Breaking Ground

Key Findings from 10 years of Australia's National Dryland Salinity Program

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Know-how to tackle salinity

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Australia's National Dryland Salinity Program is a collaborative research and development effort that is investigating the causes of, and solutions to, the national problem of dryland salinity. It was initiated by Land & Water Australia (formerly LWRRDC) in 1993 and has involved a wide range of funding partners and research organisations. It has been managed by Land & Water Australia since its inception.

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Finally, Dr Richard Price managed the National Dryland Salinity Program for 11 years from its inception to the production of these synthesis reports. For the first 10 years Richard worked as a program manager within Land & Water Australia and in this final year as a consultant to Land & Water Australia. Throughout this period, Richard's enthusiasm, drive, keen insights, extensive network and excellent program management skills have been fundamental to the success and impact of the NDSP. This has been an important contribution to salinity research in Australia, and to the wider understanding within the Australian community of the salinity challenge we face and how to manage it.

The National Dryland Salinity Program is jointly supported by the following organisations

Australian Government Department of Agriculture, Fisheries and Forestry
Land & Water Australia
Rural and Industries Research and Development Corporation
Meat & Livestock Australia
CRC for Plant-based Management of Dryland Salinity
Grains Research & Development Corporation
CSIRO
National Land & Water Resources Audit – An Initiative of the Natural Heritage Trust
Murray-Darling Basin Commission
Land, Water & Wool

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FOREWORD

This report represents in part the culmination of an extraordinary adventure.

The National Dryland Salinity Program (NDSP) was established in 1993 by Land & Water Australia, the National Landcare Program, the Murray Darling Basin Commission and the State governments of New South Wales, Queensland, Victoria, South Australia and Western Australia, in recognition of the need for a coordinated approach to dryland salinity research in Australia. The NDSP has invested over $40 million into new knowledge and understanding, technologies, decision-support systems and information products that are helping people across Australia to manage dryland salinity.

This investment has led a national shift in salinity research and policy, responding flexibly to the changing political environment and on-ground demands over this time. It played a major role in the report to the Prime Minister's Science, Engineering and Innovation Council, that provided a compelling case for establishment of the National Action Plan for Salinity and Water Quality (NAP). The NDSP had already brought the States and industry together under a national approach to salinity research and management. An independent review of the NDSP in 2003 confirmed the pre-eminent contribution it has made to developing solutions applicable at catchment and farm scales.

Over this past year, the 11th year of the program, the NDSP has invested a full year in harvesting and synthesising the efforts of over 300 researchers who investigated the causes, costs, consequences, solutions and management of dryland salinity in Australia over the past 10 years of the program.

This great portfolio of scientific and practical knowledge has been synthesised into three landmark reports, of which this is one. The three synthesis reports are designed to help people to make better decisions at farm scale, at catchment scale, and in developing policy respectively, based on the best available knowledge in Australia about salinity.

The foundation for these reports, and their companion resources, is solid science. This ground breaking research has brought together the contributions of hydrologists, economists, soil and plant specialists, ecologists, sociologists, biologists, agronomists, geologists, mathematicians, engineers, professional communicators and many others.

The synthesis process has been based on collaborative learning and analysis, spiced with vigorous discussion, debate and argument in public meetings and among partners. Drafts of the reports were road-tested in workshops in every State, involving catchment managers, farmers and their advisors.

The NDSP has been about more than just science. Indeed, it has been about professional communication developing solutions for farmers, catchment managers and others, backed by good science. This ambitious attempt to pull together a vast amount of scientific knowledge, and to package it to make it more useful for its end users, was made possible through funding from Land & Water Australia, the Department of Agriculture, Fisheries and Forestry (under the NAP), the Murray-Darling Basin Commission, Meat & Livestock Australia, the Rural Industries R&D Corporation, the Grains R&D Corporation, the Department of Natural Resources & Mines (Qld), the Department of Agriculture (WA) and the Department of Water, Land and Biodiversity Conservation (SA).

On behalf of the Governing Board and the NDSP partners that invested so much in this program, I commend these reports to you.

Kevin Goss, Chairman
National Dryland Salinity Program

NDSP MANAGEMENT STRUCTURE

Australia's National Dryland Salinity Program (NDSP) comprised the following members:

NDSP Management Board

- Kevin Goss (Chair), Murray-Darling Basin Commission
- Bobbie Brazil, Land & Water Australia
- Peter Butler, SA Department of Water, Land & Biodiversity Conservation
- Shawn Butters, Victorian Department of Sustainability and Environment
- Tony Byrne, Rural Industries Research and Development Corporation
- Ian Cox, Westpac Banking Group
- Terry Enright, Grains Research and Development Corporation
- Bob Nulsen, Department of Agriculture, Western Australia
- Greg Pinkard, Tasmanian Department of Primary Industry, Water & Environment
- Mick Poole, Centre for Legumes in Mediterranean Agriculture
- Richard Price, Kiri-Ganai Research Pty Ltd
- Ben Russell, Meat & Livestock Australia
- Brian Vandersee, Queensland Department of Natural Resources and Mines
- Simon Veitch, Department of Agriculture, Fisheries and Forestry
- Ross Williams, NSW Department of Infrastructure, Planning and Natural Resources

NDSP Operations Committee

- Cameron Allan, Meat & Livestock Australia
- Peter Barker, NSW Department of Infrastructure, Planning and Natural Resources
- Colin Bastick, Tasmanian Department of Primary Industry, Water and Environment
- Stuart Kearns, Grains Research and Development Corporation
- Russell Haines, Rural Industries Research and Development Corporation
- Michael Crawford, Victorian Department of Sustainability and Environment
- Sharon Davis, Murray-Darling Basin Commission
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- Lisa Gray, Department of Infrastructure, Planning and Natural Resources (NSW)
- Mark Warnick, Department of Natural Resources and Mines (QLD)

SUMMARY

The National Dryland Salinity Program (NDSP) was established in 1993 and its first five-year phase focused on understanding causes of dryland salinity and establishing a national collaborative research and development effort. The three themes for the first five years were:

- Mapping and monitoring;
- Economic analysis; and
- Estimating recharge.

A larger second phase, completed in June 2003, involved new funding partners. Research projects were grouped into seven themes that aimed to fill remaining gaps in understanding salinity and develop practical, profitable and sustainable solutions.

The seven themes related to understanding and managing salinity were:

- Audit and Monitoring;
- Policy and Operating Environment;
- Industry Solutions;
- Productive Use of Saline Resources;
- Environmental Protection and Rehabilitation;
- Infrastructure Management; and
- Regional and Community Initiatives.

This document outlines the implications of 10 years of NDSP research and development.

The program has been influential in coordinating and steering the direction of research and development. It has given us:

- An increased awareness of the impact of dryland salinity;
- A better understanding of the costs of dryland salinity to a range of stakeholders – agricultural and non-agricultural;
- A knowledge of the extent of dryland salinity; and
- R&D in non-agricultural areas such as environment and biodiversity, social impacts and infrastructure.

For policy makers, NDSP tells us:

- There is still much to be done;
- The focus has shifted to include impacts on infrastructure – roads, bridges, buildings and other engineered structures;
- Practical and economic solutions are not easy to find and their impact may not be felt for decades;
- Salinity management should be integrated with other natural resource management strategies; and
- In some cases we will have to live with salinity and must find the institutional and practical means to make that possible.

SUMMARY

NDSP'S COMMITMENT TO SALINITY RESEARCH IN THE PAST 10 YEARS

Total allotted to NDSP in Phases I and II: $40 million

NDSP focus: 92 per cent of budget spent on R&D to understand and manage salinity

10 YEAR ACHIEVEMENTS — HIGHLIGHTS

Ten years of NDSP research have resulted in significant advances in knowledge, tools, applications, policy options, and catchment management, infrastructure and farming system practices.

Audit and Monitoring

- Refinement of a catchment classification system as a tool for planning and evaluation (the Groundwater Flow System concept);
- Completion of a national salinity audit, including an assessment of future risks and groundwater trends;
- Turning the spotlight on emerging regions, in particular in Queensland and Tasmania; and
- Development of a national evaluation framework, providing a structured system to update knowledge.

Policy and Operating Environment

- Policy snapshot of current salinity costs;
- Access for local government to salinity information; and
- New directions for institutional arrangements.

Industry Solutions

- Understanding that lucerne can be profitable — but only up to a point;
- Understanding that deep drains can work — but disposal remains a problem;
- Building farmers' skills and capacity to manage salinity through action research; and
- Development of simple groundwater monitoring systems for farmers.

Productive Use of Saline Resources

- Identification of productive uses of saline lands — many options but few winners; and
- A decision guide to estimate costs/benefits of desalination options.

Environmental Protection and Rehabilitation

- Development of the FLOWTUBE model to provide a rapid 'what-if' tool for planners;
- Modelling to provide new insights for water managers, including understanding of recharge and water yield trade-offs; and
- Assessment of environmental impacts, recognising that it is still early days in understanding impacts on biodiversity.

Infrastructure Management

- Assessment of national infrastructure management costs; and
- Development of a decision support system to assess engineering options, describing how these can be cost effective in some situations.

Regional and Community Initiatives

- Salinity management packages to 12 Murray–Darling Basin regions/regional planners; and
- A national network of communication facilitators to meet regional demands for salinity management information.

KEY MESSAGES

Following this decade of national research effort, **six key messages** have emerged across the seven themes:

One: Salinity costs are significant and rising, hence responses must be strategic

- Costs of dryland salinity are projected to increase by 60–70 per cent over the next 20 years.
- New findings suggest the best we can hope for from most of the current recharge control treatments (which manipulate recharge levels to restore water table equilibrium to slow salinity damage) is a slowing of the rate of future salinisation. Rehabilitation of existing salinity damage is generally not economic owing to the sluggish response of water tables to recharge reductions.
- The focus should be on preventing future damage to high value assets — using cost effective treatments. NDSP has shown it will be imperative to prioritise on-ground investment carefully to prevent wasting money.
- Close attention will need to be paid to analysing the costs and benefits of protecting public and private assets. The challenge will be to put in place policies that direct the right balance of public and private funds to meet public and private benefits.
- To date, studies have concentrated on assessing the costs of salinity. Attention now needs to be directed towards the benefits of various forms of policy and management intervention.
- Engineering works will be an important and inevitable part of protecting high value assets. Such works should proceed with caution, but knowledge and tools exist that can assist design of such interventions to minimise downstream consequences.

Two: Profitable options for reversing the trend are lacking (but under development)

- The notion that salinity will be comprehensively fixed with targeted revegetation treatments or discharge management should be dispelled. There is no 'silver bullet'. Hopes of finding a clever, low-cost solution such as planting a relatively small part of the landscape with trees in strategic areas no longer hold credibility.
- The hydrogeology of the Australian landscape is extremely complex, with multiple processes at work. Thus, there will be parts of the landscape (principally overlying local aquifers) where treatments could yield a net benefit.
- To make major progress in extensive treatments to prevent further salinisation, it will be important to develop solutions that are profitable for those managing the greatest area of land: farmers and graziers. Improved farming options that increase perennial vegetation may remain the most likely means of attaining salinity management responses at the scale needed. Further research will be critical.
- Living with salt will also become an inevitable consequence of not having profitable plant-based solutions immediately to hand. Some saltland pasture systems already have proven to be viable, as well as profitable, but these systems need refinement and a mindset change for many farmers.

Three: There is no one salinity problem: It challenges us to look beyond traditional policy instruments

- Results from Groundwater Flow System modelling that analyses flow and recharge patterns, confirm that the many forms of salinity expression require a corresponding diversity in response (including no response). NDSP has advocated strategic responses based on **prevention, recovery and adaptation**.
- NDSP has developed a range of strategies from analysing responses using the Groundwater Flow System and FLOWTUBE, a rapid catchment appraisal model able to assess the impact of recharge control strategies on water tables. These strategies take into account perennial farming systems, engineering works and productive uses of saline lands.
- The externality concept, whereby the actions of some people impose a net cost on others, may not always be valid for dryland salinity. Hence encouraging landholders to internalise off-farm 'costs' by creating markets in recharge credits and debits may not be appropriate for all areas. For example, 'leaky' farming systems in cleared catchments can cause salinity but they can also provide twice as much water for consumptive use compared with the amount of water available pre-clearing, and can provide significantly more water than low-recharge farming systems. Socio-economic benefits generated from the 'excess' water, and from the 'leaky' farming systems themselves, may outweigh salinity impact costs or the net benefits of recharge control.
- Even for regional and intermediate aquifers, where discharge sites are more remote from recharge areas, the externalities principle does not always hold. This is because in these aquifers the lateral movement of groundwater tends to be very slow (up to thousands of years), meaning that benefits of recharge control are usually localised – at least in the short-term. Again, the gains from internalising off-site costs by defining salinity credits (or recharge rights) and allowing trade between farmers appear to be smaller than previously thought.

Four: Integrated catchment management must be seen as only one approach to deal with dryland salinity

- New information on groundwater flow systems highlights the need to develop institutional options other than integrated catchment management in some parts of Australia. In some regions, groundwater flow systems (for example, some regional and intermediate systems) transcend surface catchment boundaries, requiring cross-catchment action to achieve co-ordinated surface and groundwater outcomes. In other regions, salinised land is a higher priority issue than salinised water resources. In these areas, planning and management on a more localised 'community of common concern' basis may be more appropriate.
- Tools exist at regional and catchment levels that can help target specific interventions and predict their likely responses. In particular, modelling can support better vegetation management decisions.

Five: Vegetation management remains the key to managing water resources, although the cost-benefit of revegetating catchments requires careful analysis

- Salt carried by surface water run-off and saline groundwater discharge into waterways imposes costs on downstream users. In water supply catchments, revegetating cleared land can reduce water yield and increase stream salinity due to less dilution.
- Cost-benefit analysis is needed before revegetation policies are implemented to protect water resources. Where water is scarce, desalination may be more cost-effective (given the problem here is more likely to be a groundwater than surface water problem).
- There is a significant difference in water use between trees (or woody perennials) and grasses (perennial or otherwise). In some parts of the landscape, only trees (or woody perennials) may reduce leakage to reasonable, if not required levels. These trees are best placed where leakage contributing significantly to groundwater recharge is likely to intersect with salt-stores. In much of the remaining landscape we may need to provide high volumes of clean surface water. Managing native grasses as low input systems may provide high volumes of clean water and biodiversity benefits as well. These systems need to be explored along with the better-known perennial-based pasture systems such as lucerne.
- NDSP research suggests that because of the magnitude of the challenge associated with revegetation (including cost), it is critical to at least maintain and enhance the current quality and quantity of vegetation.

Six: Lack of capacity is an important, but secondary constraint, to managing salinity

- NDSP findings indicate that lack of skills, management expertise, poor access to information and financial difficulties are by no means the most significant factors in constraining land use change. In the absence of commercially attractive treatment options, it is unrealistic to expect farmers to change their current annual farming systems in favour of perennials or agroforestry. Under these circumstances no amount of capacity building or training will facilitate change.
- Other constraints for moving forward lie in the lack of clarity of rights and responsibilities, ascribing cause and effect and clearly specifying the benefits and costs of different courses of action.

These messages show us we need to think more critically about what we perceive as salinity management.

Priorities for Future R&D

Many R&D priorities are identified in this report, but the three highest priorities are:

1. Developing the means to value environmental benefits: so that decisions based on alternative salinity management options takes into account the full range of value at stake in decisions;
2. Developing profitable industry solutions: so that economically, environmentally and socially feasible options are in the hands of those managing the vast majority of Australian landscapes;
3. Reconciling farm and catchment decision trade-offs: so that the potential conflicts in rational decisions at one scale with rationale decisions at another are minimised in the meantime (awaiting the outcomes of priority 2 above).

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Boxes, charts and tables

1. INTRODUCTION

THE NATIONAL DRYLAND SALINITY PROGRAM (NDSP) is a collaborative research, development and extension (R,D&E) program investigating causes of, and solutions to, the national problem of dryland salinity. The program is made up of a consortium of members from Australian industry and government organisations with an interest in managing salinity. This report looks back on NDSP achievements in terms of economic, social and environmental outcomes – commonly known as the triple bottom line. It examines progress towards understanding the salinity problem and solutions that have been developed. In particular, it assesses performance NDSP's performance against its stated objectives.

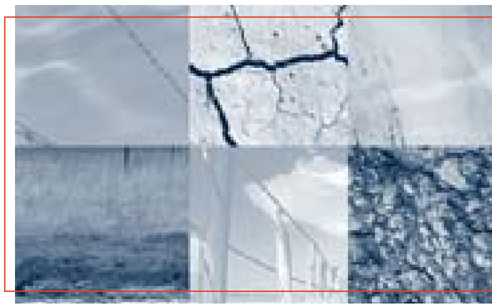
NATURE OF THE PROBLEM

It is now known that dryland salinity is mainly a function of rising groundwater tables, caused by increased recharge following replacement of native vegetation with annual crop/pasture systems. Salts deposited below ground are brought to the surface causing damage to agricultural yields and infrastructure, and contaminating streams.

While the basic processes underpinning dryland salinity have been known for some time, the capacity to predict its location and future spread has been limited because of the hydrological complexity of the Australian landscape. Similarly, early efforts to model the impact of different control treatments were frustrated by the complexity and lack of data with which to establish biophysical relationships. Variable time lags associated with salinity and groundwater flows have added to challenge of developing predictive tools. It is against this backdrop of uncertainty that NDSP was born.

BACKGROUND TO NDSP

The NDSP's origins date back to 1993 when the first five-year phase of the program began. This initial phase had a strong technical focus and aimed to improve our knowledge of the causes and impacts of salinity. It made significant headway in developing better research methods, coordinating research efforts and engaging rural communities in catchment management planning. It also helped break down barriers between different disciplinary groups and government institutions, and elevated awareness of salinity issues. Phase I of NDSP ended in 1998.



The second phase, beginning in 1998, evolved out of NDSP Phase I's findings and accomplishments. The new program took a different focus and encompassed a broader range of issues, consistent with a growing awareness of the wide-ranging impacts of salinity and the diversity of approaches that would be needed to address the problem. Phase II examined catchment processes, industry, engineering, policy, local government, environmental and regional dimensions of salinity.

The program was funded by a consortium of government and industry organisations with a stake in salinity. Primary contributors were:

- Land & Water Australia (LWA);
- Murray–Darling Basin Commission (MDBC);
- the Commonwealth Department of Agriculture, Fisheries, Forestry Australia (AFFA);
- CSIRO;
- Grains R&D Corporation (GRDC);
- Rural Industries R&D Corporation (RIRDC); and
- Meat & Livestock Australia (MLA);
- the six State Governments.

1. INTRODUCTION

The operational structure consisted of an Operations Committee and Communications Team. The Operations Committee was responsible for selecting projects, maintaining technical quality and facilitating information exchange among the nation's researchers. The Communications Team comprised a network of State coordinators — one in each State except Tasmania — and a national coordinator. They were responsible for getting key messages out into the field.

Other players involved in salinity

It is important to note that not all salinity R&D is undertaken through NDSP. The 1990s saw a burgeoning of organisations becoming involved in salinity research and extension. A nationally-focused Cooperative Research Centre (CRC) was set up in 2001 to investigate plant-based solutions to salinity. At least three other CRCs have also conducted research into certain aspects of the problem.

Further, some of NDSP's member organisations have undertaken independent research activities. For example, CSIRO is involved in salinity work through its *Healthy Country* initiative and the MDBC oversees its own portfolio of applied salinity research. Industry R&D corporations and State government agencies have also increased their investments in salinity.

NDSP MISSION

NDSP's mission evolved over the course of Phase II. In the 1998 Management Plan the primary goal was to:

"Research, develop and extend practical approaches to effectively manage dryland salinity across Australia."

In pursuing this mission, the program set out to fulfil three main tasks:

- Improve coordination of R&D and extension efforts;
- Influence the direction of R&D by setting priorities and leading by example; and
- Fill R&D gaps at the national level by funding a portfolio of projects.

As time went by, it was recognised that NDSP had an important role as knowledge broker of salinity information to various target audiences. NDSP web-site states that the program aspires to be "Australia's lead knowledge broker of R&D and extension efforts to combat dryland salinity." To fulfil this role, NDSP needed to place greater emphasis on improving information sharing, increasing the capacity of decision-makers and informing public and industry policy.

NDSP OBJECTIVES — PHASE II

Four objectives were developed for NDSP's second phase.

Objective 1: Institutional arrangements

This objective aimed to "develop options for operating environments which encourage the prevention of salinity and the appropriate management of its impacts." Institutional arrangements were implied to be part of the operating environment. They included:

- The formal rules and social norms which govern people's behaviour;
- The governance structures and organisations for overseeing natural resource management (NRM); and
- Regulations, incentives and market mechanisms that influence decision making by resource managers.

The objective supported the premise that institutional arrangements are crucial in influencing change. Technical options are more likely to be taken up if delivered in a policy-making or farm environment conducive to better decision-making.

The central challenge was to develop institutional arrangements and policy instruments that reduce the transaction costs of implementing change. However, the planned strategies were somewhat wider than this, as they also sought to address other aspects of the operating environment such as:

- Developing principles and practices that help catchment communities to become more self-reliant in managing salinity;
- Improving extension systems; and
- Informing policy makers about the causes and extent of salinity to improve investment in natural resource management.

Objective 2: Causes, costs, consequences and solutions

This objective sought to "develop understanding and demonstrate principles and practices to address the causes, costs and consequences of dryland salinity".

Part of this objective was to develop methods to quantify costs and consequences of salinity. The objective met a growing demand by catchment-based and other groups for improved methods and information to underpin their planning processes. Landholders and resource managers would be in a better position to determine whether or not they should act, and if so, in what way, if the extent and array of costs imposed by salinity were more clearly defined.

Objective 2 also had a strong focus on developing solutions in partnership with primary producers and regional communities. Industry partners were keen to develop production methods that either maintained or increased profitability, while reducing groundwater recharge.

A third aim was to develop practices to monitor the change in costs and consequences through time.

Objective 3: Management of saline resources

This objective dealt with the concept of living with salinity. It aimed to "develop an understanding, and demonstrate principles and practices, which enable the beneficial use or rehabilitation of landscape resources impacted by dryland salinity".

The rational was based on the understanding provided by NDSP Phase I that the extent of salinity was likely to increase in all States irrespective of the kinds of preventative measures envisaged. The inevitable expansion of saltland was likely to challenge resource managers to ensure that affected land would not further degrade and create other NRM problems.

So there is an incentive to manage rather than ignore saltland, NDSP took the lead set by the Productive Use and Rehabilitation of Saline Lands (PUR$L) initiative to advocate saltland management as an opportunity rather than a sign of defeat.

Strategies and actions under this objective include R&D into saltland agronomy, aquaculture, biodiversity conservation and development of new commercial enterprises on saltland. It had a strong focus on trialing and demonstrating new management practices.

Objective 4: Landscape processes

This objective was mainly concerned with basic research into biophysical aspects of salinity. It aimed to "develop an understanding of landscape processes and ecosystem functions in areas affected by, or at risk from, high water tables and salinity".

The rationale for this objective was twofold. First, despite knowledge of the fundamentals of salinity's causes and impacts, there remained some questions about movement of salt through catchments and about the relationship between salinity processes and other forms of terrestrial and aquatic degradation. Second, while the impact of salinity on biodiversity was tacitly acknowledged, little research had been done to quantitatively understand it.

The main thrust was therefore to establish scientific principles and knowledge about salinity and the linkages between biodiversity conservation, use of land and water resources for primary production and amenity values from resources threatened by salinity.

THEMES

Investment in NDSP by partner organisations was promoted by developing seven distinct themes. These themes addressed the specific concerns of certain stakeholder groups and therefore helped to provide a focus for partners to target their investments. The themes were designed to cut across the four objectives. Some themes canvassed multiple objectives, while in other cases a theme was dedicated to meeting a single objective — as shown in Chart 1.1.

The seven themes were designed to examine all aspects of dryland salinity, ranging from the physical causes of salinity and its impacts, through to innovative solutions to tackle the problem — including institutional arrangements and technical treatments.

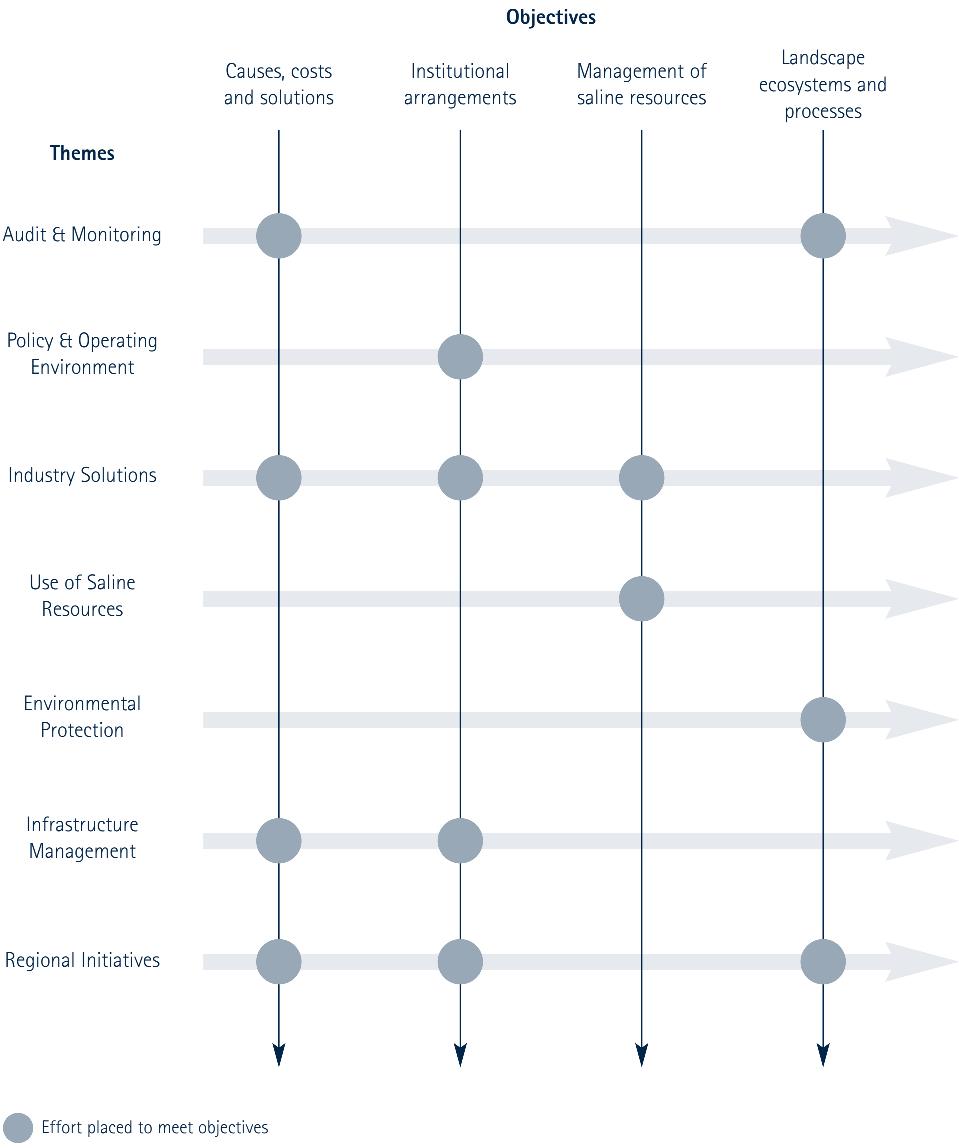
The themes are:

1. **Audit and Monitoring** — to examine the extent and rate of change in dryland salinity and its impacts at regional and national scales.
2. **Policy and Operating Environment** — to generate knowledge that would support better policies, institutional structures and incentives for promoting appropriate dryland salinity management.
3. **Industry Solutions** — recognising that agricultural industries are in the front line with respect to suffering losses from salinity, but are also part of the solution and in a position to contribute significantly to salinity management. NDSP had a heavy focus on the grains industry, as this sector is expected to be most at risk from salinity.
4. **Productive Use of Saline Resources** — to look at ways to live with salt by viewing salinity as a new resource. Projects that examined new farming systems and industries that profitably use or rehabilitate saltland, were canvassed.
5. **Environmental Protection and Rehabilitation** — to develop ways of measuring the environmental impacts of salinity and understanding how to control them. Salinity has potential to threaten natural areas, resulting in a loss of biodiversity, habitat and landscape amenity values.

6. **Infrastructure Management** – to manage engineering aspects of salinity, and its impact on public and private infrastructure.

7. **Regional and Community Initiatives** – to promote investment in a national network that would link different State, regional and community activities.

Chart 1.1. Cross-cutting themes and objectives

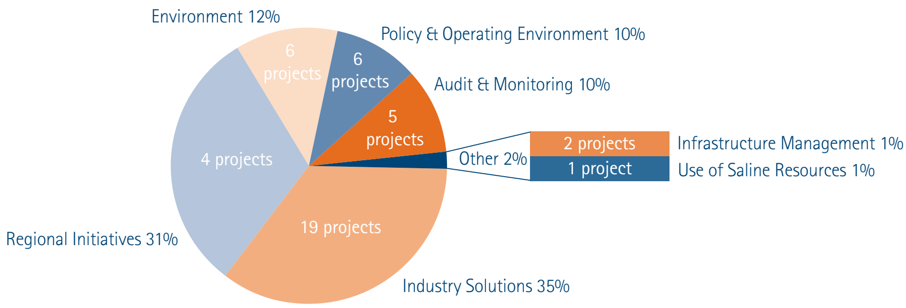


NDSP INVESTMENT STRATEGY — PHASE II

The second NDSP phase had a cash budget of about $24 million over five years. About 92 per cent of the budget was spent on R&D and project-related extension activities. In all, 43 projects were undertaken, most managed by LWA on behalf of the program's partners, but some managed externally by one of the partner organisations. Most projects fell under the *Industry Solutions* theme, although a few had quite small funding inputs (Chart 1.2).

Chart 1.2 shows funding allocated to each theme. Funding levels varied across themes, partly reflecting the different priority afforded to each theme and interests of parties in the NDSP consortium. Further, some themes were more expensive to investigate than others due to the nature of the research involved.

Chart 1.2. Allocation of funds and number of projects across themes



Source: NDSP

Two-thirds of the funding was allocated to just two themes, namely *Industry Solutions* (35 per cent) and *Regional and Community Initiatives* (31 per cent). The GRDC was a heavy supporter of *Industry Solutions*. It funded or co-funded five projects under this theme. The lion's share of funding allocated to *Regional and Community Initiatives* was used to support two major projects — *Million Hectares for the Future* and *Tools to Investigate and Plan for Improved Management of Salinity*. These were collaborative projects involving the GRDC, LWA, MDBC and State agencies.

Much of the *Audit and Monitoring* work was done in collaboration with the National Land and Water Resources Audit. It received 10 per cent of the funds. Relatively minor levels of investment were made in *Productive Use of Saline Resources* ($200,000) and *Infrastructure Management* ($300,000). Despite this, NDSP was the catalyst for a $9 million investment by Australian Wool Innovation and Meat and Livestock Australia in the Sustainable Grazing on Saline Lands initiative.

Investment in communication

About six per cent of the budget (or $1.5 million) was used to finance the communication effort, including the Communications Team and products such as *Salt* magazine, *Focus on Salt* newsletter and the NDSP web-site. This expenditure was not tied to specific projects, but used to implement the Communication Strategy. If extension and communication activities associated with some R&D projects are taken into account, the money spent on communication would be considerably higher. Moreover, some R&D projects would be more appropriately categorised as communication projects. Indeed, if the *Million Hectares for the Future* and *Salinity Tools* projects were viewed this way, allocation to communication would be around 20 per cent of total budget (plus individual project communication expenditure).

Was the strategy well targeted?

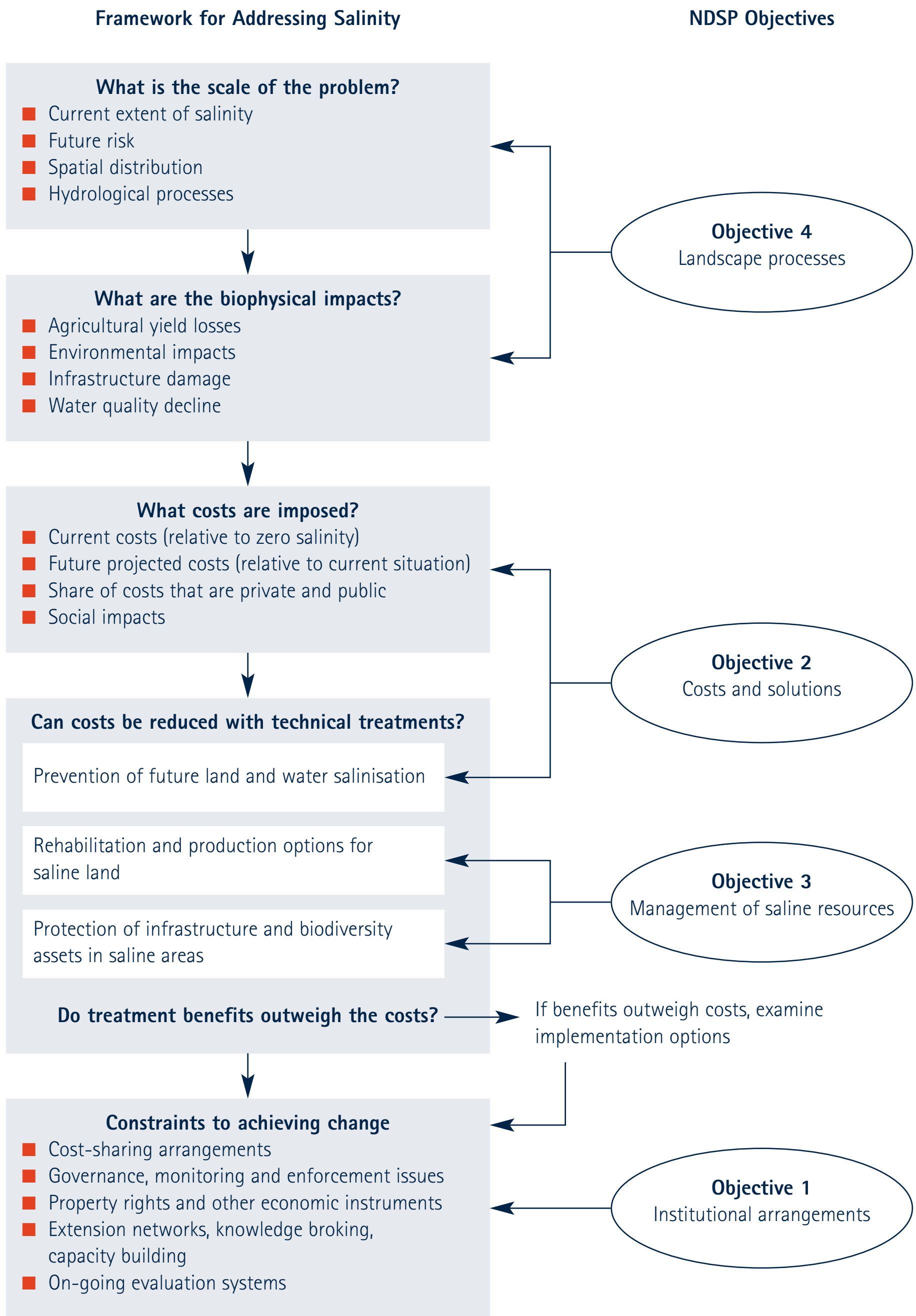
To examine the investment strategy's appropriateness, a cross-check of the four program objectives was made against a decision-making framework developed by the National Land and Water Resources Audit (NLWRA 2002). This framework, shown in Chart 1.3, is a stepped guide to help resource managers make investment decisions to manage NRM problems. It prompts the decision-maker to consider:

- The current and projected geographic extent of the NRM problem;
- Its biophysical impacts;
- Causal factors;
- Economic significance (current and future costs);
- Potential treatments to rectify the problem and their cost effectiveness;
- Net benefits of proposed management options in economic, social and environmental terms; and
- Constraints to implementing management options.

The framework highlights the need to understand the basic science underpinning salinity, its scale, the need for technical solutions (to prevent, rehabilitate and productively adapt), and know about alternative institutions and support structures for dealing with salinity. NDSP objectives line up fairly well with these information requirements. They cover biophysical aspects of salinity to institutional constraints and policy issues. However, the stated objectives — particularly Objectives 2 and 3 — do not explicitly consider the potential net benefits of control treatments. It is here the program could have been strengthened by examining how salinity management might deliver a net benefit.

The challenge faced by NDSP Phase II was that it dealt with such a broad range of salinity issues. Whereas the main paradigm of salinity management in the first phase was largely an agricultural one, the second phase tried to deal across the spectrum of salinity issues, from rural to urban and production to conservation. From an investment perspective, this meant the program was dealing with different issues in different environments, making it difficult to apply a simple investment framework to identify knowledge gaps and target R&D effort for greatest return.

Chart 1.3. Matching NDSP objectives to a salinity management framework



2. THE EVALUATION APPROACH

THE EVALUATION USED AN INPUT-OUTPUT-OUTCOME framework to assess performance. This approach examines the different inputs brought to bear on salinity management by NDSP and other organisations. The outputs from NDSP projects and activities are identified and, where possible, progress in salinity management is mapped back to these outputs. In an environment where multiple players contribute to similar goals, it is not always possible to attribute outcomes to a particular organisation. In these circumstances, a judgement is made as to whether NDSP's contribution was critical to realising the outcome. Consideration is also given to whether the outcome would have been achieved without NDSP. Another test of the program's effectiveness is whether or not NDSP has successfully filled gaps in resolving the salinity problem.

TRIPLE BOTTOM LINE FRAMEWORK

The evaluation uses a triple bottom line (TBL) approach to map outputs to beneficial outcomes. The concept of TBL accounting is not new. But it has become more important as stakeholders increasingly demand an account of what impacts a program has had, not just on the financial bottom line but also social and environmental benefits. The aim is to provide clear and testable mapping from program outputs to impacts that influence society's well-being. Chart 2.1 outlines an application of the framework to salinity.

Inputs

NDSP had four main inputs to tackle dryland salinity. These were:

- New R&D to fill knowledge gaps;
- Communication and knowledge broking services;
- Coordination services to make extension initiatives and research efforts more effective; and
- Quality assurance services to improve the technical quality of R,D&E.

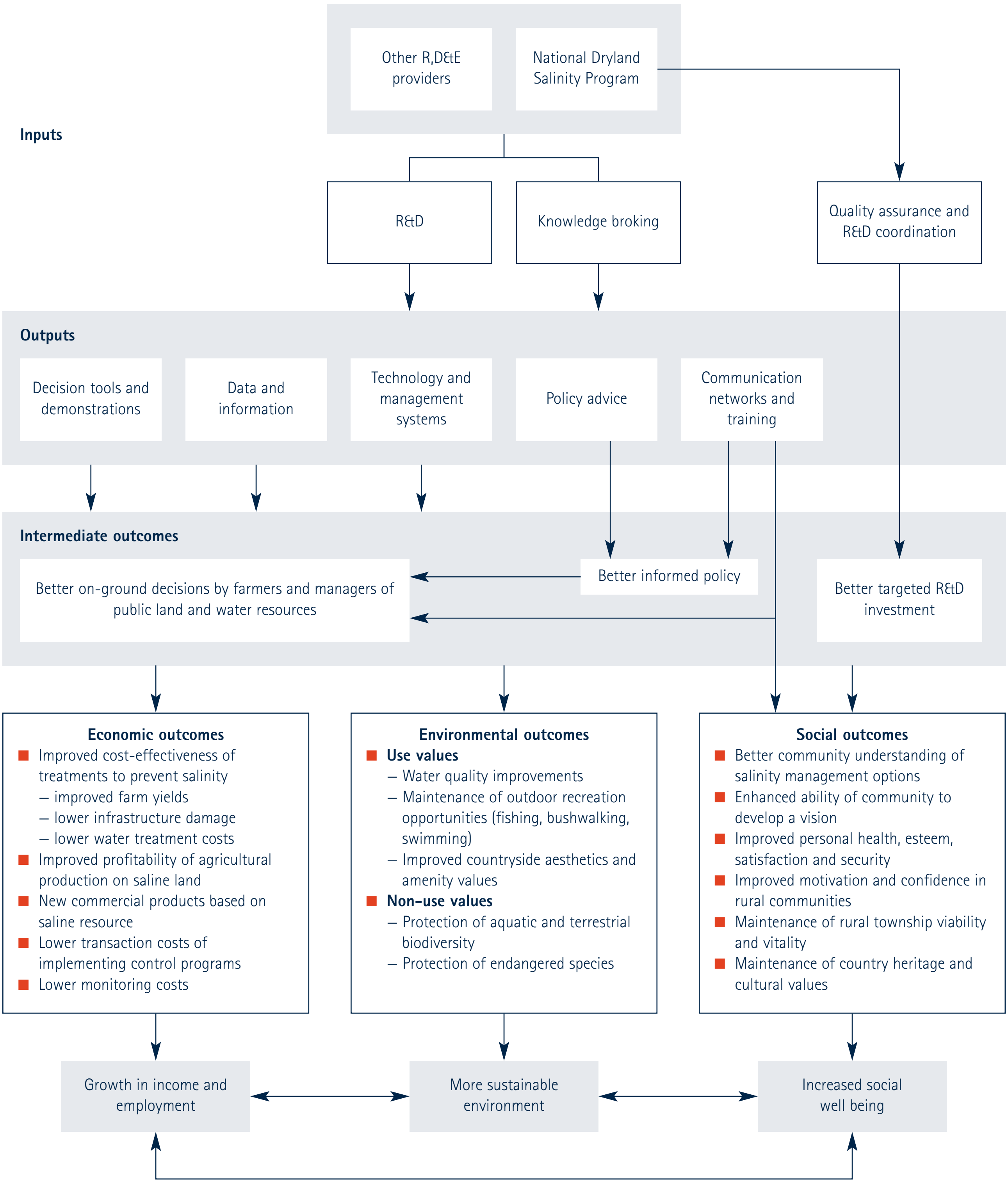
These inputs must be considered alongside other research provider inputs. For example, the CRC for Plant-based Management of Dryland Salinity was established in July 2001 with a budget of $107 million over seven years (about $15 million a year). The CRC is a national research organisation with 284 researchers representing nine partner organisations across four States. While it is difficult to determine the total expenditure on salinity R&D, data from the Australian Bureau of Statistics indicate that about $341 million was spent nationally in 2000–01 on NRM research (ABS 2001). Salinity expenditure would be a subset of this total. NDSP's budget for R&D and related costs in the past 10 years has been $41 million.

Outputs and the adoption process

NDSP outputs include data, decision tools, new knowledge, new technology and demonstrations. Other less tangible outputs include enabling processes such as policy advice, information networks and training.

For these outputs to yield benefits, they need to be adopted and lead to better decision-making by private individuals, industry groups or public agencies. It is helpful to view the adoption process as having four essential elements. As depicted in Chart 2.2, decision-makers must be aware of issues, understand the problem, be motivated to address it (that is, they must perceive benefits outweigh costs) and have the capacity to innovate. Valuable outputs are those that reduce deficiencies in one or more of these four elements — thus increasing favourable conditions for adoption and/or leading to better decision-making. Note that in some

Chart 2.1. The triple bottom line framework



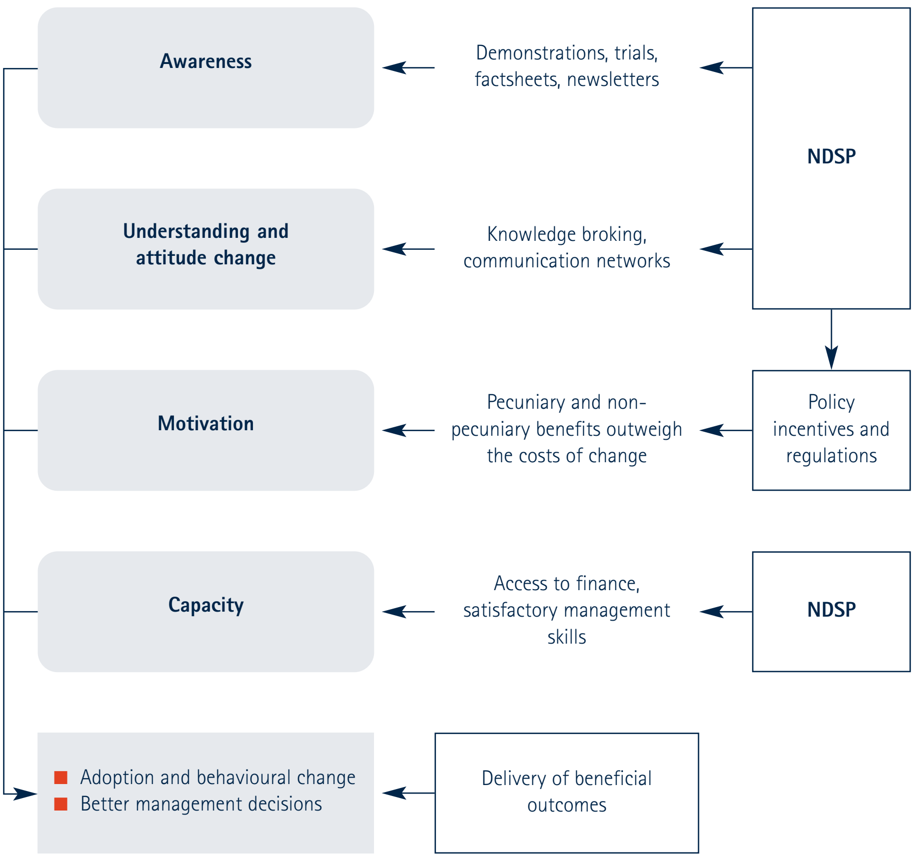
circumstances a good decision may be to do nothing in response to salinity, so R&D outputs can promote change and prevent wasteful expenditure on unprofitable actions.

NDSP was able to use several levers to influence change. For example, it was able to reduce the transaction costs of accessing information, partly through providing communication networks. It was also able to inform industry and government policy. Government policy can have a profound impact on incentives for farmers and other land managers.

The adoption process depicted in Chart 2.2 is helpful to explain why beneficial outcomes may not happen, even where the program has delivered many outputs. Unless outputs are well targeted and overcome all gaps in the adoption chain, behavioural change may be limited. For example, some salinity control treatments may not be taken up if enough landholder incentives are not provided through the policy-operating environment to help landholders supply public good benefits such as wetland protection. If an individual perceives private benefit from a salinity treatment as small relative to costs incurred, the treatment has little likelihood of being adopted — beyond altruistic actions.

Chart 2.2. Four necessary elements to facilitate adoption

Data source: CIE chart.



Most outputs are only valuable if they contribute to a change in the way things are done. An exception is community awareness and understanding, which has a value in its own right regardless of whether or not it influences behaviour. Greater understanding leads to an improved vision of what the future holds for salinity-affected communities.

Intermediate outcomes

On the road to adoption, we expect to see intermediate outcomes, which are attitudinal and infrastructure changes, produced by outputs, that allow people to accept new technology more readily. Intermediate outcomes include improved on-ground decisions, better-informed public and industry policies for addressing salinity and better-targeted investment in R&D. The challenge is to determine the extent to which NDSP outputs have led to these beneficial changes. In some circumstances the impact of NDSP activities could be quite indirect — for example its potential influence over the R&D investments made by other organisations. We identified six indicators of intermediate outcomes:

- Increased awareness;
- Attitudinal changes and increased understanding;
- Enhanced capacity for farmers and other land managers to change;
- On-ground land use change;
- Policy changes; and
- Changes in R&D direction.

The time lag between going from outputs to intermediate outcomes through to final outcomes is variable, depending on the nature and complexity of the innovation. In some cases, the adoption timeframe could be rapid. An example might be development of a salt-resistant high yielding wheat, which is a relatively simple innovation and commercially attractive to growers. However, more often than not, salinity management tools are complex and difficult to trial or evaluate on-ground. So even if the new innovation has strong economic and practical merit, it could take time for the technology or principles to be adopted. Therefore, it is to be expected that the time lag to realising final benefits will be somewhat longer for NDSP relative to other R&D programs.

While our evaluation focused on observable outcomes which have been realised over the duration of NDSP, we made allowance for changes that might occur due to the program's legacy impacts. The important question to ask is "What would the future situation have looked like had it not been for NDSP?" Because the impacts of salinity are expected to worsen in the next 50 years or more, the assessment must involve an examination of what future costs (economic, environmental and social) are likely to have been avoided by the program.

Triple bottom line outcomes

Intermediate outcomes are a step towards final outcomes. The final link in the chain is mapping behavioural changes to tangible economic, social and environmental benefits (or costs) — known as triple bottom line outcomes. The types of potential outcomes expected to flow from salinity R,D&E were summarised in Chart 2.1.

Some outcomes can be readily valued in dollar terms. But in the context of salinity, some impacts transcend individual preferences and monetary measures – impacting on ethics, intergenerational equity and moral duties – about which economics can say little. It is clear these factors matter to people, as reflected by development of safe minimum standards, which are often built on moral imperatives and respect for basic rights and intrinsic values. Further, social outcomes are often associated with the R&D process, such as through community empowerment in the decision process. These benefits are important and should be reflected in a triple bottom line account.

This report does not provide a detailed cost-benefit analysis of program outcomes. Such an assessment would require a close examination of outputs produced by each of the 43 NDSP projects and survey information about the extent to which these outputs have been adopted by target user groups and are making a difference to the way decisions are made. Resources to undertake such a task would be exorbitant. Instead, the approach relies on asking a wide range of salinity stakeholders to make a subjective judgement of the scale of outcomes associated with the program. Wherever possible, available survey data is used to assist make these judgements. Estimates of the program's potential economic impact are made by a series of what if analyses.

DATA SOURCES

The evaluation draws on a variety of data:

- Stocktake reports produced by NDSP that document each project's outputs;
- Surveys quantifying uptake of salinity treatments, decision aids, management principles and other research outputs;
- Attitudinal surveys focusing on salinity and Landcare issue consultations with researchers and NDSP partner organisations; and
- Proceedings of an NDSP workshop held in March 2003 at which researchers reported their findings.

The survey

While the information sources above were helpful to understand salinity management achievements, there is still relatively little information available to assess on-ground change. There is a lack of State or nationally-based benchmarking, monitoring and evaluation frameworks to access reliable data. Where substitute frameworks exist, frequently data collected in one period have been inconsistent with later collections, which makes it almost impossible to draw sensible conclusions about progress.

With scarce information available, about 200 stakeholders and researchers were surveyed to assess perceptions about the extent of progress in salinity management in the past five years. Respondents were asked to:

- Rate the level of progress made in salinity management in the past five years (across a number of discipline areas);
- State which single aspect of salinity deserves highest priority for future R&D;
- Rate whether they are now better equipped to manage salinity or advise on salinity issues; and
- Assess costs being imposed by salinity and the extent to which NDSP might ultimately reduce these costs.

2. THE EVALUATION APPROACH

The web-based survey was administered to a sample of researchers and stakeholders drawn from NDSP's database and subscribers to *SALT* magazine, *Focus on Salt* and *SaltList* (all NDSP products). Participants included people from all States and Territories.

The survey results are incorporated into a wider assessment of NDSP's achievements outlined in the next section of this report.

3. KEY ACHIEVEMENTS AND OUTPUTS

OVER THE LIFE OF NDSP A SIGNIFICANT CHANGE in the way salinity management is approached at policy, management, production and conservation levels can be witnessed. NDSP produced a diverse range of outputs, including physical products such as research reports, decision aids, web-sites, demonstration sites and salinity risk maps — to less tangible outputs such as communication networks and management principles to inform policy, management and on-ground action. Here the program's key achievements over the last five years on a theme-by-theme basis are examined.

Where there is evidence of NDSP influence, a key conclusion, management tool or example of adoption, the following icons have been used to highlight them:

Key NDSP influence | *Key NDSP tool* | *Evidence of adoption* | *Key NDSP conclusions*

BOX 3.1. AUDIT AND MONITORING PROJECTS

- *Extent and Impacts of Dryland Salinity – National Land & Water Resources Audit*
- *Salinity Hazard Mapping for Queensland Cropping Lands*
- *Water Table Changes in NSW Western Slopes*
- *National Evaluation Framework*

AUDIT AND MONITORING THEME

The goal of the *Audit and Monitoring* theme was to better understand the physical extent of dryland salinity and processes governing its future spread. Studies were centred at regional or catchment level, with less attention given to paddock level measurement and modelling. Four projects were funded to examine these aspects (Box 3.1).

National Salinity Audit — an assessment of future salinity risk

The Australian Dryland Salinity Audit project mapped, at national level, areas at risk of developing shallow water tables in the next 50 years. The project brought together knowledge and data held by State agencies, developed data-sharing protocols and identified data gaps. The Salinity Audit has outlined the dimensions of the problem in terms of space and time.

- An estimated 5.7 million hectares is at risk from shallow water tables – projected to increase to 17 million hectares if the status quo exists.
- The mapping has helped estimate current and future salinity costs – and shown salinity costs extend beyond the farm gate.
- This information has focused attention on salinity and motivated formation of the National Action Plan for Salinity and Water Quality.

Key NDSP influence

Turning the spotlight on Queensland

The *Queensland Hazard Mapping* project examined prospects for future worsening of salinity in Queensland cropping areas. Until recently, salinity was not considered a significant threat there. However, this project found that 21 per cent of Qld's cropping land was at high risk from dryland salinity over the next 50 years. This finding attracted significant media attention and, with other work emerging from Qld, has raised public awareness of salinity as an issue. An important policy question is how much native vegetation should be retained as a buffer against future salinity. This project provides estimates of the impact of further clearing on water tables.

Key NDSP influence

Understanding long-term groundwater trends

A detailed study in the NSW western slopes aimed to disentangle the effects of land use change and climate variability on rising groundwater. The project results highlight the need for careful interpretation of groundwater trends. While the general relationship between rising water tables and land clearing holds, it is modified by climatic cycles and fluctuations in annual rainfall. This means water table observations over a short period cannot be extrapolated into the future with confidence.

This work, with NDSP evaluations of salinity mapping techniques, has significantly enhanced knowledge about the strengths and weaknesses of options for determining salinity risk and hazard.

Key NDSP tool

Airborne geophysics as a tool for salinity management was a spin-off from the mining industry. NDSP benefit-cost analysis has proved airborne geophysics can be a useful tool in some circumstances, but thorough homework is essential first. The cost of flying to assess and identify salt stores below the ground can seem attractive over large areas, but still needs to be supplemented with considerable field work and expert interpretation.

The NDSP study recommended that areas be flown only when it is clear how the geophysics will inform salinity management and why conventional systems would be less effective. Individual surveys should cover at least 20,000 ha for economies of scale and be carefully matched to identify the required target. Careful consideration was needed to establish exactly what information was being sought, and therefore the most appropriate company, geophysical system, its setup and tools to use (magnetics/ radiomagnetics/ airborne electromagnetics).

To maximise potential for sound decisions when preparing farm and catchment salinity management plans, the study recommended a minimum core of datasets be used. These include bore hole data, aerial photos, satellite imagery, meteorological data and maps of terrain and geology to supplement airborne geophysics data. Following this advice can result in major savings and more reliable outcomes.

The National Evaluation Framework — a structured system for updating knowledge

In making salinity risk forecasts, there is a trade-off between the immediate need for information to make policy decisions and the accuracy of information available. Putting off the decision until better information is available is often not an option. Therefore, a need exists for judicious use of existing information combined with an efficient and effective means of updating the knowledge base over time. The National Evaluation Framework project resulted in:

- A system for adaptive updating of knowledge;
- Guidelines to monitor key biophysical attributes that define current and future dryland salinity risk; and
- Recommendations about the spatial and temporal design of monitoring programs in each groundwater flow system type.

Evidence of adoption

The adaptive framework provides a means for State agencies to carry out management, monitoring and research activities that systematically build on existing knowledge. This approach has been adopted by the Monitoring and Evaluation Working Group of the Natural Resource Management Council and will underpin monitoring activities associated with the National Action Plan (NAP) for Salinity and Water Quality.

POLICY AND OPERATING ENVIRONMENT THEME

Projects in this theme aimed to equip industry and community groups, and public policy makers at local, State and National level with knowledge and tools required to enhance decision-making. The theme also addressed the question of whether new institutions, policy instruments or support structures are needed to help change land use management. The main projects are listed in Box 3.2.

Catchment Classification — a tool for planning and evaluation

The Catchment Classification project showed we are not dealing with one salinity problem. It is now known that, even in the coarsest of aggregations, at least three different types of groundwater flow systems (GFS) exist, defined as local, intermediate and regional systems. Each has different characteristics in terms of the distance between recharge and discharge sites, time lags involved in reaching a new water table equilibrium and responsiveness of water tables to salinity control treatments. The hydrogeological and topographical features associated with each GFS provide a basis to evaluate the effectiveness of salinity management options in particular catchments. Specific outputs are:

- A low-cost means of understanding — at a broad level — hydrological processes at work in a given catchment without having to collect detailed information. This is achieved by transferring knowledge from well-documented catchments to other, less studied catchments.
- Development of a national map that classifies catchments according to the three types described above, which is a significant advance in guiding regional management strategies. The framework was used by the National Land & Water Resources Audit to map salinity risks across Australia.
- More detailed assessments at a 1:250,000 mapping scale have been conducted in the Murray–Darling Basin and Queensland. These assessments are assisting communities to identify priority areas for treatment.

BOX 3.2. POLICY AND OPERATING ENVIRONMENT PROJECTS

- *Catchment Classification – Groundwater Flow Systems*
- *Determining the Costs of Dryland Salinity*
- *Structural Adjustment in Agriculture and the Capacity to Implement Catchment Plans*
- *Capacity of Local Government to Contribute to Management of Dryland Salinity*
- *Enhancing Institutional Support for the Management of Salinity*

Evidence of adoption

The Corangamite Catchment Management Authority (CMA) in Western Victoria used the *Groundwater Flow System* approach and *FLOWTUBE* to develop its second generation Salinity Management Plan.

The CMA picked up the technology to describe how the catchment works and what intervention methods are possible. Following consultation across the region and a project applying NDSP technology, 17 systems were identified and the CMA has been able to match investment in its Management Plan with the particular groundwater flow system. The CMA is now applying other tools to prioritise risk in sub-catchments and is looking at GIS information in a pixilated format (20 m x 20 m) to enable the region to prevent rather than cure the impacts of dryland salinity by dealing with threat rather than risk.

Key NDSP conclusions

Of more fundamental importance are the new principles established by this work. First, it has led to a new appreciation of the long time lags between changes in land use and subsequent responses in the water table. Even with significant reductions in recharge it would take decades to establish a new equilibrium in most groundwater systems. The externality concept, whereby the actions of some people impose a net cost on others, may not always be valid for dryland salinity. Hence encouraging landholders to internalise off-farm 'costs' by creating markets in recharge credits and debits may not be appropriate for all areas. For example, 'leaky' farming systems in cleared catchments can cause salinity but they can also provide twice as much water for consumptive use compared with the amount of water available pre-clearing, and can provide significantly more water than low-recharge farming systems. Socio-economic benefits generated from the 'excess' water, and from the 'leaky' farming systems themselves, may outweigh salinity impact costs or the net benefits of recharge control. **These two findings have profound implications for salinity management.**

A snapshot of the current costs of salinity

The *Costs of Dryland Salinity* project (also known as the 'Costs' project) had the dual aim of assisting community groups to understand the full impacts of dryland salinity in their catchments and improving the consistency with which costs are estimated through the development of a set of guidelines.

Key NDSP tools

- A geographic information system (GIS) database has been produced and is accessible in an interactive form on the NDSP web-site.
- Guidelines for estimating salinity costs are now available to community groups needing to support their catchment plans.
- The study found that salinity costs $304 million a year in the Murray–Darling Basin, which includes agricultural yield losses, in-situ infrastructure damage and costs associated with saline water. Impacts to irrigated agriculture were not quantified.
- The project has raised awareness of salinity impacts but does not make future cost projections, which is the more relevant measure for policy makers.

Evidence of adoption

Project results, together with methodology reports that describe how to assess impacts and costs of dryland salinity, are being used extensively across Australia. Examples include:

The Glenelg-Hopkins CMA in Victoria has used the project outcomes to prepare the region's Second Generation Salinity Strategy.

In the tender document for the Wimmera CMA's Second Generation Salinity Strategy, one tender specification was that the successful consultant must use the methodologies developed by the Costs project to assess salinity impacts and costs.

NSW Agriculture is using the project results to develop and implement a computer model to assess the marginal benefits and costs of reducing recharge across various NSW catchments.

The information is also being widely used by schools, universities, private consultants, industry groups and local government.

Salinity information made accessible to local government

Another project focused on local government's role in managing salinity. This was essentially a scoping study to find out how local government viewed its role in salinity management, constraints on its further involvement and contributions it could potentially make. The project served to raise awareness among the 450 regional local governments through dissemination of an interactive CD-based information kit and focus group discussions.

New directions for institutional arrangements

Key NDSP tools

This project aimed to build capacity among policy makers to use the principles of institutional arrangements that facilitate change. It examined the current regulatory environment, incentive structures and support networks which farmers and other land managers currently operate in. Building on this platform, the project established a set of principles for understanding the requirements of a national policy framework.

INDUSTRY SOLUTIONS THEME

Projects funded under the *Industry Solutions* theme investigated alternative technologies to prevent salinity, rehabilitate saline land and provide options for adaptive management. The projects were mostly focused at farm-scale. Results have narrowed down feasible options, made information more accessible to farmers and developed new monitoring technology. However, none of the treatment options examined are stand-out winners in widespread applicability and commercial viability for farmers. A selection of projects is reviewed here (Box 3.3).

BOX 3.3. INDUSTRY SOLUTIONS PROJECTS

- *Evaluating the Impacts of Deep Drains on Crop Productivity and the Environment*
- *Farming Systems with Lower Recharge for Western Australia*
- *Million Hectares for the Future*
- *A Simple Device for Monitoring Deep Drainage*

Lucerne can be profitable — up to a point

The *Lower Recharge Farming Systems* project examined the potential for lucerne pastures to be a profitable way of managing on-farm salinity. The project took a participatory R&D approach which involved trialling lucerne on Western Australian properties at a commercial scale and holding field days around these trials. The results were again confirmed in the economic analyses associated with another NDSP project, *Economic Evaluation of Salinity Management Options in Cropping Regions of Australia*.

Key NDSP conclusion

- Lucerne has potential to reduce groundwater tables, particularly in areas underlain by a local aquifer.
- Lucerne is a workable, profitable system on some farms, but not a universal solution. Only a relatively small area can be grown, after which extra lucerne production cannot be used profitably by livestock.
- It is now understood that perennial-based farming systems are only commercially viable in a narrow range of circumstances, and will require further R&D if they are to become a viable option.
- The project has helped increase the area of commercial-scale lucerne trials in WA, which will be useful to monitor the performance of this production system in the long-term.

Key NDSP influence

The results of NDSP's production research may appear disappointing at first, however they have contributed to arguments in support of the CRC for Plant-based Management of Dryland Salinity as well as a new farming systems program, Grain & Graze, supported by MLA, LWA and GRDC. Without further research to develop profitable farming systems (including radical notions of farming systems), it is unlikely extensive preventative measures will ever be adopted across Australian landscapes at the scale needed to deal with salinity.

Evidence of adoption

Robert Beard from Meckering WA was a collaborating farmer on the *Lower Recharge Cropping Systems* project. "Knowing the economics of grazing lucerne will help determine our plans for paddock rotations in the future," he said. "A well designed plan may mean rearranging paddocks to realise the full potential of lucerne in the farm's rotations. We are also bearing in mind the ability of lucerne to use more water than annuals over the year, therefore preventing or slowing down the spread of salinity."

Key NDSP conclusion

Deep drains can work but disposal remains a problem

About 10,000 kilometres of deep drains have been constructed on rural properties throughout Australia, suggesting that farmers perceive some on-farm benefits associated with drainage. However, before a recent study in the WA eastern wheatbelt, little scientific evidence supported these beliefs. The project found that, in some conditions, drains reduced water tables for 200–300 metres each side. This finding helps explain farmers' enthusiasm for constructing drains and demonstrates their potential to be a useful treatment for salinity in some circumstances. However, the results are not universal, and the adverse impacts of saline water disposal on the environment and water resources remain an outstanding issue and a priority for further R&D.

Building farmers' skills and capacity to respond to salinity

The *Million Hectares for the Future* project arose out of an industry concern that markets for Australian grain could be jeopardised if consumers perceived that grain was being grown using unsustainable farming practices. The project's aim was to develop an environmental improvement system (EIS) and encourage the equivalent of one million hectares of farmland to be managed under the system.

Key NDSP tools

- The EIS aimed to provide farmers with indicators to monitor their recharge and tools to identify the salinity benefits of different treatments. To that end, a leakage calculator has been produced, which has increased awareness of salinity among group members.
- But farmers expressed little interest in developing and adopting an EIS because they remain unconvinced about the validity of salinity risk information and the benefits of management options — both in terms of on-farm profitability and catchment benefits.
- Nevertheless, the project made headway in establishing grower networks in WA and South Australia to share information about various approaches to tackling salinity.

Making groundwater monitoring easier

Key NDSP tools

A drainage meter has been produced by CSIRO with NDSP funding that is capable of monitoring the amount of water that drains below crop root zones to recharge groundwater. The meter is buried under the crop and drainage rates can be monitored by remote control on a computer.

- Data are now being collected and distributed to participating farmers on a routine basis via the Internet.
- Several Landcare groups are testing the meter but the cost is prohibitively high for widespread uptake by individual farmers.

Key NDSP conclusion

- The incentive for monitoring is weak in situations where there are few economically viable solutions to reducing recharge.

PRODUCTIVE USE OF SALINE RESOURCES THEME

Productive use of saline land — plenty of options but few winners

The *OPUS* project (*Options for Productive Use of Salinity*) focused on the concept of using salinity as a new resource. It was a scoping project that investigated about 140 different innovations and enterprises built around using saline land or water. The main output was a database containing a brief synopsis of each innovation, including key contacts to assist users with further information.

- The database is accessible from NDSP web-site. The demand for it is strong, as evidenced by the 2664 hits on the *OPUS* web-site section from December to February 2003.
- Five industries were singled out for an economic evaluation. While saltbush pastures are economic in some circumstances, many other innovations are either uneconomic or only feasible in niche applications.

This project was found to have had an enormous impact beyond its envisaged scope. Many of those surveyed suggested that the project helped the PUR$L initiative place the 'living with salt' philosophy on the national agenda. One of the project's conclusions, that only saltland pastures will provide a means of adapting to salinity over extensive areas, formed the basis of a $9m R&D investment by AWI and MLA under the Land Water & Wool initiative, of which the largest of the seven on-farm, NRM-focused sub-programs is *Sustainable Grazing on Saline Lands (SGSL)*. The NDSP Communication Team provided strategic, regional and national communication support for SGSL.

BOX 3.4. PRODUCTIVE USE OF SALINE RESOURCES PROJECTS

- *Options for the Productive Use of Salinity (OPUS)*
- *Sustainable Grazing on Saline Lands (on-going to 2006)*

Key NDSP tools

Key NDSP influence

ENVIRONMENTAL PROTECTION AND REHABILITATION THEME

This theme mainly dealt with developing a better understanding of the fundamental biophysical relationships between land use change and rising water tables. A core objective was to examine environmental impacts of salinity — terrestrial and aquatic. In all, six projects were undertaken to investigate various aspects of these relationships (Box 3.5).

Modelling provides new insights for water resource managers

Catchment reafforestation activities produce a range of impacts that are difficult to quantify and predict. NDSP has funded modelling work using a geographic information system (GIS) version of a water balance model to simulate trade-offs between water yield and salt loads in catchments. This model is being used by regional groups and State agencies for planning. For example, it has been used to estimate changes in water security in the Goulburn-Broken Catchment under various levels of plantation forestry and has been applied by State agencies to estimate the contribution of irrigation activities to salt loads discharging into waterways.

This modelling work is important to ensure that when decisions are made about salinity treatments, other unintended problems are not created. For example, treatments to reduce recharge may also reduce run-off and hence potential water yield (and streamflows) under some circumstances. This understanding suggests catchment managers need to proceed with caution when implementing certain treatments that have been considered as best-bets in the past.

BOX 3.5. ENVIRONMENTAL PROTECTION AND REHABILITATION PROJECTS

- *Predicting the Combined Environmental Impact of Catchment Management Regimes on Dryland Salinity*
- *Risk and Restoration Potential for Remnant Vegetation in Salinising Landscapes*
- *Understanding the Recruitment Biology of Vegetation Communities on Saline Soils*
- *Assessment of a System to Predict the Loss of Aquatic Biodiversity from Changes in Salinity*
- *Generation and Delivery of Salt and Water to Streams on a Catchment Scale*
- *Biogeochemical and Physical Processes in Saline Soils and Potential Reversibility*

Key NDSP conclusions

Evidence of adoption

In the Goulburn-Broken catchment, there are plans to convert large areas of pasture to forestry plantations in the coming decades. However, large-scale afforestation development can significantly alter the hydrologic regime and thus affect water allocation.

This study evaluated the impact of converting pasture to blue gum plantations on mean annual water yield and flow regime in the Goulburn-Broken catchment by combining a simple mean annual water balance model with a plant growth model (3PG) to estimate reduction in mean annual water yield.

The results showed the maximum reduction in mean annual flow would be eight per cent for Lake Eildon and 14 per cent for Goulburn Weir if all suitable areas are planted to blue gum. However, under a moderate scenario where social and economic factors were considered, the area of blue gum plantation would be significantly smaller. As a result, reduction in mean annual flow would be two per cent at Lake Eildon and four per cent at Goulburn Weir.

The effect of plantations on flow regime was also investigated by linking flow duration curve analysis with data from paired catchment studies. It was found plantations would significantly reduce low flow. When combined with the system simulation model for Goulburn, it was predicted that the fraction of time water allocations are less than 100 per cent increases from three per cent to seven per cent under the maximum plantation scenario. The model also predicted that unregulated flows would decrease by six per cent and 27 per cent under the moderate and maximum scenarios, respectively.

Environmental impacts better understood — but it's still early days

Several projects examined the environmental impacts of salinity. The emphasis was on developing indicators of critical thresholds, above which salinity might cause irreversible damage. Several outputs have stemmed from this work:

Key NDSP tools

- A method to assess the likely fate of Yate woodland in areas at risk from waterlogging and salinity;
- A monitoring system which uses the density of macro-invertebrates to indicate aquatic biodiversity;
- A decision tree approach to developing options for managing and prioritising protection of remnant vegetation in salinity-prone areas; and
- A system to classify saline soils according to their soil chemistry. Indicators have been developed for each of 22 different saline soils and guidelines produced on how to manage them.

While these projects have contributed to our basic understanding of some types of environmental impacts, the research has possibly raised more questions than answers.

INFRASTRUCTURE MANAGEMENT THEME

This theme dealt with potential costs of salinity damage to infrastructure and examined alternative engineering options to protect assets from damage. The cost of *in situ* damage to public and private assets such as roads, buildings and railways was quantified, together with *ex situ* impacts on infrastructure caused by deteriorating water quality. Box 3.6 lists the projects undertaken under this theme.

Putting a number on infrastructure damage costs

The *Costs* project estimated that present value cost of damage to public and private infrastructure could outweigh the cost of agricultural yield losses. Over the next 20 years, infrastructure damage was estimated to represent 70 per cent of the total costs of salinity, with the other 30 per cent being due to yield impacts.

- The *in situ* costs of salinity damage to infrastructure are estimated at $89 million per year and could be 70 per cent higher by 2020. In net present value terms this equates to $341 million over 20 years.
- The net present value of a five per cent increase in water salinity, turbidity and sedimentation by 2020 is estimated to be $1433 million over the next 20 years – attributable to increased water treatment costs and repair/replacement costs.
- While the accuracy of these estimates needs verification, these results have raised awareness among the community and decision-makers that salinity impacts are not just an agricultural problem.

Engineering options can be cost effective in some situations

The *Engineering Options* project collated information on a broad range of engineering techniques to control salinity. It identified situations where engineering options are likely to have most application, their relative effectiveness and costs of implementation. It also reviewed constraints associated with the technologies, such as environmental impacts of salt water disposal.

- A web-based decision support tool was developed which allows users to access fact sheets on different options (including groundwater pumping, surface drainage and sub-surface drainage) and apply basic cost-benefit modelling.
- The review has shown that engineering options can be cost effective in some situations, particularly for protection of high value assets (such as wetlands) where a relatively quick response is required.
- A separate study was commissioned to examine the economic and technical feasibility of desalination technologies. This concluded that while desalination is becoming more affordable, the technology is only economic in situations where demand for fresh water cannot be met by cheaper sources.
- The uptake and usefulness of this information to town planners and engineers has not been examined closely. However, it is evident that NDSP is not the only program to have examined engineering options. For example, the Rural Towns Program operated by the WA Department of Agriculture has made considerable headway in evaluating the feasibility of various options for some WA towns.

BOX 3.6. INFRASTRUCTURE MANAGEMENT PROJECTS

- *Economic Appraisal of Infrastructure Assets Under Threat*
- *Evaluating the Efficacy of Engineering Options for Dryland Salinity Management*
- *Economic Assessment of Desalination Technologies*

Key NDSP tool

Key NDSP conclusions

REGIONAL AND COMMUNITY INITIATIVES THEME

FLOWTUBE — a 'what-if' tool for planners

Evidence of adoption

FLOWTUBE is a rapid catchment appraisal model capable of examining the impact of recharge control strategies on water tables. The tool was originally developed for use in Western Australia to assist the State's Salinity Council to shape its investment strategy. NDSP provided funding for the model to be refined and calibrated for use in other States. Outputs of this work are:

Key NDSP tool

- A major reappraisal of the efficacy of recharge control treatments;
- The finding that groundwater flows respond more sluggishly to recharge control treatments than was previously thought. For large parts of the landscape it is predicted that revegetation treatments will have little impact on water table rise — and what impact does occur will be a long time coming, particularly in intermediate and regional systems;

Key NDSP conclusions

- Catchment case studies from the Audit showed that large-scale tree planting would represent a very poor investment in most catchments studied (NLWRA 2001). The analysis concluded that engineering options and/or saltland production systems would be more economic than catchment-wide changes involving agroforestry and perennials.

Packaging the information in TOOLS

BOX 3.7. REGIONAL AND COMMUNITY PROJECTS

- *FLOWTUBE Rapid Catchment Assessment Appraisal Model*
- *Tools to Investigate and Plan for Improved Management of Salinity*

The *Tools* project was designed to improve packaging of salinity information for extension officers, consultants and leading growers in the Murray–Darling Basin and beyond. It also aimed to build regional networks of salinity experts. In total, about 850 people attended 36 regional workshops. The workshops used the outputs of other NDSP projects such as *OPUS* and the *Catchment Classification* work.

The project produced 40 fact sheets that take users through various aspects of salinity management.

Detailed reports were prepared for 12 catchments capturing the broad range of knowledge relevant to each. These reports, in conjunction with the workshop process, underpinned development of a number of catchment management plans across the Basin.

Evidence of adoption

Victoria's Wimmera was the first catchment in the Murray–Darling Basin to develop a Regional Information Package with the *Tools* project. Two years on, the iterative process of developing an understanding of groundwater flow systems and management options has helped shape development of the catchment's second-generation salinity management plan.

Bernie Dunn of the Wimmera Catchment Management Authority believes that the *Tools* project "assisted in challenging current paradigms".

"It has provided a useful conduit for national research and development outcomes and products," he said.

A collaborative workshop approach combining local knowledge and groundwater expertise has helped develop a new salinity management plan based on regional scale maps of groundwater flow systems.

"It's important to have outside professionals come into the region with new information and responding to regional planning needs," Bernie concluded.

4. NDSP OUTCOMES

THIS SECTION EXAMINES THE EXTENT TO WHICH NDSP outputs have contributed to (or led to) positive economic, environmental and social outcomes. The focus is on making demonstrable links between program outputs and beneficial outcomes. The real test of NDSP's relevance and value is whether its major research conclusions have filtered into management decisions, at a public/private policy level and on-farm. Survey information is drawn on to build a picture of whether NDSP outputs have had an impact on national, regional and on-farm decisions.

It is important to note that NDSP was only one source, albeit a major source, of knowledge to assist resource managers and others deal with dryland salinity. There is a high degree of noise in survey and other evaluation results that makes it difficult to directly attribute some changes specifically to NDSP.

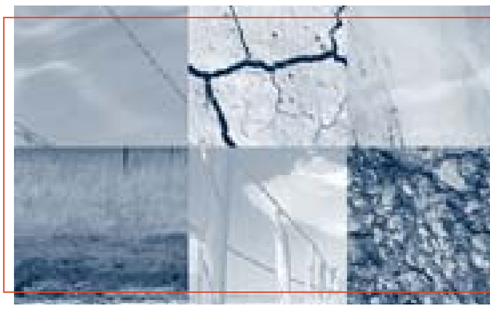
INTERMEDIATE OUTCOMES

There are six indicators of intermediate outcomes:

- Increased awareness;
- Attitudinal changes and increased understanding;
- Enhanced capacity to change among farmers and other land managers;
- On-ground land use change;
- Policy changes; and
- Changes in the direction of R&D.

Evidence of these changes is examined below. Wherever possible, inferences are made about the share of progress attributable to NDSP.

Salinity awareness has increased



NDSP has been effective in raising the profile of salinity among rural landholders, politicians and the public. It has achieved greater recognition of issues through publication of:

- National Land & Water Resources Audit salinity maps;
- Cost estimates that salinity is imposing on farmers and communities;
- Television documentaries such as the *Silent Flood*, screened at prime time on the ABC in 2001 and watched by 12–13 per cent of TV-owning households in Sydney, Melbourne, Brisbane, Perth and Adelaide, with a total audience of 864,000 people;
- Newspaper articles, such as the series that ran in *The Australian* about the impacts of salinity on the Murray River and its communities; and
- A user-friendly web-site which receives 4000–5000 visits each month (e-analysis 2003).

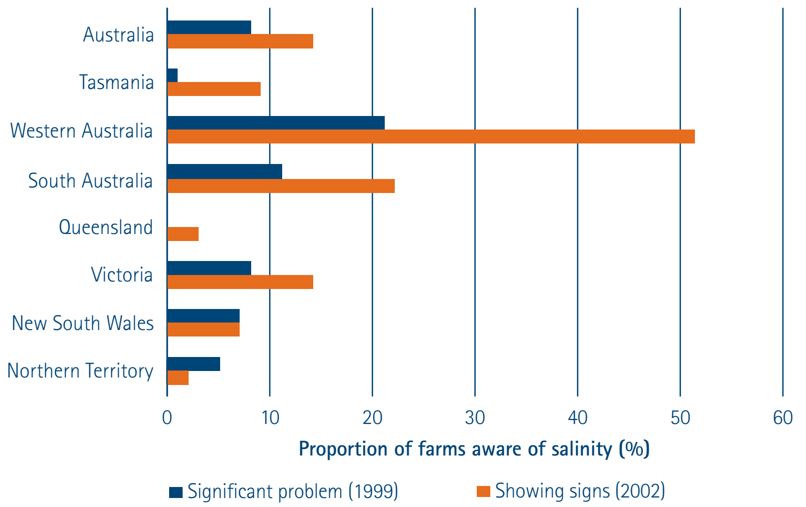
Increased awareness about salinity has translated into positive outcomes. NDSP has been largely responsible for catalysing the National Action Plan for Salinity and Water Quality (NAP), stimulating stakeholder demand for information and bringing salinity centre-stage as an important core business issue for industry associations to address (as testified by the GRDC and MLA).

Survey data suggests that farmers in most States have an appreciation of the scale of the problem on their properties (Chart 4.1). In 1999, ABARE conducted a Landcare Survey, which estimated the proportion of farmers in each State reporting salinity as a *significant problem* on their property (Alexander *et al.* 2000). In 2002, the Australian Bureau of Statistics (ABS) estimated the proportion of farmers reporting land that is *showing signs* of salinity (ABS 2002).

While the level of public and political awareness has certainly grown, it is more difficult to ascertain whether stakeholders have a greater depth of knowledge and understanding about the issues. It is one thing to raise awareness — sometimes through the inappropriate release of alarmist information — and another to improve the quality of public debate. In the interests of mustering public support and funding for an issue such as salinity, there is a temptation to overstate the issue to achieve greater impact. Alternatively, the complexity of the issue is over-simplified for a mass audience.

Mainly, NDSP has avoided this temptation, although its focus on the costs of salinity rather than the net benefits of controlling salinity has skewed the debate somewhat. There is a tendency for salinity to be viewed as a problem that must be solved at all cost — rather than concentrating on those actions which will provide a good triple bottom line return on investment.

Chart 4.1. Farmer awareness of salinity on their properties — survey evidence



Data source: 1999 figures are from the ABARE Landcare Survey (Alexander *et al.* 2000). Target population is all broadacre and dairy farms with EVAO ⩾$22,500 (85,574 farms). The 2002 figures are from the ABS Salinity Survey (ABS 2002), which is based on a target population of all Australian farms (140,856).

Farmer attitudes to salinity and land degradation — changes are evident but mixed

Long-held attitudes, cultural beliefs and social norms are partly responsible for resistance to change and can inhibit the adoption of 'environmentally friendly' land use practices. Thus, one of the objectives of NDSP's communication strategy was to enhance community understanding of salinity issues and to change attitudes.

A national survey by the Institute for Rural Futures (Reeve 2001) shows that attitudes among the farming community have changed since 1991, but the changes have been mixed across States. The main findings are:

- Nationally, levels of concern about land degradation have lessened (despite heightened levels of awareness — see Chart 4.1).
- The trend differs across States with *increases* in the level of concern being expressed by farmers in Victoria, South Australia and Western Australia. The author concluded that this attitudinal shift could be due to the seriousness of salinity problems experienced in these States and the media attention that they have received.
- The other States — Tasmania, Queensland and New South Wales — showed *decreases* in the level of concern.
- Farmers are becoming more aware of the potential for agricultural practices to have impacts beyond the farm gate and there is increasing acceptance of the need for external expertise in dealing with land degradation problems. Given the emphasis placed by NDSP on assessing and communicating the diverse range of salinity impacts, it is likely that NDSP can claim some responsibility for this growing understanding of the public impacts of salinity.
- There has been a slight polarisation of views about conservation versus development, with fewer holding a neutral position and more with extremely pro-conservation or pro-development views.
- There is a growing awareness among farmers of the complexities and uncertainties associated with degradation issues, and fewer believe there are simple solutions.

While attitudes are one variable influencing farmer behaviour, in the case of salinity the lack of cost-effective treatments for managing the problem is likely to be the bigger hurdle to overcome.

Management skills and capacity have been enhanced

It is evident that over the course of NDSP, farmers and rural community groups have increased their demand for information — possibly indicating an enhanced capacity to process and act on salinity information.

- In a survey of 136 stakeholders including farmers, advisers and public (CIE 2003), NDSP ranked well alongside other organisations as a provider of general salinity information (Table 4.2). The most popular sources of information — in order of usage rates — were *Salt* magazine, *Focus on Salt*, and the NDSP web-site. About two thirds of respondents had used these information sources. Usage rates dropped off for more specialised NDSP publications. The results should be interpreted with care because the respondent sample was drawn from a group of people who had previously signalled interest in the program.

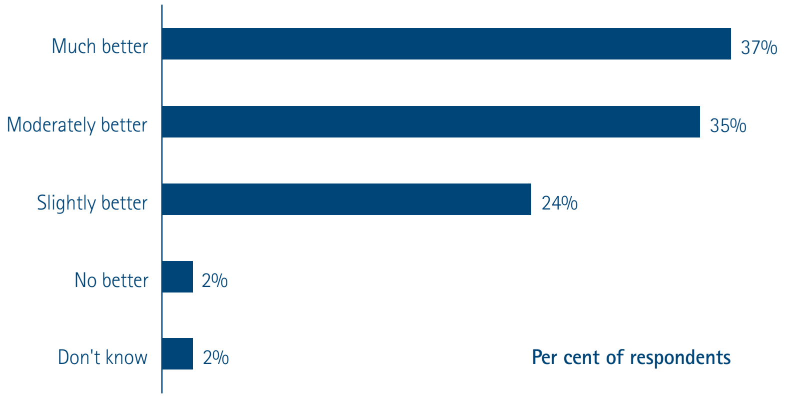
- The survey also asked people to think back over the past five years and indicate whether they now felt better equipped to manage salinity and/or advise others (Chart 4.3). Almost 40 per cent said that they felt much better equipped. Less than two per cent of respondents said that no improvement had been made.
- The NDSP web-site has been growing in popularity with its highest visitation since formal web-site monitoring and evaluation started in December 2001 being December 2002 to January 2003. The site currently receives about 4000 visits per month (e-analysis 2003).
- In another survey (GRDC 2002), the total proportion of farmers who recalled seeing *SALT* magazine had increased from 29 per cent in 1999 to 54 per cent in 2002.

Table 4.2. Usage of NDSP information products

INFORMATION SOURCE	FORMAT	PROVIDER	PROPORTION OF SAMPLE USING (%)
Salt magazine	Magazine	NDSP	66
Focus on Salt	Magazine	NDSP	62
NDSP web-site	Web-site	NDSP	59
MDBC web-site	Web-site	MDBC	53
NAP web-site	Web-site	AFFA	49
Australian Landcare Magazine	Magazine	Landcare Australia	49
Productive solutions to dryland salinity	Book	GRDC	40
SaltList	E-mail list	NDSP	37
Assessing the causes, impacts, cost and management of salinity	Book	NDSP	37
Australian Natural Resources Atlas	Web-site	NLWRA	32
Trees, Water & Salt	Book	RIRDC	26
Guidelines for identifying & valuing the impacts of salinity	Book	NDSP	24
Salinity Tools web-site	Web-site	NDSP	22
ASAN e-mail list	E-mail list	ASAN	20
Prograzier (tips & tools)	Book	NDSP	20
Dryland salinity – a farmer's guide	Book	NSW Agriculture	18
LWA CD: Sustainable primary industry reports	CD	LWA	18
OPUS database	Web-site	NDSP	16
Farming systems to manage salinity 2001	Report	WA Agriculture	16
WA Agriculture Department Farmnotes	Online factsheet	WA Agriculture	15
FLOWTUBE	CD	NDSP	9
Deep drainage calculator	CD	NDSP	4
Dryland salinity CD for local government	CD	NDSP	4

Data source: CIE survey of 136 stakeholders.

Chart 4.3. Are you now better equipped to manage salinity or advise others?



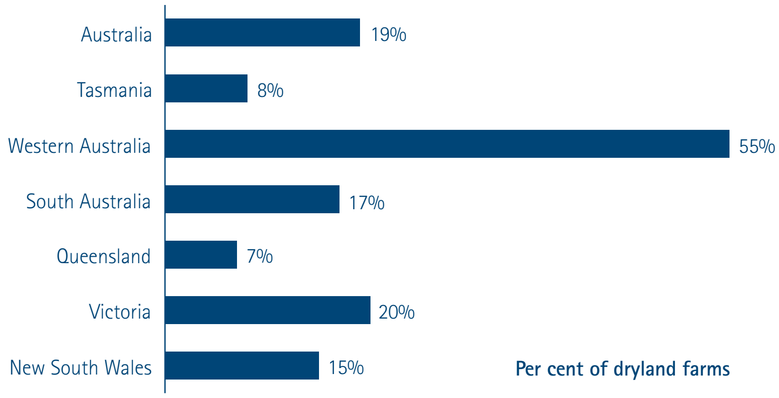
Data source: CIE survey of 136 stakeholders.

On-farm management changes have been made — but adoption levels are low

Given the nature of the R&D findings, it is inappropriate to use observations of land use change as the only gauge of program performance. Indeed, maintaining the status quo farming systems could be the best option in some catchments — for both economic and social reasons. However, there is an expectation that NDSP should have helped farmers respond to salinity by adjusting and experimenting with new farming systems.

A recent survey by the ABS titled 'Salinity on Australian Farms 2002' provided evidence that farmers are responding to salinity (Chart 4.4).

Chart 4.4. Farms that have changed management in response to salinity



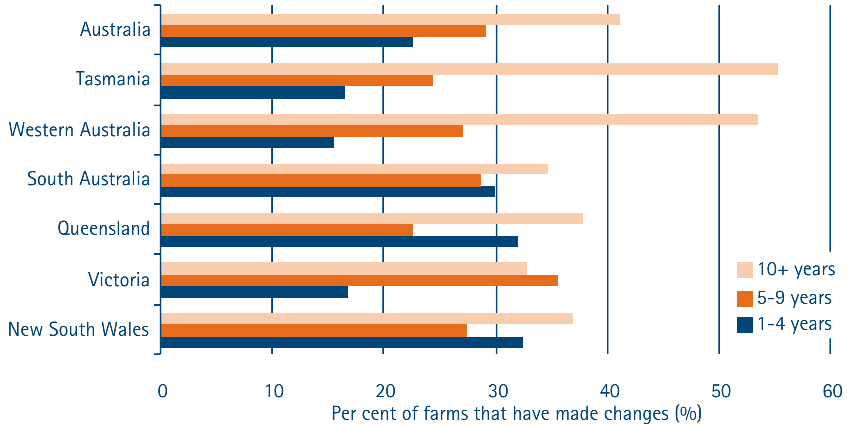
Data source: ABS (2002).

- Of the 100,844 non-irrigated farms in Australia, it is estimated that 19 per cent (or 18,883 farms) have changed their practices in response to dryland salinity.
- Western Australia (WA) has been most active in responding to salinity, with 55 per cent of farms in this State having adopted one or more practices. This reflects the relatively large proportion of WA farms showing signs of salinity (51 per cent).
- Adoption levels in the other States are lower. For example, in Victoria where 13 per cent of farms are showing signs of salinity, only 20 per cent have changed management practices.

When were the changes made?

Of the group of farmers that changed their management, about 40 per cent made first changes 10 or more years ago (Chart 4.5). These changes pre-date NDSP, although the same group of respondents could have been making on-going changes. About 30 per cent made changes five to nine years ago. A relatively small proportion (23 per cent) made changes within the life span of NDSP Phase II. However, great variation exists between States. A relatively high proportion of NSW and Qld farmers who made changes (32 per cent), first made them less than five years ago.

Chart 4.5. Timing of changes to management practices

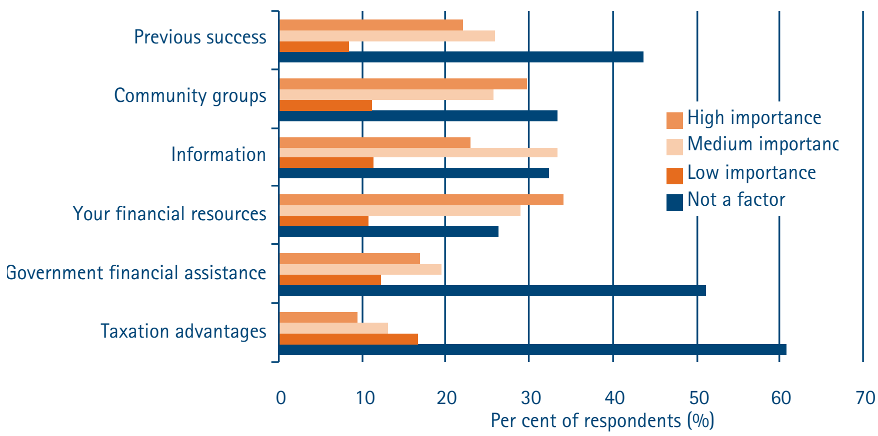


a Proportions do not add to 100 per cent because some respondents answered 'don't know' or did not respond.
Data source: ABS (2002).

What factors contributed to the change decision?

The ABS survey also asked respondents to rate the importance of different factors in helping them make the decision to change management practices (Chart 4.6). Only 20 per cent of farmers rated information as having high importance. About a third of respondents thought it was not a factor at all. Factors of more importance appeared to be belonging to a group and personal wealth.

Chart 4.6. Importance of factors in decision to change land management



Data source: ABS (2002).

What types of management practices have been adopted?

The most common salinity management practices adopted by farmers are establishing and protecting trees and fencing salinity-affected land (Table 4.7). Of those farms showing signs of salinity and/or managing salinity, 27 per cent have adopted these practices. The next most common activity was construction of levees or banks for water control (17 per cent) and establishing lucerne pastures (16 per cent). Estimates of adoption rates for each treatment (areas and lengths) are given in Table 4.8.

It is not possible to determine what increases in adoption have occurred at national level over the period of NDSP's operation because there is insufficient baseline information about adoption levels in 1998. ABARE ran a series of Landcare Surveys during the 1990s, which provide an estimate of the proportion of farmers adopting various land and water conservation practices (Alexander *et al.* 2000; Mues *et al.* 1998; and Wilson *et al.* 1995). However, these categories do not line up with the ABS survey. Nor do the ABARE surveys provide an estimate of the area of land treated with different Landcare management practices.

Table 4.7. Adoption of salinity management practices by Australian dryland farmers — 2002

MANAGEMENT PRACTICE	NUMBER OF FARMS	ADOPTION AS A PROPORTION OF ALL DRYLAND FARMS[a]	ADOPTION AS A PROPORTION OF ALL DRYLAND FARMS SHOWING SIGNS OF SALINITY OR MANAGING FOR SALINITY[b]
Salt-tolerant crops	2526	3%	8%
Lucerne pastures	5158	5%	16%
Deep-rooted perennials	3276	3%	10%
Salt-tolerant pastures	3250	3%	10%
Saltbush or bluebush	2905	3%	9%
Other fodder plants	1353	1%	4%
Trees planted or remnants protected for salinity management	8582	9%	27%
Earthworks for salinity management			
levees/banks	5429	5%	17%
shallow open drains	4130	4%	13%
deep open drains	1724	2%	5%
sub-surface drains	643	1%	2%
fencing for salinity management	8490	8%	27%

a Total population of dryland farms is 100,844;

b Total population of dryland farms showing signs of salinity or managing for salinity is 31,914.

Source: ABS (2002).

Table 4.8. Scale of treatments adopted by Australian dryland farmers — 2002

MANAGEMENT PRACTICE	AREA '000 HECTARES	LENGTH '000 KILOMETRES
Salt-tolerant crops	416	
Lucerne pastures	773	
Deep-rooted perennials	854	
Salt-tolerant pastures	238	
Saltbush or bluebush	216	
Other fodder plants	110	
Trees planted or remnants protected for salinity management	724	
Earthworks for salinity management		
levees/banks		92
shallow open drains		25
deep open drains		13
sub-surface drains		11
fencing for salinity management	438	

Source: ABS (2002).

Adoption profile for tree planting

ABARE surveys indicate the proportion of Australian farmers planting trees grew from 50 to 64 per cent from 1994 to 1999 (Table 4.9). However, most of this growth has been in high rainfall zones and is due to expansion of commercial farm forestry. The proportion of farmers planting trees for land degradation control remained relatively constant at about 20 per cent.

Table 4.9. Adoption of tree planting on farms[a]

	AS AT 1993–94	AS AT 1998–99
Proportion of farms that have planted trees [b]	per cent	per cent
for all purposes	50	64
for land degradation control	24	21
Area of trees planted on farms	hectares	hectares
total plantings	292,616	?
for commercial purposes	25,000	46,000

a All estimates sourced from ABARE Landcare surveys (Wilson *et al.* 1995 and Alexander *et al.* 2000) except for statistics on commercial plantings which were sourced from the National Farm Forestry Inventory (Wood *et al.* 2001).

b The relevant population of farms is all broadacre and dairy farms in the high rainfall and wheat-sheep zones, which was 82,069 in 1993–94 and 77,797 in 1998–99.

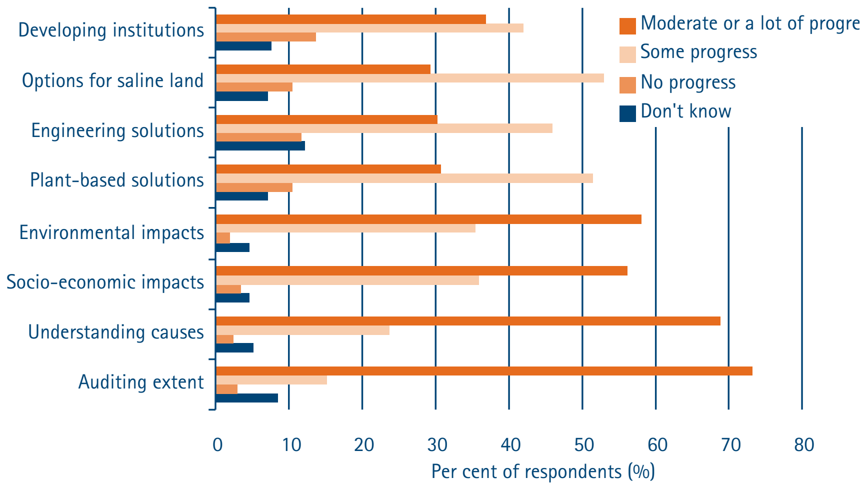
However, it is possible that the area planted by these farmers may have increased. The 1994 survey by ABARE (Wilson *et al.* 1995) established a baseline estimate of average area planted per farm, but these figures have not been updated. The survey estimated that farmers with plantations (blocks or belts) had an average area of about seven hectares per farm. This translates to a total area of 292,616 hectares. Of this, a proportion would be commercial farm forestry. Estimates contained in the National Inventory of Farm Forestry (Wood *et al.* 2001) indicate the cumulative area of commercial farm forestry has grown from 25,000 hectares in 1994 to 46,000 hectares in 1999.

Progress has been made in auditing the impacts — but less in developing solutions

Survey information indicates that most progress in salinity management in the past five years has been in establishing its extent, impacts and costs. While the level of funds directed towards developing solutions appears to have increased in the past five years (NDSP funded around $7 million in R&D in this area, and was catalytic in the successful establishment of the CRC for Plant-based Management of Dryland Salinity), the long-term nature of this research has meant that less progress has been made in this area (Chart 4.10). The survey of 198 stakeholders and researchers found that:

- Between 55 and 73 per cent of respondents believed a moderate level or a lot of progress has been made in understanding the causes of salinity, auditing its extent and quantifying social and environmental impacts;
- 37 per cent believed that the same level of progress has been made on developing institutions; and
- 30 per cent believed that progress (moderate to a lot) has been made to develop options for saline land, engineering solutions and plant-based solutions.

Chart 4.10. Perceived progress in salinity management over the last five years



Data source: CIE survey of stakeholders and researchers (sample size of 198).

Some aspects of policy have been influenced — but ill-conceived policies still exist

NDSP has positively contributed to formation of better policies for dealing with salinity. It has:

- Developed a base of core knowledge from which policy makers can draw, particularly catchment classification work;
- Developed a conducive environment to stimulate policy change — for example discussion forums, knowledge exchange networks and heightened awareness; and
- Got governments and industry groups talking to one another about salinity issues — which has helped to bring about the National Action Plan for Salinity and Water Quality (NAP).

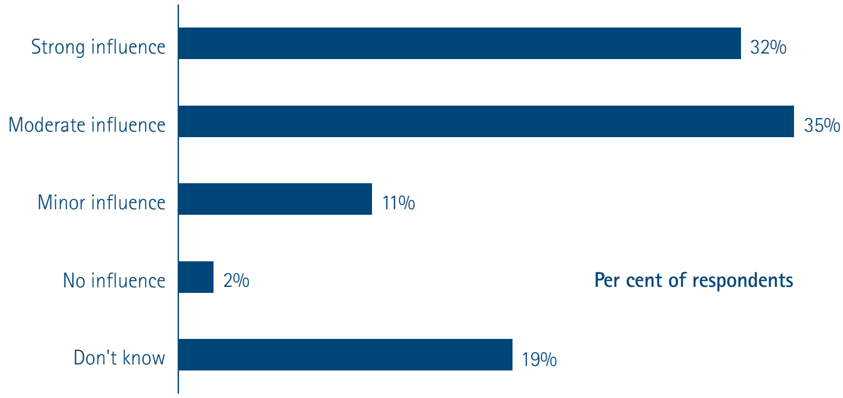
It appears, however, many major NDSP research conclusions have not yet filtered through to influence public policy at a high level. For example, the NAP endorses regional capacity-building and integrated catchment planning as a key plank to address salinity — yet findings from NDSP challenge governments to take a broader perspective. The *Catchment Classification* and *Assessment of Salinity Management Options* work in particular suggest that externalities are not as important as once envisaged and that there are limited economic options for treating salinity. While catchment management approaches may be important for managing a range of NRM issues, in the case of salinity it is important to ask decision-point questions first about the nature and timing of the problem, what society is wanting to protect or live with, how much it is willing to pay and options for action, before determining whether catchment management is the right approach either institutionally or biophysically. Moreover, the gulf between catchment-based investment frameworks and on-farm decision-making remains problematic.

The program has been influential in coordinating and steering the direction of R&D

There is a perception by researchers that NDSP has been successful in coordinating and steering the direction of salinity R&D in Australia. A survey of 62 researchers (including NDSP-funded and non-funded) conducted by the Centre for International Economics (CIE) revealed that:

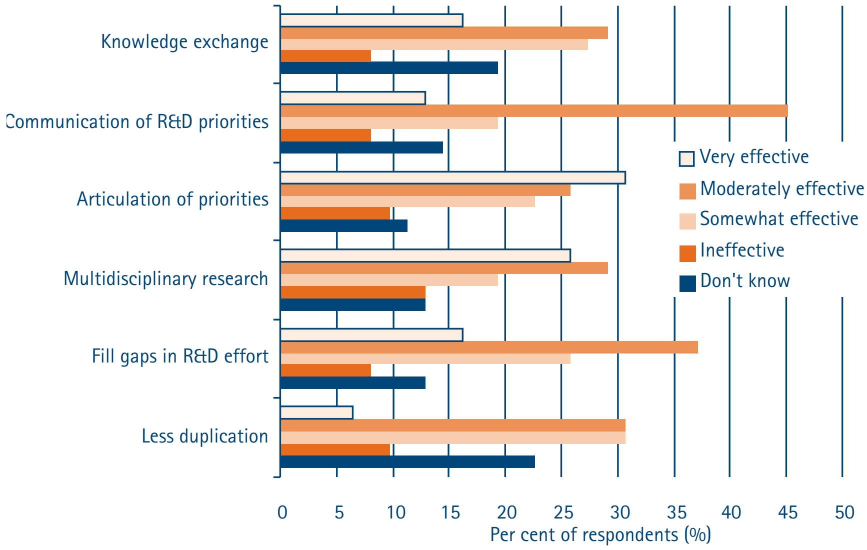
- Most respondents believed NDSP has had a moderate to strong influence on the direction of salinity R&D (Chart 4.11).
- The most effective aspect of coordination appears to have been articulation of R&D priorities. Chart 4.12 shows that 31 per cent of respondents rated this as very effective.
- This was closely followed by promotion of multi-disciplinary research, with 26 per cent of respondents giving this a very effective rating.
- At the other end of the scale, fewer respondents appear to be confident that the program effectively reduced duplication (only 6 per cent gave a very effective rating) and facilitating knowledge exchange (16 per cent thought very effective).

Chart 4.11. NDSP's influence on the direction of salinity R&D



Data source: CIE survey of 62 researchers.

Chart 4.12. Effectiveness of R&D coordination



Data source: CIE survey of 62 researchers.

THE ECONOMIC BOTTOM LINE

A number of potential economic outcomes could have arisen from the program. The main ones canvassed are:

- More productive agriculture (higher yields, lower costs);
- Lower repair costs to infrastructure;
- Lower water treatment costs;
- New commercial products based on saline resources;
- Lower transaction costs and greater effectiveness of publicly-funded control programs; and
- Lower monitoring costs through advances in technology and improved targeting of where and what to monitor.

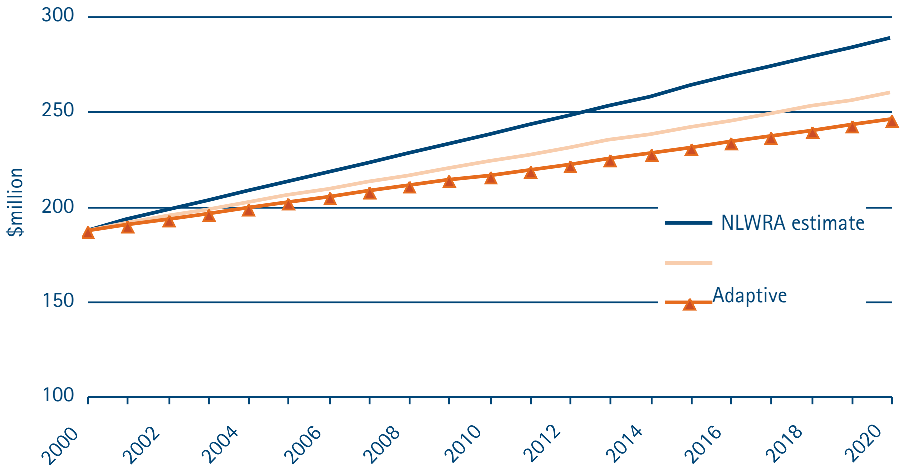
It is difficult to make definitive assessments on these impacts but the likely magnitude of benefits can be examined by undertaking some 'what-if' scenarios.

Reductions in damage costs

If NDSP has been successful in reducing future damage costs by five per cent, what is this worth? Or what is the minimum percentage cost reduction required to break-even with the $24 million spent on Phase II.

The National Land & Water Resources Audit estimates of future damage costs imposed by salinity on agricultural yields are a starting point. The NLWRA estimated salinity reduces agricultural profits by $187 million a year. By 2020 this is estimated to increase to $288 million a year (Chart 4.13). This estimate does not allow for the fact that farmers are likely to adapt to salinity and avoid some costs by taking preventative measures. An assumption is made that by 2020 costs might be reduced by 10 per cent through adaptive behaviour. This reduction is net of costs associated with implementing treatments.

Chart 4.13. Salinity cost scenarios for agricultural yield damage



Source: CIE calculations.

NDSP might deliver an added benefit by improving cost-effectiveness of these adaptations. If it was assumed a further five per cent reduction in future damage costs was attributable to NDSP, the savings relative to farmers going it alone under the adaptive scenario would amount to $80 million in present value terms (i.e. a reduction from $401 million to $321 million). Calculations are shown in Table 4.14. From this gross benefit, the cost of the program needs to be subtracted, leaving a net benefit of $56 million. The question remaining is "How feasible are the cost reduction assumptions given the outputs of NDSP?" Achieving cost reductions over and above the 10 per cent baseline adaptive scenario may be too optimistic given a lack of commercially attractive options coming out of NDSP (or anywhere else). Damage costs would need to be reduced by at least 1.5 percentage points above the adaptive scenario to recoup program costs.

Table 4.14. Potential cost reductions due to NDSP

	NLWRA ESTIMATE[a] $ MILL	ADAPTIVE MANAGEMENT $ MILL	ADAPTIVE MANAGEMENT + NDSP $MILL
Current annual cost	187	187	187
2020 annual cost	288	260	245
Increase in annual costs by 2020	101	72	58
NPV of cost increases over 20 years[b]	560	401	321

a NLWRA (2001);
b Discount rate of five per cent.
Source: CIE calculations.

With respect to infrastructure damage and downstream costs imposed by stream salinity, it is difficult to see where NDSP has had real in-roads in terms of delivering net savings. On the basis of its R&D findings, stream salinity is relatively unresponsive to revegetation treatments and there have not been any breakthroughs in developing new low-cost treatments to prevent stream salinisation. Similarly for *in situ* infrastructure, the net benefit of recharge treatments is dubious because of the relatively small area of off-site protection afforded by the treatment.

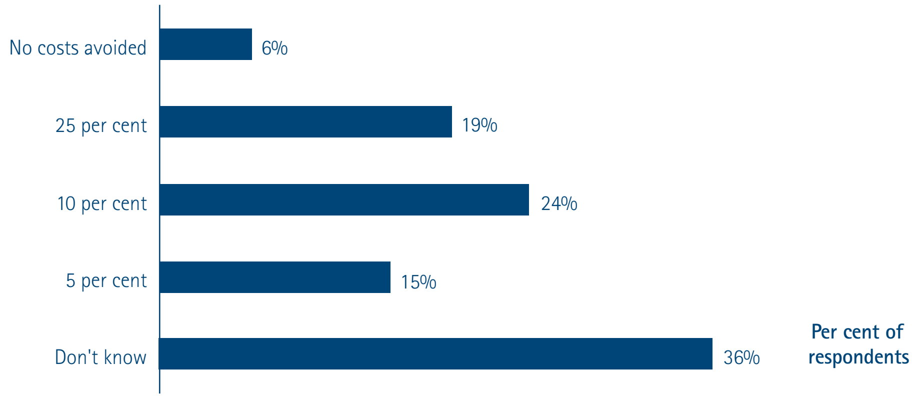
Returns from increased efficiencies of public expenditure

Another way of thinking about the economic value of NDSP is to examine whether the program will increase the efficiency of public investment in the NAP — and the threshold amount necessary to break-even with NDSP costs. The NAP has a budget of $1.4 billion over its seven year life. If it is assumed this program delivers a two per cent return on investment in present value terms, NDSP would need to almost double this return if it were to cover the $24 million of program costs for NDSP Phase II.

What do stakeholders think?

A survey of 136 stakeholders (CIE 2003) found that just over a third had difficulty putting a figure on the percentage reduction in costs likely to be achieved by NDSP. The next largest group of respondents (24 per cent) thought that the program would lead to cost savings of 10 per cent. A small proportion (six per cent) believed that no cost reductions would flow from the program (Chart 4.15).

Chart 4.15. Future costs avoided due to R,D&E to date



Data source: CIE survey of 136 stakeholders.

THE SOCIAL BOTTOM LINE

Social outcomes are difficult to define and evaluate. However, work conducted by the Bureau of Resource Sciences (Brooks *et al.* 2001) provided indicators of social factors deemed socially important. Their extensive list of indicators has been condensed into six social outcomes:

- Better community understanding of options and trade-offs;
- Enhanced capacity for communities to develop a vision;
- Improved personal health, self-esteem and satisfaction;
- Improved personal motivation, confidence and certainty;
- Maintenance of township viability and vitality; and
- Maintenance of country heritage and cultural values.

There is enhanced understanding at the regional level

- The salinity risk mapping and catchment characterisation work produced by NDSP has given regional communities a better understanding of the future challenges that lie ahead. It has provided a better appreciation of time scales involved and the problem's seriousness.
- For some communities, the mapping has caused anxiety and denial. But the Audit data have provided a basis for regional planning by reducing some unknowns existing before 1998.
- NDSP has delivered less at farm level, and there is likely to be continuing frustration by farmers about the best options for them at a paddock scale.
- The participative approaches to R&D undertaken by NDSP, such as *Million Hectares for the Future* and *the Lower Recharge Farming Systems* in WA, have been helpful in involving the farming community to come to a better understanding of trade-offs associated with treating salinity.

Living with salinity has become an accepted outcome

- Over the past five years there has been a change in mind-set among rural communities about salinity. There is greater acceptance that making defensive expenditures to repair infrastructure and progressive adaptation is likely to be more feasible than investing heavily in major engineering or revegetation works.

- Indeed, NDSP research has shown that, more often than not, the social upheaval from implementing the necessary scale of revegetation to have an impact on water tables will be far more damaging to the social fabric of country towns than living with the problem.
- Through its *OPUS* initiative NDSP has promoted the concept of living with salinity and helped to provide people with information and networks for finding out more about innovations that make use of saline land and water.
- The social vitality of country towns is highly dependent on healthy economies. Thus, to the extent that salinity imposes damage on agricultural profits and town infrastructure, there will be subsequent social impacts.
- However, the reality is the economic impacts of salinity on dryland agriculture are estimated to be relatively small when viewed in the context of total agricultural profits. The NLWRA estimates that the present value of agricultural profits will decline by 1.5 per cent over the next 20 years due to salinity – and this is not allowing for farmers' adaptive behaviour.
- It is true some pockets of rural Australia will be harder hit than others, and in extreme cases, where salinity is unresponsive to treatments, the rate of adjustment and farm restructuring is likely to accelerate. NDSP has contributed constructive advice for designing public policies and plans to address these issues.

THE ENVIRONMENTAL BOTTOM LINE

The environmental benefits of managing salinity go well beyond the farm gate. Environmental outcomes have been categorised as being one of four main types, reflecting the use and non-use values held by people for the environment:

- Protection of aquatic and terrestrial biodiversity;
- Protection of endangered species;
- Maintenance of outdoor recreation opportunities; and
- Improved countryside aesthetics.

NLWRA estimates that by 2050 there will be a high salinity hazard for two million hectares of remnant vegetation and planted perennial vegetation, 41,000 kilometres of streams or lake perimeter, and 130 important wetlands.

Low cost solutions to deliver environmental outcomes are not apparent

- NDSP found that protection of environmental assets from salinity will be costly. For example, previous hopes of saving remnant native vegetation along waterways by strategic reafforestation of areas up-slope no longer show promise as an effective solution.
- Many interventions will need to take the form of engineering works, such as pumping, interception banks and drains. Further, re-vegetation treatments have been found to be too slow to have the desired impact.
- The relatively high cost of protecting environmental assets means the R,D&E undertaken by NDSP has not motivated significant environmental works.

But information on emerging trends has been valuable

- Despite lack of technological solutions, governments, councils and rural communities are benefiting from NDSP information on salinity trends and the threat they pose to the natural environment.

- For example, work in southern WA on assessing salinity risks to remnant vegetation and native species has increased public and scientific attention on the fate of environmental assets under threat.
- Given that species loss is irreversible, it is often valuable to implement stop-gap measures that buy time and keep open the option of a more permanent solution when and if this becomes available. NDSP has worked with State Governments to assess actions that can be taken to buy time.

A start made on prioritising assets for protection — but more needs to be done

- Given the high cost of salinity control treatments, a system to prioritise environmental expenditures needs to be developed. Some of NDSP's environmental projects have started to feed into this process, but it is still early days.

5. R&D PRIORITIES FOR THE FUTURE

The achievements and key messages outlined in this report show that the knowledge base for managing salinity has come a long way. However, a role for generating new knowledge remains as critical now as ever before. This final section of the report deals with what the National Dryland Salinity Program's experience tells about R&D priorities for the future.

In dealing with R&D priorities, the section recognises that we can only determine where we need to go in future by acknowledging the significant advances made in R&D to date. These advances are captured and synthesised in the companion reports to this document: Dryland Salinity and Catchment Management: A Research Directory and Action Manual for catchment Managers (Robins 2004) and Dryland Salinity: On-farm Decisions and Catchment Outcomes (Powell 2004). This document has outlined the key messages from NDSP past investment in R&D, and upon these messages, R&D priorities are advanced.

CONTEMPORARY INSTITUTIONS FOR NATIONAL SALINITY PRIORITY SETTING

National Dryland Salinity Program (NDSP)

Between 1998 and 2003, the NDSP considered the national research priorities for salinity to be:

- Establishment of appropriate frameworks and institutional arrangements to improve the allocation of resources for dealing with salinity, taking into account the need for a mix of prevention, rehabilitation or adaptation strategies.
- Development of profitable, industry-based solutions for lowering recharge.
- Assessment of the non-agricultural impacts of salinity, including those relating to the environment and urban infrastructure.
- Development of options for managing the urban and rural infrastructure costs associated with salinity.
- Development of a complementary suite of solutions in support of plant-based management of salinity, including engineering options.
- Development of industry and community options to adapt to the concept of living with salt, where such options did not contribute to further salinity-related degradation.

The NDSP's view of future R&D priorities appears further in this chapter. This takes into account an analysis of research required to address the challenges presented by the key messages that emerged from the second phase of the NDSP. It also considers views expressed at a national research forum convened by the program in March 2003 to review its past salinity R&D investments.

Cooperative Research Centre for Plant-based Management of Dryland Salinity

The Cooperative Research Centre (CRC) for Plant-based Management of Dryland Salinity is one of the largest of Australia's one hundred or so CRCs. The CRC has goals to:

- Direct and influence plant-based research delivering agricultural production and processing systems that cope with, and arrest and reverse dryland salinity, improve water quality and sustain rural communities.
- Create awareness, will and capacity to adopt plant-based solutions to dryland salinity for the economic, environmental and social benefits of Australians.
- Provide an expanding pool of graduate researchers capable of solving the complex natural resource management issues facing Australia.

- Achieve effective collaboration among CRC researchers that transcends geography, discipline and sector, interacts purposefully with industry and the community, and takes a lead in the effort to optimise the use of Australia's intellectual and research resources.

While the CRC is not a research priority setting agency *per se*, it is the only truly national research agency dealing exclusively with the issue of dryland salinity. Its partners comprise government agencies in four different States, universities from three States, and a nationally-based research agency (CSIRO). In addition, its Board embraces representatives of national industry (Grains R&D Corporation, Meat & Livestock Australia and Landmark), stakeholder (Australian Conservation Foundation, National Farmers' Federation) and knowledge network (NDSP) interests.

The CRC does attempt to sway national thinking about salinity research priorities through a number of approaches, including supporting economic and institutional research providing contextualisation for plant-based solutions, advocating views through public submissions and statements (such as at seminars and conferences), and supporting a Policy and Advocacy Committee of the Board whose role it is to influence the institutional thinking required to complement the CRC's research outputs. Using each approach, the CRC has expressed its views about national research priorities.

These views are best summed up in its submission to the House of Representatives inquiry in 2004, recognising that while there are two important areas of research (focusing on salinity processes and effects, and focusing on the development of solutions), the national priority should clearly emphasise support for solutions-oriented research, specifically across four broad categories:

- Perennial plant-based systems for recharge areas (trees, shrubs, pastures, crops).
- Salt-tolerant plants for making productive use of salt-affected land (various species and production systems).
- Engineering systems for managing water tables (e.g. drains, pumps).
- Technologies for making productive use of salinised water resources (e.g. aquaculture, salt harvesting, desalination).

Natural Resource Management Ministerial Council and National Action Plan for Salinity & Water Quality

The National Action Plan (NAP) for Salinity and Water Quality has provided the most significant perturbation in salinity research arrangements in recent years. The NAP is a joint Commonwealth/State initiative directing around $1.4 billion towards salinity and water quality-related on-ground works through 21 regions across Australia. Complemented by the Natural Heritage Trust, these programs are based on:

> *... partnerships between all levels of community and Government, working together to protect our environment and natural resources, and sustain our agricultural industries and regional communities ... (Australian Government 2003)*

The original NAP blueprint made passing reference to the role of science in supporting the NAP. Subsequently, the Commonwealth/State ministerial arrangements in agriculture and the environment have undergone substantial changes, and the establishment of the Natural Resource Management Ministerial Council, with its supporting committees, has seen renewed interest in grappling with national science issues, such as salinity.

While the new ministerial arrangements have made national research coordination problematic (LWA 2003; NDSP 2003), the Science and Information Working Group has identified national priorities for natural resource management research in five categories, all of which have some bearing on salinity research:

- Sustainable agriculture and land use.
- Biodiversity conservation.
- Climate variability and change.
- Natural resource monitoring and indicators.
- Managing knowledge for change.

RECENT REVIEWS OF NATIONAL SALINITY R&D

Whereas the previous section dealt with the generic, nationally-based networks of institutions dealing with dryland salinity, this section deals with specific reviews by either these or other institutions aimed at establishing national R&D priorities for salinity.

Review of the National Dryland Salinity Program

The second phase of NDSP concluded in June 2003. In its final year, the program supported a comprehensive review of its achievements and future prospects. The latter review component resulted in a discussion paper, *Opportunities Report: Future Roles and Directions for the NDSP* (NDSP 2002).

The *Opportunities Report* argued that there remains a case for continued national coordination of science in support of regional salinity management initiatives. The basis for this conclusion included the identification of three critical gaps:

- Knowledge access.
- Coordination.
- R&D.

In the case of the first two gaps, the report concluded that in the absence of the NDSP, there was no existing or emerging infrastructure or institutional arrangements to support nationally-coordinated knowledge broking and generation activities that embraced government, community and industry interests. The third gap, dealing with research priorities, challenged the report's authors in that while national priorities could be derived from analyses of various reviews and policies, there was no clear articulation of the demand or a consensus about their relative importance. Through surveys and workshops of NDSP stakeholders in respect to the priorities for the future of the program, feedback indicated "a range of opinions that boils down to wanting NDSP to do all things for all people" (NDSP 2002). Consequently, the report itself failed to outline a clear list of R&D priorities for 2004 and beyond.

5. R&D PRIORITIES FOR THE FUTURE

In response to the report, NDSP engaged Mr Adrian Webb to analyse the critical questions being asked by a range of stakeholders to determine which questions still require generation of new knowledge in order for salinity management to be effective. As a result of Webb's analyses (Webb 2003), the following research priorities were identified:

- Clarification of the impacts of land use and climate variability on groundwater level changes.
- Development of land use systems for saline lands.
- Development of land use systems with a landscape focus.
- Understanding of landscape responses and management of stream salt loads.
- Development of infrastructure to capture nationally consistent datasets to underpin monitoring, evaluation and management response activities.

NDSP National Forum: Innovation, Inspiration, Celebration

In March 2003, a forum was convened to consider the achievements of NDSP-led salinity research. Included in the format was a series of reviews and discussions drawing out potential future research priorities. These priorities, against an aggregation of NDSP's themes, include:

Audit and Monitoring

- Better understanding and communication of the strengths and limitations of various monitoring, mapping and modelling techniques for planning landscape strategies.
- Economic studies to provide more rigorous estimates of not just the costs of salinity, but also the benefits of alternative intervention strategies.
- Verification of claims made by alternative mapping and monitoring techniques.
- Development of robust methods to align catchment and property level plans.
- Clear identification of the specific discrepancies between linear property, tenure and ownership systems of rights in the context of non-linear natural systems.
- Better assessment methods for estimating the likely impact of various intervention scenarios.
- Refinement of the Groundwater Flow System to finer and finer scales.

Environment

- Better understanding of the consequences of actions in one part of a complex system on other parts of the system.
- Improving means of valuing biodiversity in both public and private benefit contexts.
- Developing the means of managing biodiversity on-farm (just understanding what that means is a good first step).

Policy and Operating Environment

- Development of the capacity to quantify the trade-offs (i.e. recharge vs. streamflow) and to deal with these.
- Identifying a greater range of policy instruments to encourage land-use change to reflect the diverse nature of the way salinity expresses itself.
- Development of policy options at the broad macro-scale that support the emergence and nurturing of new industries that provide salinity management benefits.

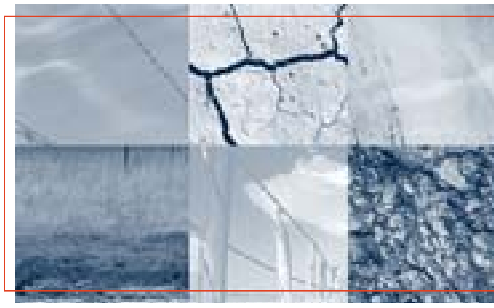
- Development of realistic assessments of carbon credit, ecosystem services, bio-energy credits and bio-fuel opportunities.
- Qualification and quantification of the social ramifications, including their flow-on effects, throughout both the urban and rural sectors.

Infrastructure Management

- Development of technologies to use and/or dispose of brine water.
- Development of desalination technologies that are more cost effective.
- Development of integrated systems of resource use where the outputs of one use become the inputs to another.

Farming Systems

- Understanding of the economics of land-use change for salinity benefit in the context of other on-farm decision imperatives.
- Development of adaptive, diverse and profitable farming systems.
- Understanding the impacts of emerging solutions under realistic levels of adoption.
- Development of integrated management approaches that bring-together agronomic, engineering and natural systems.



Analysis of State salinity strategies

Since 1998, most States have developed a salinity strategy (for example, the Strategic Framework for Salinity R&D in NSW). Embedded into each of these strategies are research priorities that emerge from the need to support implementation of the various sub-strategies outlined. In early 2003, the NDSP synthesised the research priorities common to at least three or more strategies. The common priorities identified included:

- Redesign of farming systems to mimic native ecosystems.
- Improvement in low recharge farming systems by increasing perennial vegetation into farming systems.
- Development of new industries based on living with salt, covering extensive agricultural systems and intensive water, aquaculture, energy and other industries.
- Development of new industries based on ecosystem services.
- Diversification of agroforestry options.
- Development of environmentally sound engineering technologies.
- Development of planning and resource allocation models within and across scales.
- Understanding biodiversity implications of salinity, and developing options for managing these.
- Development of market-based instrument options for influencing practices, behaviours and investments.
- Improving cost-effective assessment and monitoring techniques for all aspects of salinity impact including terrestrial, biotic and aquatic system health.

Some of the State strategies have progressed since this analysis, and new priorities have been captured by analysing the state submissions to the House of Representative Inquiry (see below).

5. R&D PRIORITIES FOR THE FUTURE

The House of Representatives Inquiry into Coordination of the Science to Combat Salinity

In August 2003, the House of Representatives Standing Committee on Science and Innovation announced an Inquiry to consider "coordination of the science to combat the nation's salinity problem". The Inquiry had three terms of reference, referring the Committee to give particular consider to:

a) use of salinity science base and research data (including the development of new scientific, technical and engineering knowledge) in the management, coordination and implementation of salinity programs;

b) linkages between those conducting research and those implementing salinity solutions, including the coordination and dissemination of research and data across jurisdictions and agencies, and to all relevant decision makers (including catchment management bodies and land holders); and

c) adequacy of technical and scientific support in applying salinity management options.

The Inquiry's terms of reference did not make explicit reference to the identification of specific research needs or to the prioritisation of such needs. However, among the 81 submissions received by the Inquiry, at least 64 drew to the Inquiry's attention an array of R&D priorities. These submissions were drawn from a roughly equal number of research agencies, individuals, government organisations and catchment management authorities, and hence is surprisingly unbiased.

The priorities identified through an analysis of these submissions include:

- Improvements in groundwater mapping and monitoring methods that can be used and responded to by producers.
- Improvements in modelling techniques to provide more useful guidance on targeted responses rather than widespread landscape change responses.
- Better understanding of the effectiveness and utility of different engineering solutions for treating rising groundwater levels, and improving design of future engineering options.
- Better understanding of the impact of salinity on freshwater environments, and the relationship between landscape and waterscape processes.
- Intensification of urban salinity research, particularly pertaining to assessment and risk evaluation, options for treatment and management and development of appropriate building codes.
- Intensification of research into vegetative solutions, including perennial plant-based systems for recharge and discharge systems.
- Development of technologies for making productive use of salinised water resources, with specific emphasis on generating marketable products and industries.
- Exploring combined systems research into multiple benefits from perennial vegetation, in particular biodiversity, carbon sequestration and aquatic systems.
- Developing innovative policy instruments that deal with the diversity of management regimes required to deal with salinity.
- Enhancing the emergence of new industries and environmental management system frameworks for existing industries that will increase the adoption of salinity management technologies as they develop.

NATIONAL SALINITY R&D PRIORITIES TO ADDRESS THE SIX NDSP KEY MESSAGES

Emerging from the reviews of the NDSP, six key messages have been articulated in this report:

1) Salinity costs are significant and rising, resources are limited, hence responses must be strategic.
2) Profitable options for reversing the trend are lacking (but under development).
3) There is no one salinity problem: It challenges us to look beyond traditional policy instruments.
4) Integrated catchment management must be seen as only one approach to deal with dryland salinity.
5) Vegetation management remains the key to managing water resources, although the benefit-cost of revegetating catchments requires careful analysis.
6) Lack of capacity is an important, but secondary constraint, to managing salinity.

The NDSP recommends that future R&D priorities be based around addressing the significant issues underpinning these six key messages. An analysis of priorities by the NDSP's national Operations Committee, taking into account the input of ideas from the various reviews and mechanisms outlined above as well as the views of each member's constituents, results in the recommended priorities for future R&D investment outline in Table 5.1. This table divides these priorities into those required for short-term tactical decision making (1–3 years) and longer-term strategic decision making.

Table 5.1: Future R&D Priorities addressing the six key messages

KEY MESSAGE 1 — SALINITY COSTS ARE SIGNIFICANT AND RISING, HENCE RESPONSES NEED TO BE STRATEGIC

Tactical R&D (Answering clients' questions)	■ Transform Audit data into management options at user-defined scales (e.g. paddock): – Interpreting data underpinning decisions and monitoring and evaluation – Improving methods underpinning decision making – Refining the Groundwater Flow System for local application. ■ Provide advice on the interactions between landscape processes (i.e. at catchment scale) and impacts (e.g. on acidity and salinity). ■ Further identify and refine significance of salinity costs for key regions and sectors.
Strategic R&D (Predicting clients' questions)	■ Identify assets (e.g. nationalising the WA Salinity Investment Framework): – identifying trade-offs between options, impacts (including benefit-cost analyses). ■ Assess community values by assets (identifying the influence that community values have on identifying assets at risk and making explicit the competitive tensions surrounding competition for limited resources). ■ Develop analytical tools to guide impact, actions, investments. ■ Identify fundamental spatial and temporal information gaps. ■ Establish adaptive networks to monitor and evaluate — providing feedback to State and national processes such as Monitoring and Evaluation Working Group: – identifying the who, when and where of monitoring – developing improved monitoring systems and information management systems.

KEY MESSAGE 2 — PROFITABLE OPTIONS FOR REVERSING THE TREND ARE LACKING BUT ARE UNDER DEVELOPMENT

Tactical (Answering clients' questions)	■ Evaluate the realistic impacts of current potential solutions-based R&D. ■ Enhance establishment of participatory R&D demonstrating potential solutions. ■ Better describe and characterise on-farm impacts of potential solutions at the farm scale. ■ Improve the level of scientific analysis of 'living with salt' options.
Strategic (Predicting clients' questions)	■ Explore a greater range of plant-based solutions, including combinations, including 'non-traditional' options, i.e. more than just a better perennial grasses. ■ Enhance coordination in engineering R&D. ■ Integrate engineering and plant-based options R&D and improve understanding of the interactions and dependencies. This requires farming systems-based research in its most comprehensive definition. ■ Develop a greater range of options for using saline water resources. ■ Develop policy options for industry development to enhance take-up of emerging options (capital market, risks, and values). ■ Develop realistic options / markets for ecosystem services.

KEY MESSAGE 3 — THERE IS NO ONE SALINITY PROBLEM — IT CHALLENGES US TO LOOK BEYOND TRADITIONAL POLICY INSTRUMENTS

Tactical (Answering clients' questions)	■ Develop capacity to quantify the trade-offs (i.e. recharge vs. streamflow) and to deal with these. ■ Identify a greater range of policy instruments to encourage land-use change to reflect the diverse nature of the way salinity expresses itself. ■ See Key Message 1 – i.e. GFS — client need at paddock/asset scale.
Strategic (Predicting clients' questions)	■ Refine capacity to link predict paddock actions — catchment reactions. ■ Assess and, if possible, quantify the social ramifications of salinity impact, including flow-on effects through both the urban and rural economies. ■ Assess the implications of demographics trends (e.g. catchment ownership) to: – underpin planning and resource allocation policy; and – underpin instruments to influence behaviour / education turnover ■ Develop realistic assessments of carbon credit, ecosystem services, bio-energy credits and bio-fuel opportunities.

KEY MESSAGE 4 — INTEGRATED CATCHMENT MANAGEMENT MUST NOT BE SEEN AS THE ONLY APPROACH TO DEALING WITH DRYLAND SALINITY

Tactical (Answering clients' questions)	■ Interpret the results of the Audit for cross-catchment implications (i.e. implications for industry sectors, communities of interests, urban development). ■ Interpret groundwater flow systems to identify critical cross-catchment cause and effect relationships between catchments.
Strategic (Predicting clients' questions)	■ Identify the limitations of catchment planning processes, particularly in relationship to groundwater flow processes. ■ Explore alternative of complementary institutional models for dealing with cross-catchment issues. ■ See priorities for Key Messages 1 and 3.

KEY MESSAGE 5 — VEGETATION MANAGEMENT REMAINS THE KEY TO MANAGING WATER RESOURCES

Tactical (Answering clients' questions)	■ Assess new vegetation options along the lines of what, where, how much and for how long (temporal issues). ■ Develop tactical tools to allow (more) precision in placement of actions. ■ Practically test 'options' and 'systems of options' — in addition to using predictive modelling.
Strategic (Predicting clients' questions)	■ Identify the likely ramifications of options in terms of trade-offs — i.e. managing salt versus managing water yield. ■ Assess the influence of climate variability and potential influence of climate change in terms of impact on alternative targets / actions. (What's good at one point in time is not good in another — how do we play the averages?) – partition impact of climate on 'targets' and temporal variability ■ Analyse the implications of different salt and water equilibrium across catchments.

KEY MESSAGE 6 — LACK OF CAPACITY IS AN IMPORTANT BUT SECONDARY CONSTRAINT TO MANAGING SALINITY

Tactical (Answering clients' questions)	■ Facilitate KASA (knowledge, aspirations, skills, attitudes) studies on options to manage salinity. ■ Identify knowledge assets and the costs and benefits associated with their transfer.
Strategic (Predicting clients' questions)	■ Identify the lack of skills capacity within government and research institutions, and the nature and implications of this for developing enduring solutions. ■ Develop capacity to undertake complex systems research.

Table 5.2 draws from the R&D gaps above and prioritises them in light of the most critical breakthroughs required to manage salinity at appropriate scales (highest priorities) and knowledge require to deal with emerging salinity management issues (high priorities).

TABLE 5.2: SUMMARY OF PRIORITIES FOR FUTURE R&D

Highest Priority

1. Developing the means to value environmental benefits: so that decisions based on alternative salinity management options take into account the full range of values at stake in decisions
2. Developing profitable industry solutions: so that economically, environmentally and socially feasible options are in the hands of those managing the vast majority of Australian landscapes.
3. Reconciling farm and catchment decision trade-offs: so that the potential conflicts in rational decisions at one scale with rationale decisions at another are minimised in the meantime (awaiting the outcomes of Priority 2).

High Priority

Climate

4. Develop ability to forecast trends and impacts incorporating climate factors (variability and change) and how this varies spatially.
5. Accounting for these in management responses.

Biodiversity

6. Identify hydrological thresholds and operating criteria for biodiversity asset management.
7. Identify benefits of biodiversity management that motivate a call to action.
8. Develop the means of managing and protecting biodiversity on farm and in public assets, in both terrestrial and aquatic systems.

Living with Salt

9. Identify the limitations to profitability of potential options and seek to overcome these where warranted.

Mapping, monitoring and data management

10. Improve high resolution mapping – the ability to locate treatment options, including:
    - improvement of interpretation
    - development of cheaper remote sensing methods
    - development of links to monitoring and evaluation frameworks
    - development of links to biodiversity conditions and trends.
11. Extend recent reviews of mapping methods to planning options.
12. Establish standards/guidelines and targets in mapping and planning.
13. Develop guidelines and pathways for improved management of salinity-related data.

Engineering

14. Improve methods for the disposal and management of saline and acid water in essential engineering works.

Groundwater

15. Assess and protect the sustainable yield of groundwater resources – including quality.

Supporting needs

Testing and demonstration

16. Road-test theory/forecasts, adding value to networks of applied R&D. This priority applies across all other priorities.

Communication and extension

17. Foster continual improvement in knowledge through facilitating two-way communication.
18. Turn Best Management Practice theory into practical decision support tools.

FROM R&D TO APPLICATION

The investment in, or attainment of, new knowledge is not an end in itself. It is critical that publicly funded R&D in salinity is not only be directed towards addressing the critical issues that those involved in managing salinity face, but be undertaken in such a way that every chance of adoption of the results is enhanced.

This will mean an investment in participatory research, where the users of research, be they farmers, local administrators, engineers or policy makers, are involved in the process of generating new knowledge. The National Action Plan for Salinity and Water Quality provides one avenue for facilitating this participation and collaboration. Other avenues exist in increasing the opportunities for industries and catchment managers to invest and work together in research. An important part of this process must be the translation of research results into on-ground action.

Glossary

Airborne geophysics	Remote sensing from the air of geophysical properties using electromagnetic induction, magnetics or radiometrics.
Agronomy	Biophysical science supporting agricultural production.
Agroforestry	A land management system enabling the production of trees and agriculture products from the same land unit.
Alley (farming)	A farming system in which belts of perennial vegetation (e.g. trees, saltbush) are interspersed with alleys of land, for productive use of annual species (crops, understorey).
Alluvium	Unconsolidated sediments (clay, gravel, sand) deposited by rivers in low-lying areas and flood plains.
Annuals	Plants that live for one growing season only.
Aquaculture	Farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants.
Aquifer	A layer of rock or unconsolidated sediments which holds and allows water to move through.
Aquifer, confined	An aquifer overlain by a confining bed (e.g. clay).
Aquifer, perched	An aquifer above and separated from a major aquifer by an impermeable layer of rock or sediment (clay).
Aquifer, unconfined	An aquifer in which there is no confining bed between the groundwater and the soil surface. The water table is the upper boundary of the groundwater.
Aquifer transmissivity	The ability of an aquifer to transmit groundwater.
Bedrock	Unweathered hard rock at the base of a soil profile.
Biodiversity	The variety of life forms – the different plants, animals and microorganisms, the genes they contain and ecosystems they may form.
Biophysical	Relating to biological and physical processes.
Break of slope	The line across a landscape at which the surface slope is reduced and where the hydraulic conductivity of the underlying material or the hydraulic gradient decrease.
Capillary rise	The drawing up of groundwater through soil pores caused by evaporation and the upward pull of surface tension forces overcoming the downward pull of gravity.
Catchment	The area of land drained by a river and its tributaries.
Colluvial (deposits)	Deposits of loose material that have been carried by gravity and are usually found at the foot of slopes or cliff lines.
Crop rotation	The growing of different crops and pastures on the same paddock in annual succession. e.g. pasture-grain-legume or pulse-legume-grain; etc.
Deep drainage	Water that drains from below the root-zone into underlying aquifer systems. Also called leakage. In some States the term 'deep drain' is used to describe an engineered drain that intercept lateral flow, through-flow or base-flow.
Desalination	Removal of salt from water.
Direct seeding	Sowing seeds directly into the ground for revegetation.
Discharge	Seepage of groundwater into streams and/or to the land surface, actively from springs or passively by evaporation.
Discharge area	Area affected by groundwater discharge.
Drainage paths	Naturally defined pathways through which run-off flows. Generally used to describe drainage depressions, gullies, drainage lines, creeks and rivers.
Drawdown	Lowering of the water table due to drainage or groundwater pumping.
Dryland salinity	Expression of salt at the soil surface or within capillary range, concentrated by the evaporation of saline groundwater discharging as a result of land use or land management.
Ecological zonation	Distribution of plant species across ecological zones because of variations in the environment (e.g. soil salinity, waterlogging and inundation).
Ecosystem	A community of organisms, interacting with each other, and including the environment in which they live.
Electrical conductivity (EC)	Ability of a substance to conduct electricity, used as a measure of water salinity. See conversion table at end of Glossary.

GLOSSARY

Electromagnetic induction	Process whereby a changing magnetic field causes an electric current to flow in conductive material (e.g. saline soil or groundwater).
End-of-valley target	A 'big picture' goal indicating how much salt will be discharged at the end of major catchments when management strategies are implemented.
Episodic recharge	Recharge as a result of unusually intense or prolonged rainfall events.
Evaporation basin	A shallow pond into which saline water is discharged to evaporate, leaving a residue of salt.
Evapotranspiration	Loss of water resulting from both transpiration by plants and evaporation.
Extension	The process of advising and providing information to land and water managers.
Geomorphology	Science of describing and interpreting landform patterns and processes of landscape formation.
GIS	Geographic Information System.
Ground truthing	A system where remotely sensed data is tested against direct measurements conducted on the ground.
Groundwater	Water beneath the surface held in or moving through saturated layers of soil, sediment or rock.
Groundwater base-flow	Stream flow that results from groundwater seepage.
Groundwater flow system (GFS)	A conceptual model to describe the response of groundwater to recharge.
Groundwater through-flow	Lateral movement of perched groundwater, often in a non-permanently saturated zone.
Halophytes	Salt-tolerant plants.
Hard water	Water containing high concentrations of calcium and magnesium salts. Hard water makes soap difficult to lather and may cause scaling or corrosion in water pipes, boilers, water heaters and other appliances, and industrial equipment.
Hydraulic conductivity	The physical property of the aquifer which determines the rate of movement of water.
Hydraulic gradient	The slope of the water table (change in hydraulic pressure over distance in the direction of flow) which helps determine the rate of movement of groundwater.
Hydraulic pressure	The pressure exerted by groundwater in an elevated part of the aquifer. This usually causes groundwater movement, possibly resulting in lateral or upward discharge.
Hydrogeology	The study of groundwater movement through soil, sediment or rock under natural or induced conditions.
Hydrology	The study of water movement.
Hypersaline	More saline than seawater.
Infiltration	The process by which surface water from rainfall, streams and irrigation channels enters the soil and is added to the groundwater.
Integrated catchment management	A process through which people develop a vision, agree on shared values and behaviours, make informed decisions and act together to manage the natural resources of their catchment.
Inundation	A condition in which free standing water occurs above the soil surface (sometimes called flooding). Waterlogging usually coincides with inundation, but many waterlogged soils are not inundated.
Land managers/holders	Those who manage land, including farmers, graziers, irrigators, cultural and environmental land holders, councils and government agencies.
Landscape	An area of land and its physical features.
Lateral flow	Groundwater flowing parallel to the natural surface. Normally confined to near-surface movement above the main aquifer.
Leaf area index (LAI)	The ratio of leaf area in a plant canopy to the area of the land beneath that canopy.
Leakage	The movement of water (rainfall or irrigation) below the root zone. In eastern Australia, deep drainage has been used interchangeably with leakage
Local groundwater system	Aquifer with a flow length of only a few kilometres.
Magnetics	Magnetic data can reveal buried drainage patterns, dykes, faults, fractures and deeper structural geology that assist our understanding of the hydrogeology of catchments.
Model	Conceptual models allow us to simplify complex systems (such as groundwater) and predict qualitatively their behaviour under various conditions. Computer models assign numerical values to many of the features of the model, input water as recharge then calculate the output (in time and space) as discharge.

Opportunity cropping	Sowing a crop only when climatic conditions present a suitable opportunity.
Percolation	The downward movement of water through soil.
Perennial	Plant that lives for several years (annuals live for only one growing season).
Permeability	The capacity of a substance (for example, soil or rock) to allow water to pass through it. Sand, for example, is said to have high permeability.
Phase-farming	Alternating farming land uses over time between annual and perennial vegetation (e.g. annual crops-lucerne-annual crops).
Piezometer	A tube (usually PVC, slotted and screened at the bottom) inserted into a confined aquifer to measure the relative groundwater pressure.
Porosity	Permeability by water, air or similar through small holes, or pores.
Radiometrics	Radiometrics detect radiation from the upper 30cm of the soil which may provide information about different types of clays or drainage patterns linked to areas where salt outbreaks occur.
Recharge	The process that replenishes groundwater, usually by rainfall infiltrating from the ground surface (river or lake bed) to the water table.
Recharge area	The area in which surface water (from rainfall, irrigation or streams) infiltrates into the soil and is added to the groundwater (c.f. discharge area).
Regional groundwater system	Aquifer with a flow length from recharge area to discharge area of hundreds of kilometres.
Regolith	Weathered or sedimentary material between the ground surface and bedrock.
Remote sensing	Collecting data using instruments remote from the data source, such as satellites or aircraft, but also ground-based instruments that collect sub-surface data.
Remnant vegetation	Native vegetation remaining after an area has been cleared.
Residual salt	Salt that is left in the landscape after the water has evaporated or receded.
Revegetation	Replacing the plants in an area which have previously been cleared.
Riparian	Belonging to the bank or shore of a river, stream or lake.
Root zone	Near-surface part of a soil profile where roots are active.
Salinisation	The accumulation of salts via the actions of water in the soil to a level that causes degradation of the soil.
Salinity hazard	Salt which, if mobilised has the potential to cause harm by discharging on the land surface and/or in streams. (See page 8 of '*Catchment Management*')
Salinity management	Intervention needed to mitigate or control salinity. Can be biophysical (plants) or engineering (e.g. drains).
Salinity mitigation	Any activity that reduces the salinity problem. For example, revegetation, improved cropping practices, reducing fallow and cultivation, planting salt tolerant species, and so on.
Salinity province	That part of the landscape in which a particular GFS (or several GFSs of the same type) operates.
Salinity risk	The probability of salt (salinity hazard) being mobilised and affecting natural, cultural or man-made assets. (See page 8 of '*Catchment Management*')
Salt, salts	'Salt' is a general term for many soluble chemical compounds, of which sodium chloride is generally the most abundant. Some salts cause hardness in water while others, in the right concentration, can be beneficial.
Salt accumulation	Salt deposited on the land from groundwater discharge or evaporated surface water.
Salt concentration	Level of salts on the land surface or in soil, rocks or water.
Salt interception scheme	Pumping or drainage that lower the water table by discharging groundwater into evaporation basins or elsewhere, thereby intercepting salt before it enters a river or reaches the soil surface.
Salt load	The amount of salt carried in water flow in rivers, groundwater or off the soil surface, in a given time period.
Salt scald	An area of land where the ground surface has been left bare after salt has destroyed the vegetation.
Seepage	The process by which water percolates downwards and/or laterally through the soil, often emerging at ground or stream level lower down the slope.
Sodicity	A measure of the amount of 'exchangeable' sodium ions in the soil. As sodicity increases so does the likelihood of soil structure decline, waterlogging and erosion.
Soil profile	A vertical section of earth from the soil surface to parent rock material, that shows the different soil horizons.

Soil water	Moisture stored in soil pores.
Sub-surface flow	Water moving laterally beneath the surface of the soil.
Sustainability	Managing our natural resources in a way that maintains their environmental, economic and cultural values, so that they continue to be available in the long-term.
Topography	The detailed description and analysis of the surface features of the landscape.
Transmission zones	Areas where water moves from recharge areas to discharge areas.
Total dissolved solids (TDS)	A measure of the salinity of water, sometimes referred to as total dissolved salts usually expressed in milligrams per litre (mg/L). An alternative measure is total soluble salts (TSS) (See Electrical conductivity (EC).
Transpiration	The process by which water is extracted from the soil, transmitted through plants, evaporated from the leaves and enters the atmosphere.
Tributaries	Watercourses (rivers, creeks, streams) which flow into another watercourse.
Water balance	A state of equilibrium when rainfall or irrigation water in a landscape is accounted for by the sum of run-off, plant water use, evaporation, recharge and changes in soil moisture content.
Waterlogging	Waterlogging will occur when the water table is at or close to the surface. Soil pores are then filled with water, plant roots become starved of oxygen, and plant growth is inhibited or even ceases.
Water table	The water table is the upper surface of groundwater. The soil profile is fully saturated below the water table and unsaturated above it.
Weathering	Chemical, physical and biological decomposition of rocks that can result in formation of a soil profile.
Wetlands	An area that is permanently, periodically or occasionally covered by fresh, brackish or saline water to a shallow depth. They support a unique range of plants and animals.
Woodlot	A small area devoted to growing trees, usually on a farm for firewood and posts.

Salinity unit conversion table

↓Start here	mS/m EC	dS/m EC	uS/cm** EC	mS/cm EC	mg/L (ppm)* TDS	gpg* TDS
1 mS/m =	1	0.01	10	0.01	5.5	0.38
1 dS/m =	100	1	1000	1	550	38
1 uS/cm** =	0.1	0.001	1	0.001	0.55	0.038
1 mS/cm =	100	1	1000	1	550	38
1 mg/L (ppm)* =	0.18	0.00018	1.8	0.0018	1	0.06
1 gpg* =	2.63	0.0263	26.3	26,300	14.3	1

* Conversion from Electrical Conductivity (EC) to Total Dissolved Salts (TDS) varies depending on the salts present and concentration. These figures are a guide only.

** Eastern States of Australia often refer to 1 uS/cm as an EC Unit

This glossary was prepared with reference to:

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