0.04

```
C   DISTANCE
L
A
S  0        2.1      4.3      6.4      8.5     10.7     12.8     15.0     17.1     19.2
S  |--------|--------|--------|--------|--------|--------|--------|--------|--------|

 10 --------------|
                  |--------------|
  9 --------------|              |
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  8 ---------------|             |-----------------------|
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  7 ---------------||-----|      |                       |
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  5 ----------------|                                    |                          |
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  1 ------------------------|                                                       |
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 12 -----------------|                                                              |
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 11 -----------------|--------------------|                                         |
                     |                    |                                         |
 13 -----------------|                    |                                         |
                                          |-----------------------------------------|
 15 -----------------|                    |
                     |-------|            |
 14 -----------------|       |------------|
                             |
 16 -------------------------|

   |--------|--------|--------|--------|--------|--------|--------|--------|--------|
   0        2.1      4.3      6.4      8.5     10.7     12.8     15.0     17.1     19.2
```

Figure 3.15. Dendrogram of climate classifications

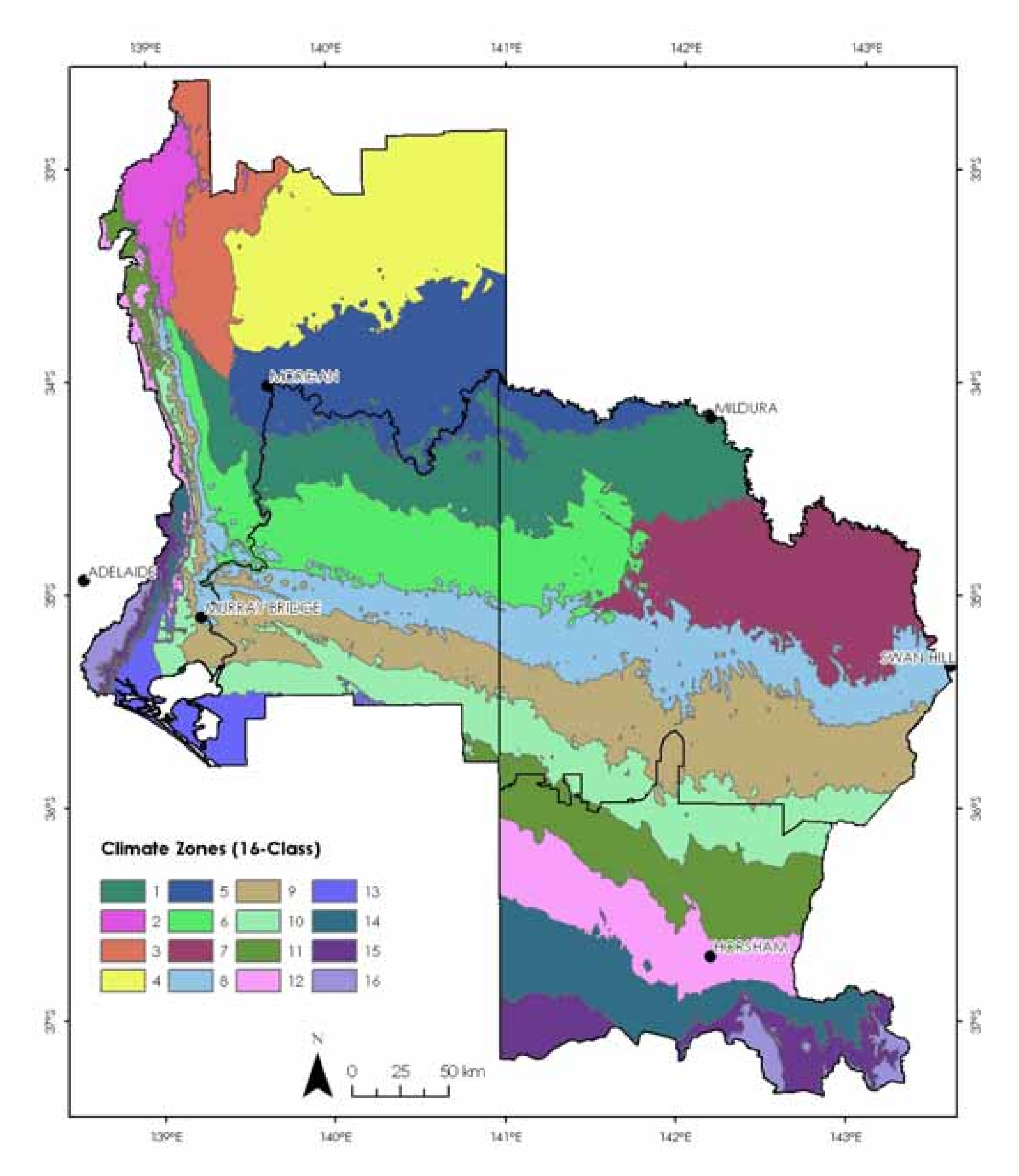

Figure 3.16. 16-Class climate zones within the Lower Murray study area.

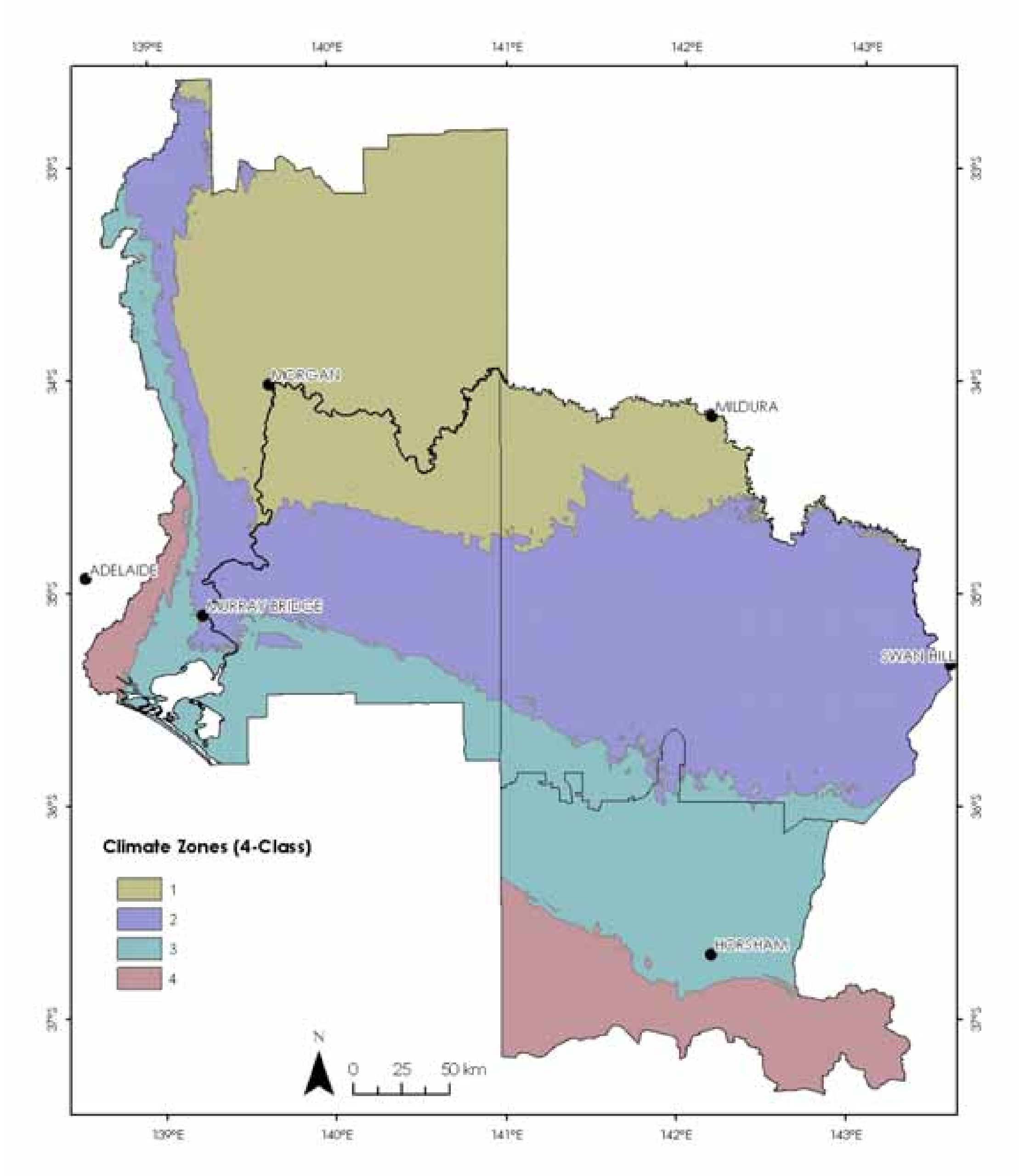

Figure 3.17. 4-Class climate zones in the Lower Murray study area. This layer was generalised from the 16-Class climate zone layer in Figure 3.16.

Remnant Vegetation

Remnant vegetation in the Lower Murray study area contains considerable variation in how it was mapped. Vegetation mapping in Victoria is very spatially detailed and attributes are associated to EVCs (Ecological Vegetation Classes). For example, many narrow roadside corridors and small clumps and/or singular paddock trees have been mapped. Consequently, over 208,000 polygons of vegetation cover are present in the Mallee/Wimmera CMAs. An EVC is a type of vegetation classification that is described through a combination of its floristic, life form, and ecological characteristics, and through an inferred fidelity to particular environmental attributes. The full list of EVCs and associated areal distribution in the study area is listed in Appendix 3. Vegetation mapping in South Australia is coarser in a spatial sense, however it contains detailed data attributes. Only 31,000 polygons of vegetation are present in the SA MDB. The unit of mapping is the SA Vegetation Class, a unit of vegetation community that describes the dominant overstorey and understorey flora as well as the community structure. The full list of SA Vegetation Classes and associated areal distribution in the study area is listed in Appendix 3.

The large number of EVCs and SA Vegetation Classes is unsuitable for input into the LUIM biodiversity risk modelling (see Section 8.1). Therefore, the data was generalised into a small and limited number of functional groupings based on very general landscape and vegetation characteristics. The new groups were agreed upon at the August 31 2005 workshop and a grouping was allocated to each EVC/Class soon after. Table 3.29 lists the groupings and the areal extent of each within the three catchments of the Lower Murray study area. Of the 5.43 million ha of remnant native vegetation in the Lower Murray study area, approximately 2.1 million ha (39%) has been classified as pyrogenic low nutrient. The majority of this vegetation type is found within the drier and low rainfall SAMDB and Mallee catchments. The other major vegetation types found in the study area are the mallee mesonutrients (22% of total remnant vegetation) and dryland woodlands/grasslands (17%).

Table 3.29. Catchment breakdown of generalised vegetation functional groupings in the Lower Murray study area.

General Vegetation Class	**Area (ha)**			
	SAMDB	**Mallee**	**Wimmera**	**Total**
Chenopod shrubland	578,070	52,522	17	630,609
Coastal	8,707	0	0	8,707
Disturbed	10	0	0	10
Dryland woodland/grasslands	595,929	217,108	120,260	933,297
Flood dependent	46,136	56,494	31,988	134,618
Mallee mesonutrients	910,534	304,264	9,307	1,224,105
Pyrogenic low nutrient	707,132	1,166,962	253,355	2,127,449
Raak	23,435	59,612	1,839	84,886
Uplands	15	0	77,106	77,121
Not Known	204,867	0	0	204,867
Total	**3,074,835**	**1,856,962**	**493,872**	**5,425,669**
% of region	**54.9**	**47.3**	**21.1**	**45.7**

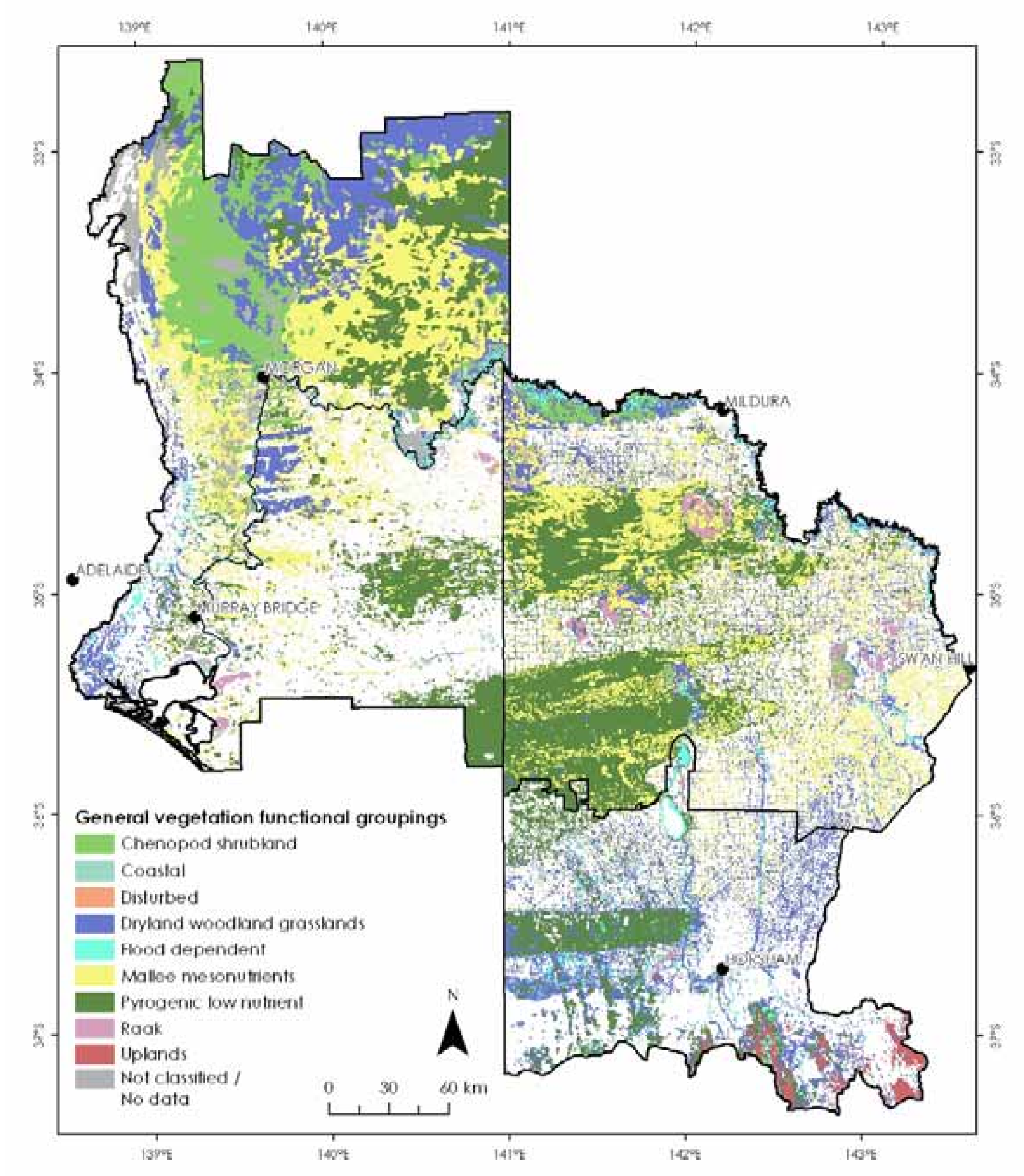

Figure 3.18. Distribution of generalised vegetation functional groupings for the Lower Murray study area.

The geographic distribution of the generalised functional groupings is displayed in Figure 3.18. Looking at Figure 3.18, vegetation appears to cover a very large proportion of the Victorian CMAs. This is an exaggeration of true cover and occurs because of an artefact of the GIS mapping. All small polygons of vegetation that have been mapped are represented in the graphic, and in many cases have been enlarged so that they do appear. The true extent of vegetation cover in the CMAs is discussed in Section 0, but briefly, approximately 46% of the Lower Murray study area under remnant vegetation. This is a high figure but is exaggerated by a small number of very large remnant patches. The remaining 50%+ of the study area cleared for dryland cropping and grazing (Section 0) is almost totally devoid of remnant vegetation cover.

Soil Types

Soil mapping in South Australia and Victoria has been undertaken using different methods and at different scales. As a result the comparability of soil data between states is limited and the mapping is in places incongruent at the border. Soil data is used for various purposes in this study as described throughout this report. In this section we discuss the derivation of a map of soil types that is used for both agricultural simulation with APSIM, and for biodiversity planning.

In South Australia the Department of Primary Industries (PIRSA) has compiled an extensive spatial database based upon soil landscape units mapped at a scale of 1:100,000. Soil landscape units have been mapped for the majority of the SA MDB region including all of the cleared dryland agricultural areas. Substantial areas of grazed remnant vegetation in the arid areas north of the River Murray have not been mapped however. Areas that have not been classified have been grouped into an *unknown* class and treated the same as other mapped classes.

The Land Systems of Victoria dataset provides information about the distribution of land types on a scale of 1:250,000. This dataset is comprised of a broad range of land resource information from a variety of sources of varying methodologies and intensities over some forty years. The reliability of information varies across regions accordingly. The Victorian land systems data has also been updated with soil property information.

Within the South Australian Landscape Units mapping soils are not specifically identified. Instead several thousand landscape units are mapped, each of these landscape units may include several soil types (with differing proportions of each) within each polygon. The Victorian layer on the other hand, maps 62 different soil groups Each of these soil groups have a soil description of one or more soil types that are present in that soil group. A single map of broad soil types for the Lower Murray was required for input into other parts of the study. Significant processing was required to create this layer and these steps are outlined below.

In order to aggregate the South Australian soil groups a look up table was created to reclassify soils types into broad soil classes which capture broad patterns of plant relevant soil properties (David Maschmedt, PIRSA, unpublished data). Each mapped soil landscape unit exhibits various proportions of different soil types. After attaching the look up table, it was also possible to quantify the proportions of the reclassified broad soil classes. Each soil landscape unit was then assigned the dominant broad soil class exhibiting the highest aggregate proportion (Table 3.30).

Table 3.30. Example of reclassifying soil types into plant relevant broad soil classes. Note that SLU ACHAuC would be reclassified into the dominant Broad Soil Class 8 whilst SLU ACHFbZ would be reclassified into the dominant Broad Soil Class 6.

Soil Landscape Unit	Soil Type	%	Broad Soil Class
ACHAuC	K3	20	8
ACHAuC	K4	30	8
ACHAuC	K5	35	8
ACHAuC	L1	15	8
ACHFbZ	J2	65	6
ACHFbZ	K1	20	8
ACHFbZ	K4	15	8

The Victorian soil data is mapped at a coarser scale than the SA soils and were therefore a little more difficult to aggregate. Each land system polygon has a brief soil description according to the Nothcote *et al* (1979) classification system. Each mapped land system polygon may consist of several different soils but there is no information of the proportions of each soil occurring within each polygon. The Victorian soil descriptions are not easily related to the South Australian descriptions. Few common soil classes could be found to match across the border.

In the absence of detailed metadata, and in order to aggregate the Victorian soils a few assumptions about the data had to be made. Where more than one soil type is described the first soil type described is considered to be the soil that dominates the greater proportion of the polygon. Soils were aggregated along the direct branches of their subdivisions profile after Northcote *et al*. (1979) (i.e. a Uc soil could only be a Uc soil not a Um or Uf) with the exception of the duplex soil groups. Duplex soils were grouped according to the expected water holding capacity of the soil as indicated in the soil description (i.e. sandy duplex is considered different to duplex clay.)

Table 3.31. Reclassification codes for Victorian soil mapping.

Description	**Broad Soil Class**	**Description**	**Broad Soil Class**
Calcareous earths	1	'Yellow duplex soils, Pale sands'	3
'Calcareous earths, Calcareous clays'	1	Yellow sands	3
'Calcareous earths, Saline loams'	1	Sandy loams	4
'Calcareous earths, Sandy red duplex soils'	1	'Shallow loams, Calcareous earths'	4
Red brown earth	1	'Shallow loams, Sandy red duplex soils'	4
'Brown clay, red clay, Brown duplex'	2	Shallow stony loams	4
Brown clays	2	'Shallow stony loams, Stony red duplex soils'	4
'Calcareous clays, Calcareous earths'	2	Duplex	5
'Calcareous clays, Calcareous earths, Sandy red duplex soils'	2	Duplex soils	5
'Calcareous clays, Red duplex soils'	2	'Duplex soils, Sands'	5
Grey clay	2	Mottled duplex soils	5
'Grey clay, Red clay, Red & brown duplex'	2	'Mottled duplex soils, Red duplex soils'	5
Grey clays	2	'Mottled duplex soils, Yellow duplex soils'	5
'Grey clays, Grey sands'	2	Mottled sandy duplex	5
'Grey clays, Red duplex soils'	2	Sandy mottled duplex soil	5
'Grey gypseous clays, Sandy red duplex soils'	2	Sandy mottled duplex soils	5
'Red brown clays, Grey clays'	2	Red duplex	6
'Red clays, Grey clays'	2	Red duplex soils	6
'Red clays, Grey clays, Red duplex soils'	2	'Red duplex soils, Brown duplex soils'	6
Saline clays	2	'Red duplex soils, Yellow duplex soils'	6
'Duplex soils, Grey clays'	2	'Red duplex, yellow duplex'	6
'Red duplex, Calcareous clays'	2	Sandy red duplex soils	6
'Sandy red duplex soils, Grey gypseous clays'	2	'Sandy red duplex soils, Red duplex soils'	6
'Sandy red duplex soils, Saline clays'	2	'Sandy red duplex, yellow duplex'	6
Pale sands	3	Yellow duplex	7
'Pale sands, Sandy mottled duplex soils'	3	Yellow duplex soils	7
'Pale sands, Yellow duplex soils'	3	'Yellow duplex soils, Saline soils'	7
'Reddish yellow sands, Sandy red duplex soils'	3	'Yellow duplex soils, Sandy yellow duplex soils'	7
'Sandy duplex, mottled sandy duplex'	3	'Yellow duplex, brown duplex'	7
'Sandy mottled duplex soils, yellow sands'	3	'Yellow earths, Yellow duplex soils'	7
Shallow stony sands	3		

Table 3.32. Broad soil class description for the Lower Murray.

Soil Value	Description
1	Calcareous
2	Clay
3	Sands
4	Loams
5	Duplex soils
6	Sandy Duplex soils
7	Red brown Earths
8	Sand over Clay
9	Loamy texture contrast
10	Sandy to sandy loam gradational soil
11	Loamy to clay loamy gradational soil
12	Deep cracking clay
13	Deep calcareous soil
14	Shallow soil over calcrete, limestone or basement rock
15	Wet soils

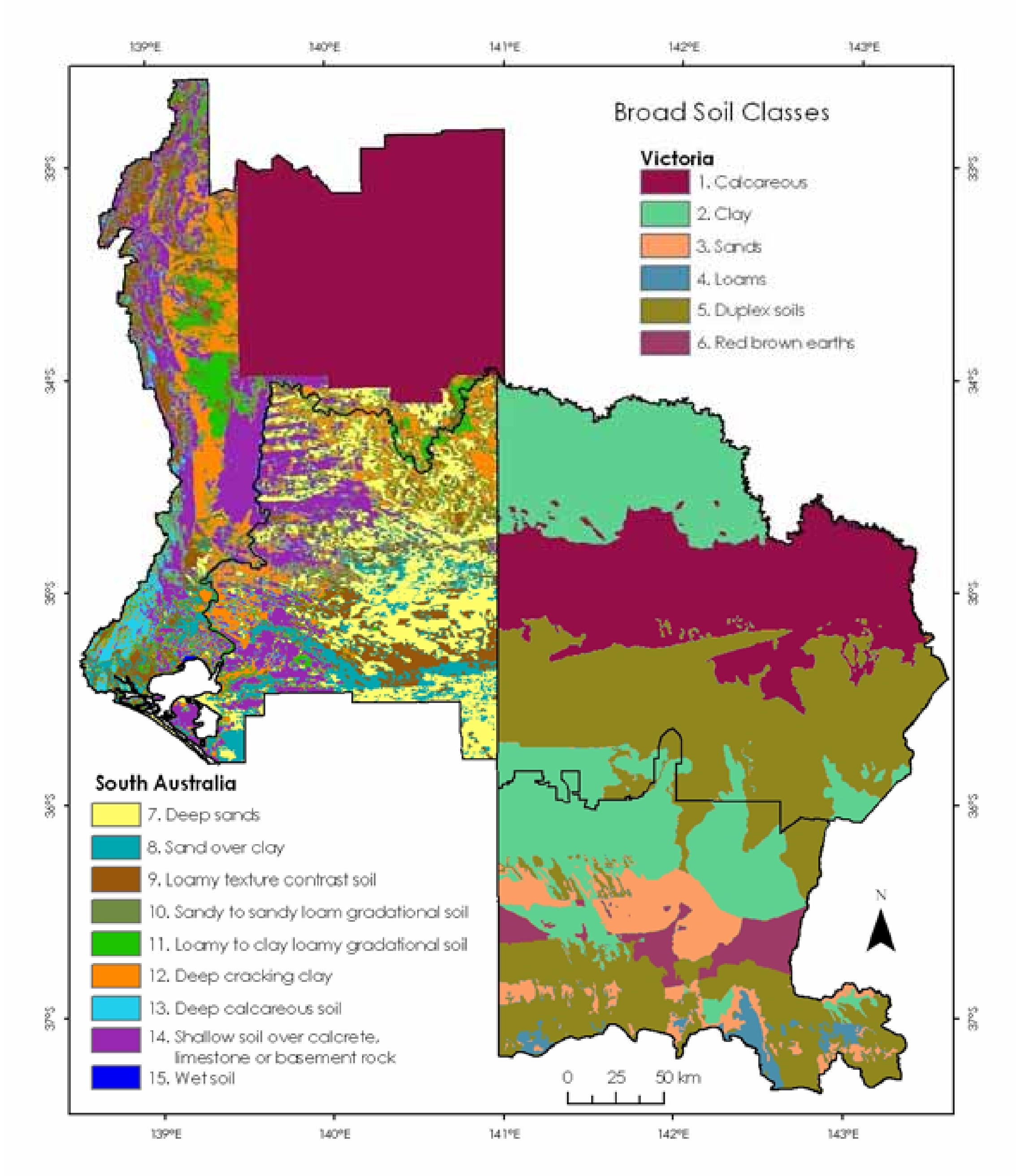

Figure 3.19 - Reclassified broad soil classes for the Lower Murray.

Depth to Groundwater and Dryland Salinity

Knowledge of the variation in the depth to groundwater (the distance from soil surface to the top of the water table) is important for assessing the risk of dryland salinisation. Land areas are at high risk of dryland salinisation in areas where there is substantial deep drainage (drainage beyond the root zone) and where the depth to groundwater is shallow.

Several disparate attempts have been made at modelling and mapping the spatial distribution of depth to groundwater across the Lower Murray Region. We integrated and enhanced four existing data layers describing the depth to groundwater to create a single layer across the study area.

Groundwater elevation data from SA DEH for the SA MDB was resampled to 1 ha grid cell resolution and subtracted from the Shuttle Radar Topography Mission

(SRTM) data (see Section 7.2.1) to give a depth to groundwater surface. Recently updated as part of the Mallee Review project, high resolution depth to groundwater data based on the SRTM topographic data was available for the northern part of the Mallee CMA which was bilinearly resampled to 1 ha resolution. High resolution depth to groundwater data based on the SRTM topographic data was sourced for the Wimmera CMA. To fill the gap between the Wimmera and the Mallee Review study area the original groundwater surface for the Mallee CMA was acquired from REM and this was subtracted from the SRTM topographic data to produce depth to groundwater information. These four surfaces were then merged to produce a single depth to groundwater surface at 1 ha resolution based on the SRTM high resolution topographic data.

There are significant areas of land with very shallow depths to groundwater. Specifically, over 6,000 sq.km of land has a water table within 5m of the surface (Table 3.33, Figure 3.20). Where these areas are subject to increased deep drainage caused by the replacement of deep rooted native vegetation with agricultural land uses, the risk of dryland salinisation is high.

Table 3.33. Area of land at different groundwater depths in the Lower Murray.

Depth Class	Area (ha)	% study area
< 2m	170,100	1.4
2m - 5m	438,700	3.7
5m - 10m	1,041,000	8.8
10m - 20m	1,926,600	16.2
20m - 40m	3,730,400	31.4
> 40m	4,564,500	38.4

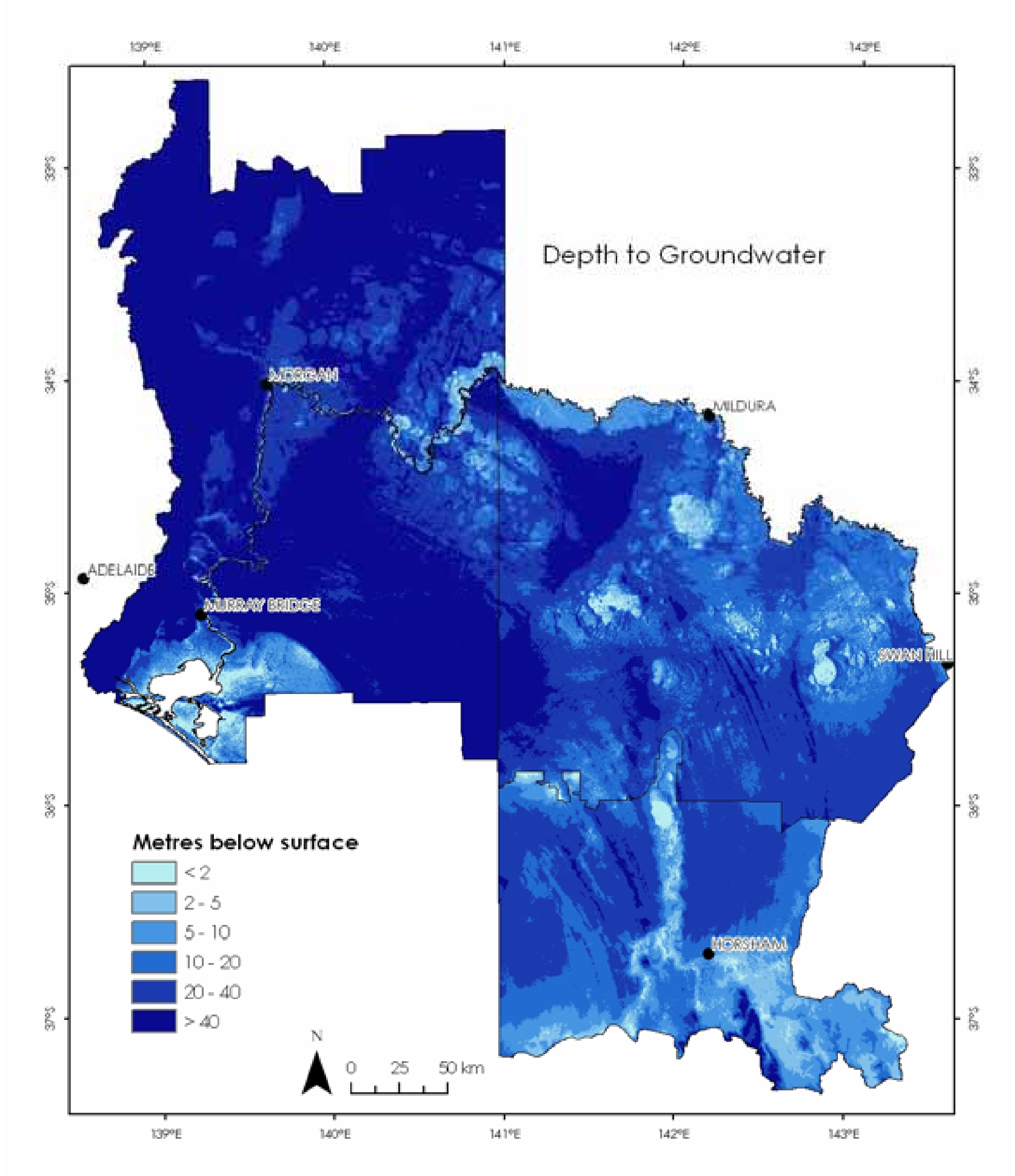

Figure 3.20. Spatial distribution of depth to groundwater in the Lower Murray.

Wind erosion risk

Wind erosion risk is dependent upon both the inherent potential for soils to erode and the influence of land use, cover and management. Soils in the Lower Murray have varying wind erosion potential according to the level of clay content in the soil profile. Sandy soils of low clay content are common and tend to have an inherently higher susceptibility to erosion by wind. Land clearance and agricultural production has exacerbated the problem of wind erosion on susceptible soils through removal of the soil-binding action and wind speed mitigation provided by deep-rooted perennials increases the risk of soil erosion.

A map of soil wind erosion potential was created by merging the SA soil data from DWLBC and the Victorian land systems data (Figure 3.21). Although there is an inherent difference in the scale at which these 2 datasets were captured, the two match up reasonably well. Soil wind erosion potential is classified into six classes from low to extreme (Table 3.34).

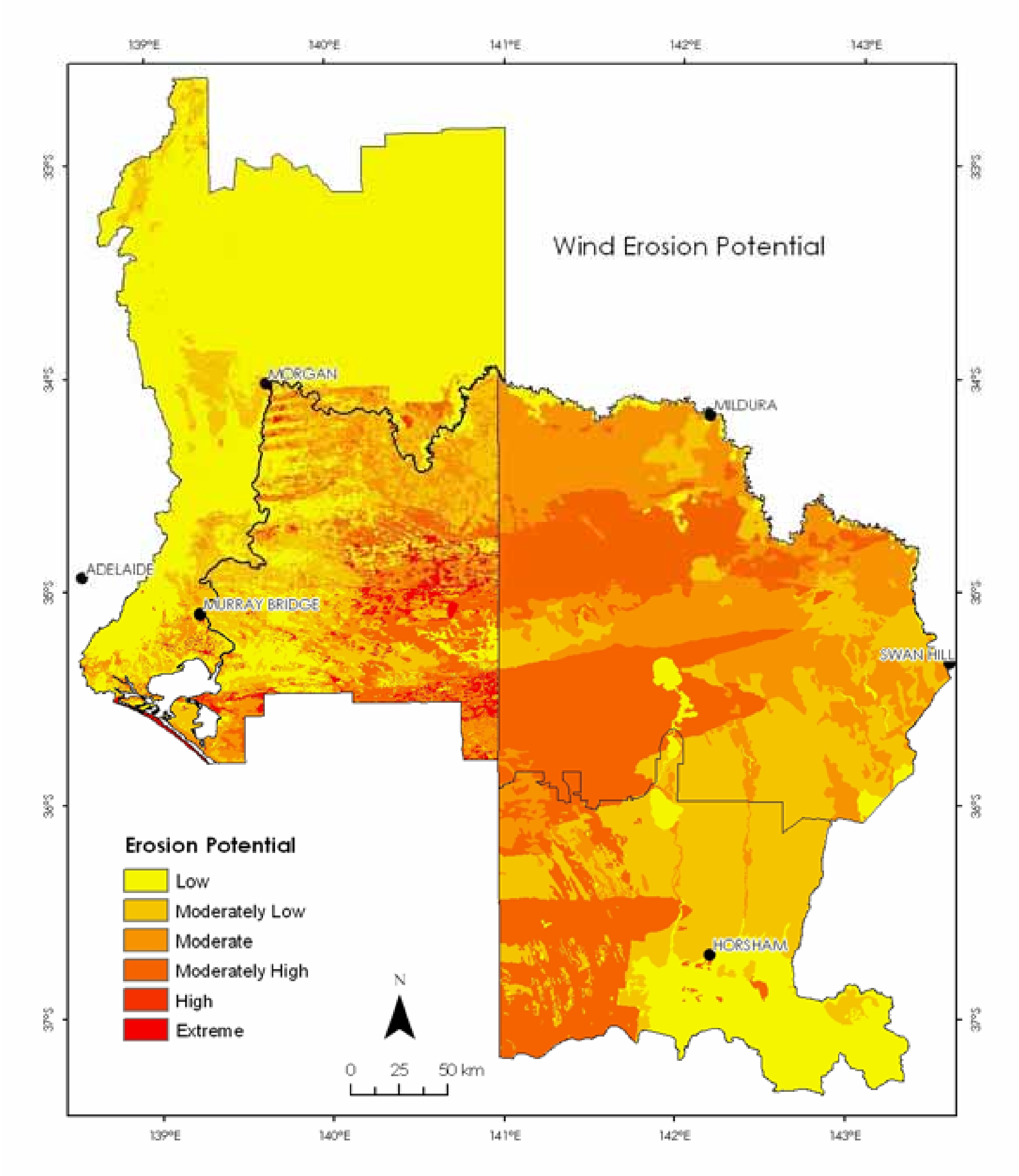

Figure 3.21. Distribution of wind erosion potential in the Lower Murray

Nearly 23% of the Lower Murray study area is classified as having a wind erosion potential of *moderately high* or higher with nearly 150,000 ha classified as *extreme* (Table 3.34).

Table 3.34. Summary areas of wind erosion potential in the Lower Murray

Code	Description	Area (ha)	% study area
1	Low	4,163,621	35.1
2	Moderately low	2,889,430	24.3
3	Moderate	2,227,253	18.8
4	Moderately high	2,429,223	20.5
5	High	14,045	0.1
6	Extreme	147,791	1.2

Bioregions

Bioregions are cartographically mapped geographic regions designed to capture homogeneity within and heterogeneity across biophysical environments. Biogeographic regionalisation can occur at a variety of scales. Regions represent homogeneous biogeographic units at a particular scale of analysis and form units suitable for broad scale assessment, planning and analysis especially within natural resource management.

The Interim Biogeographic Regionalisation of Australia (IBRA) is a continent-wide regionalisation and divides Australia into 85 bioregions and 404 sub-regions (DEH 2005). These have become a commonly used reporting unit for regional and national scale environmental assessments such as the National Land and Water Resources Audit. The Mallee CMA has set a resource condition target for revegetation of 30% of each bioregion. We also set targets for bioregions for the SA MDB and the Wimmera CMA in our sustainability ideal models. A total of 8 bioregions and 20 sub-regions occur over the Lower Murray study area. The distribution of bioregions and subregions is presented in Table 3.35 and Figure 3.22 and Figure 3.23.

Table 3.35. Summary of bioregion and subregions within the Lower Murray study area. See Figure 3.22 and Figure 3.23 for location of each bioregion.

Bioregion	Area (ha)	Sub-region	Area (ha)
Broken Hill Complex	82,583	Barrier Range Outwash	82,603
Flinders Lofty Block	565,549	Broughton	191,634
Kanmantoo	235,595	Central Victorian Uplands	67,663
Murray Darling Depression	10,228,179	Dundas Tablelands	27,113
Naracoorte Coastal Plain	61,819	Fleurieu	235,586
Riverina	376,129	Glenelg Plain	15,464
Victorian Midlands	318,797	Goldfields	137,864
Victorian Volcanic Plain	2,368	Greater Grampians	86,178
		Lowan Mallee	1,853,293
		Mount Lofty Ranges	24,247
		Murray Fans	22,287
		Murray Lakes and Coorong	125,063
		Murray Mallee	4,811,667
		Murray Scroll Belt	289,821
		Olary Spur	349,654
		Robinvale Plains	64,055
		South Olary Plain, Murray Basin	1,839,275
		Tintinara	46,365
		Victorian Volcanic Plain	2,373
		Wimmera	1,599,124

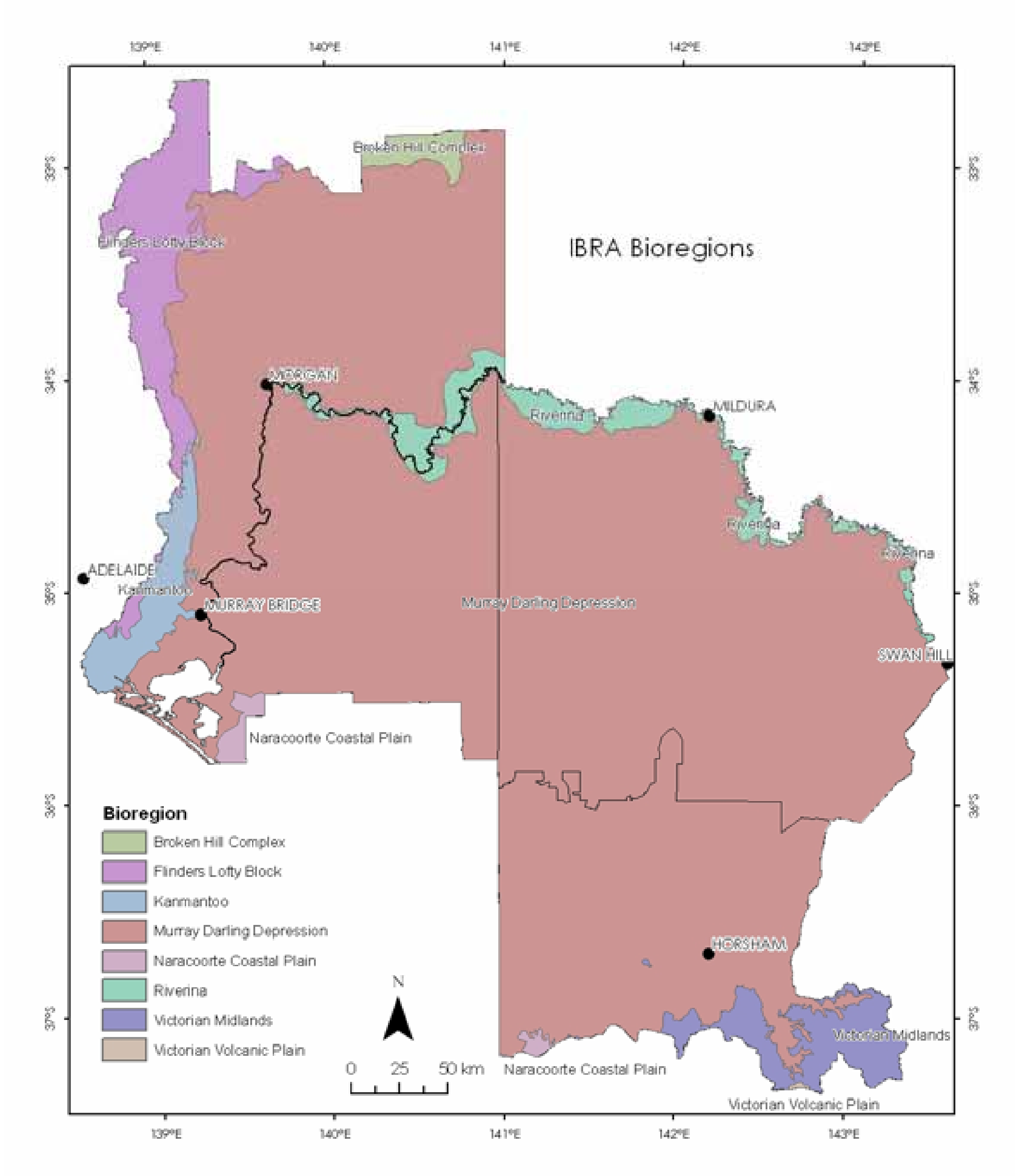

Figure 3.22. Distribution of IBRA bioregions (DEH 2005) in the Lower Murray