Natural Diversity Recovery Catchment Program

2010 Review

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July 2011

ISBN: 978 1 921703 21 8

Recommended citation
Wallace, K., Connell, K., Vogwill, R., Edgely, M., Hearn, R., Huston, R., Lacey, P., Massenbauer, T., Mullan, G., and Nicholson, N. 2011. *Natural Diversity Recovery Catchment Program: 2010 Review*. Department of Environment and Conservation, Perth, Western Australia.

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Acknowledgments
The following are acknowledged for their assistance at various stages during the development of this review:
Alisa Krasnostein, Madeleine Clews and Karla Forrest for editing, Graeme Olsen for providing an independent review of the document, and Ali B Design. In addition, the following provided helpful comments and advice during the preparation of the document: Amir Abadi, John Bartle, Greg Durell, Darren Farmer, Jennifer Higbid, John Lizamore, Cliff Lloyd, Ray McNight, David Mitchell, and Margaret Smith.

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Natural Diversity Recovery Catchment Program: 2010 Review

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FOREWORD

In 2001 the department published a comprehensive review of its salinity work in the south-west, a region recognised internationally as a biodiversity 'hotspot'. At that time salinity was recognised nationally as a major environmental problem and considerable funding was allocated to salinity management. Since then interest in salinity has waned, particularly as declining annual rainfall has, in some areas, led to falling saline watertables. Nevertheless, recent evidence suggests that the impacts of salinity will be of a similar order to that predicted in the past, but it will evolve over a longer time period under the current, drier climate regime.

Nationally, interest in salinity has declined with the cessation of the National Action Plan for Salinity and Water Quality. This is, perhaps, not surprising given the difficulties and risks in managing water at landscape scales. Hydrological data collected and analysed over a minimum of 10 years are essential to characterise individual catchments for most engineering and revegetation interventions. Furthermore, although some actions have immediate, positive effects, most take much longer to develop. Where total catchment management is required, as it is in the case of biodiversity assets on valley floors, then decades are required to achieve natural resource outcomes. At the same time, some continued degradation of assets is inevitable before management interventions halt, and then reverse, change. Hydrological momentum in south-west systems is considerable—the impacts of some 100 years of changed land use are difficult to reverse.

Consequently, dedicated effort over long timeframes is required to first halt degradation, and then recover assets threatened by salinity. In Western Australia, salinity threatens some 850 species of plants and animals with regional or global extinction. Thus salinity and its companion processes, such as waterlogging, are among the most potent threats to biodiversity in the south-west. This is an issue of international interest.

The Natural Diversity Recovery Catchment Program is the department's key program tackling salinity. This program aims to protect significant biological communities threatened by salinity. Currently there are six recovery catchments from six biogeographical areas. They represent a wide range of wetland and valley floor biological communities, and make an important contribution to maintaining the character, and recreational and future opportunity values of the south-west. Three of the six natural diversity recovery catchments contain wetlands listed under the Ramsar Convention as Wetlands of International Importance, and collectively they contain 11 threatened species and three threatened ecological communities.

This review details the expenditure and outputs of the Natural Diversity Recovery Catchment Program from 1996–2006, with additional commentary on events up to and including 2010. While progress has been slower than hoped, work within the Toolibin Lake catchment demonstrates that there are successful management interventions, although maintaining key operational works continues to be challenging. At the same time, a wide range of ancillary benefits are also realised through departmental work to protect biodiversity assets. These include protection of some public roads, better hydrological management of farmland, and contributions to new industry development. Given that most catchments are predominantly farmland, facilitating the development of a more productive, diverse and resilient agriculture that is environmentally sensitive is an important task of recovery catchment work.

Finally, it has become clear that understanding landscape hydrology and ecology is of increasing importance with a drying, variable climate. In this regard knowledge accumulated through work in the diverse recovery catchments will be crucial to support departmental and state management capability. Interactions among food, water, energy, climate variability and biodiversity will increasingly challenge our state and nation throughout the 21st century.

The Department of Environment and Conservation will continue to take the long view of our community needs, and maintain, and where resources allow, expand, the Natural Diversity Recovery Catchment Program.

Keiran McNamara
Director General

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OVERVIEW

The primary objective of the Natural Diversity Recovery Catchment Program, as defined in 1996, is:

> *To develop and implement a coordinated Wetlands and Natural Diversity Recovery Program targeting at least six key catchments over the next 10 years to ensure that critical and regionally significant natural areas, particularly wetlands, are protected in perpetuity* (Salinity Action Plan, page 23).

A secondary objective has been recognised as part of the wider aims of natural diversity recovery catchments. This secondary objective was published in the *Buntine-Marchagee Natural Diversity Recovery Catchment Plan (DEC 2007)* as:

> *To develop knowledge and technologies to combat salinity throughout the agricultural region.*

This chapter summarises the main body of the report, and includes the following sections:

- **Headline achievements** – 12 key achievements from the Natural Diversity Recovery Catchment Program
- **Recommendations** – summarises the report recommendations
- **Setting** – outlines the general environment affecting the salinity initiative of the department [1]
- **A unique national endeavour** – describes the national context of the program
- **Summary of the Natural Diversity Recovery Catchment Program** – summarises the main body of the report, including:
  - expenditure and outputs
  - outcomes
  - cost-effectiveness.

HEADLINE ACHIEVEMENTS

Over the six natural diversity recovery catchments:

- All 11 threatened species and three listed threatened ecological communities endangered by altered hydrology have persisted, but continue to be at risk. Of these biodiversity assets, one of the listed threatened ecological communities (at Toolibin Lake) would almost certainly have been degraded to the point of de-listing by 2009 without management intervention through the Recovery Program.
- Habitat management has been initiated for areas visited by at least 27 species of migratory waterbirds protected under one or more of the Japan, China and Republic of Korea-Australia Migratory Bird Agreements (JAMBA/CAMBA/ROKAMBA) and the Convention on the Conservation of Migratory Species of Wild Animals (CMS).
- Revegetation and other works have improved the probability that a wide range of other biological communities threatened by altered hydrology will persist. These works, particularly revegetation and improved management of remnant vegetation, have also improved the outlook for many terrestrial native animals at landscape scales. Three of the recovery catchments [2] contain very important, representative assemblages of terrestrial biodiversity that would make them priority targets for conservation even without the wetland assemblages; and two others [3] contain important samples of poorly conserved terrestrial assemblages.
- Foundation investigations and initial management activities for three areas listed as Wetlands of International Importance under the Ramsar Convention are well advanced.
- Sections of public roads and related infrastructure in three recovery catchments are now significantly better protected from flooding and other impacts from altered hydrology.
- Agricultural land management in relation to altered hydrology has been improved over six recovery catchments totalling 700,000 hectares. About 35 per cent of expenditure through the program is for works on private land, including land purchase.
- Significant water management knowledge has been gained that may be applied to other localities in the south-west. The natural diversity recovery catchments, together with the water resource recovery catchments, represent the main mechanism for understanding hydrological processes at catchment scales. Further developing this knowledge is vital for effectively managing biodiversity, land, water and infrastructure resources in the South West Land Division [4].
- An important contribution has been made to resource establishment and testing of new industries (mallee industries and salt harvesting).

1. Throughout this document, the word department used alone always refers to the Department of Environment and Conservation, or one of its predecessors, the Department of Conservation and Land Management.
2. Lake Bryde, Lake Warden, Muir-Unicup.
3. Buntine-Marchagee, Toolibin Lake.
4. The South West Land Division broadly encompasses the area south and west of a line connecting Kalbarri and Esperance.

- An effective model for catchment-scale management of public assets has been developed.
- Past and current works represent a nationally unique attempt to recover and conserve biodiversity assets threatened by altered hydrology in southern agricultural environments.
- Two awards have been received since 1996—the project partners at Toolibin were awarded the Institution of Engineers Australia National Salinity Prize in 2002; and Buntine-Marchagee was highly commended through the Australasian project of the Global Restoration Network in 2009.
- Effective partnerships have been maintained with local landholders, regional natural resource management (NRM) groups and state agencies, particularly the Department of Agriculture and Food (WA), and the Department of Water. These partnerships have been crucial to implementing on-ground works.
- Experience over the past 15 years has demonstrated that, for successful whole of catchment management, institutional arrangements will be based on an organisation with a vested interest in the health of the whole catchment, and with a long-term commitment of resources to management. To date, the natural diversity recovery and water resources catchments provide the best state examples of catchment management.

RECOMMENDATIONS

Concerning the future of the Natural Diversity Recovery Catchment Program and the role of the Natural Resources Branch, it is recommended that:

1. *The goal of the Natural Diversity Recovery Catchment Program becomes:*

   To develop and implement works within the South West Land Division that protect, and where practicable recover, the biodiversity of significant, natural wetlands and associated valley biological communities from the adverse effects of altered hydrology. Primary values underpinning this goal will be specified for each catchment project.
2. *Consideration is given to re-allocating funds within the department's salinity initiative to bolster work in the natural diversity recovery catchments.*
3. *All current recovery catchments have recovery plans to the final draft stage by June 2013.*
4. *The department seeks to expand the Natural Diversity Recovery Catchment Program as resources become available. Priorities for consideration, should funds become available, will be biological communities threatened by altered hydrology in the Hutt River and Lake Gore catchments.*
5. *Key technical and operational issues within the recovery catchments are addressed.*
6. *Work within the department to develop an industry based on mallees is maintained until June 2014, at which point progress should be reviewed. This date is consistent with DEC's formal commitments to the Future Farm Industries Cooperative Research Centre.*

SETTING

Water is a fundamental resource. Therefore, management of water quality and quantity are prominent issues in human socio-economics. From about 1990 until 2005 this was reflected in Western Australia (WA) by the wide acceptance that increasing salinity impacts on natural land, water and biodiversity resources was a pre-eminent environmental issue in the south-west. This situation developed over 120 years of changing land use, particularly with vegetation clearing for agriculture since about 1890[5].

Some 18 (72 per cent) of the 25 million hectares of land in the south-west corner of WA have now been developed for agriculture. This major landscape change overlays one of the most diverse Mediterranean biota in the world, and the only recognised global biodiversity 'hotspot' in Australia. Although 2.35 million hectares of the wetter part of the south-west is set aside in state forest and conservation reserves, the remainder of the seven million hectares of retained native vegetation is scattered and occurs mostly throughout the drier, and arguably more biodiverse, area of the state.

The destructive impact of agricultural development on biodiversity has been exacerbated by the associated changes in hydrology. The conversion of native, perennial bush to annual crops and pastures has led to a reduction in overall water use by plants. In the state's low relief, southern agricultural landscapes this has led to rising groundwater levels, mobilisation of soil-stored salt and extensive salinisation. In valley floors waterlogging and inundation have also increased. These processes are especially damaging to the natural ecosystems of valley floors and along drainage lines. It has been estimated that, as a consequence, 850 native species are threatened with global or regional extinction.

5. Agricultural land was being developed by 1830, with small areas in the inland agricultural zone by 1840. However, substantial clearing did not begin until much later.

The recent biological survey of the wheatbelt (Keighery et al. 2004) also found that salinised freshwater wetlands do not provide habitat for many salt-tolerant species, that is, the loss of freshwater wetlands to salinity has not even increased the habitat for many saline-tolerant species. There is also evidence that altered hydrology, including secondary salinisation, threatens the invertebrate communities of naturally saline lakes.

Altered hydrology, including widespread salinisation, not only threatens remaining wetland biodiversity; it continues to degrade farmland, water resources and rural infrastructure. In 1996 the State Government responded with the *Western Australian Salinity Action Plan*, and funding from this became the core around which the Department of Environment and Conservation's[6] (DEC's) salinity initiative was developed.

To arrest and then reverse the degradation processes initiated 120 years ago is an enormous challenge and inevitably a long-term task. Unsurprisingly, it has proved difficult to maintain momentum to manage altered hydrology, particularly salinity. Five key reasons are:

- high costs of intervention, which is in part due to the lack of economically viable water management technologies
- the large amount of catchment-scale knowledge and research required to understand systems and plan effective management action. This issue is exacerbated by the fact that each catchment has its own unique set of characteristics that must be understood to underpin effective management
- long timeframes over which focused, strategic action is required for significant impact. This sits uncomfortably with one to five-year funding regimes
- uncertainty about effective management strategies, particularly in the context of environmental variability, including the impacts of climate variability
- difficulty of producing positive outcomes in the short term (less than 10 years), particularly under circumstances where even slowing degradation is a positive outcome.

The challenge of managing water is exemplified at a basin-scale by the difficulty in achieving biodiversity outcomes from the significant resources allocated to the Murray-Darling system; and the major resource input required to win important, but slow changes in the Denmark and Collie water resource catchments. In all cases the aims are sound but we are dealing with complex problems requiring long-term application of significant resources. Often it has proved less socio-politically risky for program managers to remain unfocused. For example, when funding bodies are allocating payments to landholders and catchment groups at catchment and regional scales, it can be socio-politically safer to distribute funds on the basis of landholder equity and group capacity-building, rather than by targeting expenditure to clearly stated on-ground outcomes where risks and uncertainty are high, and failure is highly visible.

All the above issues have contributed to fading interest in salinity. The word 'salinity' appears only twice in the *Caring for our Country Business Plan for 2009–10* (Commonwealth of Australia, 2008). Nevertheless, the problem has not disappeared. Recent predictions are that private land affected by salinity in WA will increase from 0.82 million hectares to an estimated 2.9–4.4 million hectares. This will have commensurately high impacts on natural water and biodiversity resources, as well as substantial impacts on rural buildings and other infrastructure including roads and railways. In the case of biodiversity, it is estimated that some 450 flowering plants and 400 invertebrates are at risk of global or regional extinction as salinity continues to unfold over the next 100 years or so.

Despite waning interest in salinity, water quality and quantity are now major issues worldwide and nationally. Effectively managing the interactions between water requirements, food production and energy demands in the context of predicted global climate change is of the utmost importance. Maintaining the multiple benefits from biodiversity is challenging under this scenario.

Thus, the problem of salinity has not gone away—it has just become one element of a much more complex set of linked issues. The technologies and knowledge we develop in recovery catchments to manage salinity are a vital part of the hydrological package that is essential to address the tightly linked issues of water, food, energy and biodiversity.

A UNIQUE NATIONAL ENDEAVOUR

The Natural Diversity Recovery Catchment Program is unique in Australia. It is the only long-term operational program working to conserve and recover selected, important biodiversity assets threatened by altered hydrology at catchment scales within southern agricultural areas. The program has received ongoing support for more than a decade, including from the state government and three consecutive, departmental chief executive officers. This consistent support has been crucial to management success and contrasts with attempts

6. In 1996 the Department of Conservation and Land Management. In July 2006 this department was combined with the Department of Environment to form the Department of Environment and Conservation.

to achieve landscape-scale change over much shorter timeframes, or with less consistent resources.

Although the program involves risks and uncertainties, the anticipated gains are large and the costs are modest compared with other natural resource management programs. In addition, the short-term gains to broader community benefits are significant.

Terminating the recovery program would result in valuable wetland and riparian biodiversity assets becoming increasingly fragmented and degraded, and species and community extinctions would be inevitable. It would also foreclose the opportunity to test what resolute, long-term remedial action can achieve.

In a broader sense, failure to deal effectively with altered hydrology would degrade a range of community values including sense of place, recreational values and landscape aesthetics. Human health and infrastructure may be threatened by the loss of nutrient-stripping and flood protection functions of wetlands and related riparian zones, and future generations would lose significant opportunities. From a long-term economic perspective, it is far easier and cheaper to prevent or minimise natural resource problems, rather than fix them after they have occurred. Ironically, there is scant praise or reward for those who prevent problems in contrast with those who are seen to resolve them.

Conversely, effective implementation of the recovery program will protect important biodiversity assets representing the values described above. Simultaneously, it will deliver a wealth of knowledge that better positions current and future generations to manage biodiversity, water and agricultural lands in a changing environment. Sections of rural infrastructure and large areas of agricultural land will be better protected, and new industries encouraged. Even under the worst case scenario of minimum gains in terms of natural resource asset values, the gains to future generations in knowledge of landscape processes and management technologies alone will justify expenditure.

SUMMARY OF NATURAL DIVERSITY RECOVERY CATCHMENT PROGRAM

The above background explains the importance of the department's salinity initiative and its component programs. Of these programs, the Natural Diversity Recovery Catchment Program is the largest and most important. The remainder of this chapter summarises the material in the full review.

The Natural Diversity Recovery Catchment Program was established under the *WA Salinity Action Plan* (1996) to: "ensure that critical and regionally [that is, south-west agricultural region] significant natural areas, particularly wetlands, are protected in perpetuity". The program has been supported through a number of government reviews of salinity policy. However, although there have been recommendations to expand the program, no additional state recurrent funding has been provided since the original 1996 allocation. The initial allocation has been sufficient to establish six natural diversity recovery catchments (Table 1, see also Map 1).

Table 1. Six natural diversity recovery catchments, their size, year established and summary of key biodiversity assets (see Table 3 for details).

Name	Catchment Area (ha)	Year established	Key biodiversity assets
Buntine-Marchagee	181,000	2001	Threatened ecological community, threatened species and wide range of wetland and riparian assemblages
Drummond	39,500	2001	Freshwater claypans, priority ecological communities and threatened species
Lake Bryde System	140,000	1999	Threatened ecological community, threatened species, and wide range of wetland and riparian assemblages
Lake Warden System	212,000	1996	Listed as a Ramsar Wetland of International Importance, Priority ecological communities, wetlands, used by migratory species and has a wide range of wetland and riparian assemblages
Muir-Unicup	70,000	1996	Listed as Ramsar Wetland of International Importance. Priority ecological community, threatened species and has a wide range of wetland and riparian assemblages
Toolibin Lake	48,000	1996	Listed as Ramsar Wetland of International Importance. Contains a threatened ecological community (listed at state and Commonwealth levels).

Between November 1996 and June 2006, $16.17 million of recurrent funds originally allocated under the *Salinity Action Plan* have been spent through the Natural Diversity Recovery Catchment Program. This represents the majority of both state funds and overall expenditure on the program. However, additional funding, particularly through Commonwealth and private sources, has also made an important contribution. Details of the state recurrent expenditure, outputs and outcomes during this period are summarised below with some important developments during the 2006–09 period also included to bring the review up to date. A detailed description and analysis of work in the catchments is provided in the full review. It should be noted that most expenditure is to counteract the downstream impacts arising from replacing perennial native vegetation systems with the annual crops and pastures of agriculture.

Expenditure and outputs [7]

The seven major categories of expenditure and related outputs are summarised in Table 2. It is important to note that 30 years is generally considered the minimum length of time over which data must be collected to characterise climate and thus understand hydrology. It is therefore unsurprising that the first five to 10 years of work in each catchment has been dominated by investigations and monitoring ($4.44 million, 28 per cent of expenditure) aimed at understanding how catchment hydrological processes affect the biodiversity assets being managed.

Typically, at least 10 years of investigations are required to understand catchment processes and to begin the design and feasibility assessments for capital intensive on-ground engineering works. Thus, the first phase of on-ground activity in catchments is characterised by works that are required for longer-term success, but which may or may not be the most urgent in the medium term. These include strategic revegetation and improved protection and rehabilitation of remnant vegetation in the catchment ($4.54 million and 28 per cent of expenditure). Such works are ultimately important contributions to achieving recovery goals, so represent 'no regrets' actions with very low risk of failure. In many cases these works also improve the conservation outlook for upland, terrestrial biodiversity.

As hydrological understanding increases, surface water management works are generally implemented to reduce waterlogging, groundwater recharge and other threats near and within biodiversity assets targeted for recovery. Some of these works directly contribute to protecting farmland and public roads. To date the only recovery catchment with significant groundwater management infrastructure is Toolibin Lake. However, similar works may be required at other sites. Expenditure on engineering

Table 2. Summary of recovery catchment expenditure and outputs against core activities 1996–2006. Table 5 and associated text provide further details and analysis.

Activity	Outputs	Expenditure ($ million)	Expenditure (% of total)
Expansion of conservation estate through land purchase	1,394 ha purchased	1.14	7%
Revegetation to buffer remnant vegetation, provide new habitat and hydrological control	4,920 ha revegetated 4.8 million seedlings	3.72	23%
Improved protection of remnant vegetation on private property	5,161 ha protected 350 km fencing	0.82	5%
Engineering works on Crown lands to protect public assets	39 sites	2.94	18%
Engineering works on private property to protect public assets	Not listed	0.66	4%
Monitoring, research and investigations including impact assessments (other than funds allocated against specific management projects)	Not applicable	4.44	28%
Management of committees, recovery planning, communication and volunteer management	Not applicable	1.72	10%
Other (e.g. development of recreation/interpretation sites)	Not applicable	0.73	5%
Total		16.17	100%

7. In this document, outputs are defined as measures of management activity—such as area revegetated, kilometres of drainage works, etc.—while outcomes are defined as measures of goal achievement, including threat amelioration.

works to 2006 totals $3.6 million (22 per cent of expenditure).

Some 10 per cent of total expenditure ($1.72 million) supports recovery planning, communication activities, management of committees and related activities.

Overall, it is estimated that some 35 per cent of total expenditure is for works directly involving privately owned farmland.

Outcomes

Management success in recovery catchments needs to be reviewed over decades because the outcomes of most interventions at landscape scales to counteract secondary salinity can rarely be fully assessed in shorter time periods. This reflects the difficulty of resolving problems that have developed over more than 100 years. Exacerbating this situation is that the path to recovery may be different from and more difficult than the process that developed the problem. For example, restoring soil structure after salinisation needs more than just recession of the shallow saline groundwater. At the minimum, it also requires time for the salt to leach from the soil profile. The positive results from management are even more difficult to assess where, as in the case of salinity in the south-west, landscape degradation is continuing. Thus, management that either slows the rate of decline or decreases the final, full expression of salinity is, in many cases, a highly beneficial outcome.

Biodiversity

The key outcomes realised to date for each recovery catchment are briefly summarised below. Substantial outputs have also been achieved for each recovery catchment, and these are detailed in Appendix 2.

Buntine-Marchagee: Recent conceptual models of salinity development in the wheatbelt have given greater emphasis to the management of surface water before it affects biodiversity assets on valley floors. In this context, the broadscale surface water management currently being implemented at Buntine-Marchagee, which integrates surface engineering, revegetation and other improved practices, is an important success. Initial work focused on landholders in an 860-hectare demonstration sub-catchment, with work largely completed in 2006. In the future, this type of work will be expanded and more tightly focused on key biodiversity assets. The quality of the work in this catchment is underlined by it being listed as a "Highly Commended Australasian project" by the Global Restoration Network. The threatened ecological community remains intact.

Drummond: The initial phase of revegetation and investigations was completed in 2009. Much of this initial activity was conducted throughout the 39,500 hectares of the Soloman-Yulgan Brook and Mt Anvil Gully catchments. This work was aimed at 'no regrets' actions to improve water retention in the upper catchment and protection of vegetation, landscape connectivity and hydrological function. Increasing understanding and support for the program was also a priority. Recovery activity over the latter years has focused on the priority assets which were identified through the investigations to date. The assets, two freshwater claypans and their biological communities, are located within Drummond Nature Reserve. It is currently predicted that some additional revegetation work and a small amount of surface water engineering will ensure that these key asset targets are secure in the short to medium term. In summary, it is anticipated that projected recovery works will maintain the current, good condition of biological communities of the freshwater claypans. However, further investigations will be required to assess the management required for the wandoo woodland.

Lake Bryde: Investigations and early modelling indicate that conserving significant parts of this major wetland complex depends on extensive surface water management works (including the main constructed waterway) to control waterlogging and groundwater recharge on the valley floor. Most of the works on reserved land were completed during 2009, and this will greatly improve the protection of native vegetation on the valley floor together with some of the smaller wetlands. Additional works on private property are then proposed. Further investigations are also needed to monitor the effectiveness of surface water management and to determine the urgency of direct groundwater management around key wetlands. The threatened ecological community, which includes one species of declared rare flora, persists at three locations. While vegetation condition has continued to decline in some areas, the construction of the waterway should halt decline due to waterlogging of important areas of valley floor vegetation. In addition, the waterway will ultimately provide the basis for surface water management in relation to Lake Bryde itself.

Lake Warden: While the salinity of surface inflows must be controlled, and previous and ongoing revegetation and other works will contribute to this, detailed investigations and modelling have shown that the immediate problem is overfilling of the lake system. In 2009 the initial engineering works to relieve the problem were completed, and the planning and impact assessment of more substantial works is now well underway. The priority 1 and priority 3 ecological communities in this system are currently conserved, and provided the next phase of engineering works is implemented, the recovery goal should be achieved.

Muir-Unicup: This is an exceedingly complex hydrological and biological system. Although widespread tree farming in the catchment has helped protect conservation values, there are significant management issues related to increasing salinity and acidity. Operational works by DEC have largely eradicated one surface saline scald on the inflow to Yarnup swamp and there is some anecdotal evidence of Baumea recovery. Private re-diversion of flows has helped recovery of Baumea swamps in the Geordenup/Neeranup Swamp system. Current knowledge will allow further small scale recovery works to be undertaken, but more intensive works require further investigations. These investigations are underway and appointment of a catchment hydrologist under contract has helped this process. The 10 threatened species at risk from altered hydrology in this catchment are currently conserved.

Toolibin Lake: Management has largely achieved two key physical indicators of lake recovery (depth to groundwater and quality of surface inflows) and there are areas of vegetation recovery including significant areas of seedling regeneration. Mechanical and electrical problems with groundwater pumps have, however, resulted in some groundwater rises and recovery criteria are under review. Despite improvements in physical recovery indicators, and areas where vegetation condition has remained stable or improved, vegetation decline continued over substantial areas until about 2005. There is evidence that vegetation condition has now stabilised, however, whether this is correct will not be confirmed until the next round of monitoring is complete. Due to dry conditions and the by-passing of saline flows, there has been little opportunity to assess other biological indicators which are based around lake filling events. Twenty-four waterbirds, 11 displaying breeding behaviour, were recorded on Toolibin and Dulbining (upstream of Toolibin) following a partial fill event in 2006–07. A further six species of waterbirds were recorded during the same period immediately downstream at Walbyring Lake, and it is likely that these birds were also present in the project area. In summary, progress to date against recovery indicators is a major achievement given the intensity of hydrological threats to the lake and its biological communities. In 2002 the project partners at Toolibin were awarded the Institution of Engineers Australia National Salinity Prize. The threatened ecological community at Toolibin remains intact, but almost certainly would have disappeared without recovery actions.

Upland biodiversity assets: Works to conserve and recover wetland biodiversity assets threatened by altered hydrology also benefit biodiversity higher in the landscape. In particular, revegetation, remnant vegetation protection and other recovery works in the upper landscape are making an important contribution to biodiversity conservation in general by increasing the area of effective habitat for many terrestrial species. In this respect, the targeting of revegetation into specific catchments ensures a much greater probability of current biodiversity persisting. This is because focusing habitat reconstruction increases the likelihood that population viability thresholds will be exceeded. It should be emphasised that three of the recovery catchments—Lake Bryde, Lake Warden and Muir-Unicup—contain very important representative assemblages of terrestrial biodiversity that would make them priority targets for conservation even without their important wetland assemblages. In addition, Toolibin and Buntine-Marchagee also contain important samples of poorly conserved terrestrial assemblages.

Climate change: A much better understanding of hydrological processes and their management in relation to biodiversity is developing through the work in recovery catchments. This is essential to managing the impacts of climate change in the south-west. In this regard, it is a distinct advantage that the recovery catchments are spread across six different IBRA (Interim Biogeographic Regionalisation of Australia) sub-regions.

Other benefits

Although the Natural Diversity Recovery Catchment Program is aimed at biodiversity conservation, it contributes to a much wider set of outcomes. The most important are summarised below.

New industry development: During the life of the program, nearly $1 million of program funds has been used to subsidise the planting of commercially prospective plants, mostly oil mallees. In the low-medium rainfall zone of the south-west, the lack of a plant resource base is a key barrier to developing a successful biomass industry based on woody perennials. At the same time, if the revegetation component of catchment recovery is commercially driven, the government costs of recovery could be greatly reduced. Thus, the strategic work in recovery catchments to achieve conservation objectives is, concomitantly, supporting the development of new industries which in turn may contribute to conservation. In addition to contributing to the development of prospective, commercial plant species, the commercial feasibility of salt harvesting (it is not feasible under current circumstances) has been well tested by work in relation to Toolibin.

Improved management of other public assets and private property: About 35 per cent of expenditure has directly contributed to improved management of private property. In addition, surface water management works at Buntine-Marchagee, Lake Bryde and Toolibin are helping to protect a number of public roads from flooding and other water damage. Current and proposed works at Lake Warden will contribute to flood mitigation for the town of Esperance. Finally, recovery works at Muir-Unicup have contributed to the management (through revegetation) of lands held by the Department of Water, and are making a contribution to the improved management of parts of the Tone Catchment which is a water resources recovery catchment. The natural diversity recovery catchments, taken together, are improving water management within their 700,000 hectares of catchments. If all recovery catchment works are completed and maintained, this will be a substantial contribution to hydrological management across this area.

Contribution to management of climate change: Revegetation and rehabilitation works under the Recovery Program represent DEC's single largest, direct contribution to carbon sequestration in the south-west [8]. In addition, given that many impacts of climate change will unfold through the hydrological cycle, the elucidation of hydrological functions across the different types of recovery catchments, all in different IBRA sub-regions, will provide valuable knowledge for the management of altered hydrology driven by climate change. These changes are predicted to include increased climate variability, increased frequency of extreme climatic events, and decreased average annual rainfall.

Broader application of knowledge generated: Knowledge generated in recovery catchments is informing a spectrum of land management including agricultural practice (for example, documenting the interaction between revegetation and groundwater) and management of urban salinity (for example, value of groundwater pumping).

The full complement of benefits generated through the biodiversity assets in recovery catchments and their management is summarised in Appendix 1.

Value for money review

As part of this review it is important to assess whether the natural diversity recovery catchment program provides value for money. Here, value for money is defined as government investment generating an acceptable level of overall, state community benefits where the assessment of benefits takes into consideration both negative and positive impacts. For a publicly funded program the judgement of "an acceptable level" is ultimately socio-political and, in addition, requires evaluation against statutory requirements. Also, while some benefits can be evaluated using financial methods, many public benefits are not assessable in these terms. For example, supply of adequate potable water and air of a quality consistent with human health are threshold assessments [9], not financial ones.

Given the above, assessing value for money here involves addressing three questions:

a. Is the natural diversity recovery catchment program consistent with the department's statutory functions and published policies and goals?
b. If the answer to (a) is yes, does the program remain a high priority in relation to the relevant departmental goals, and if so, is the investment level appropriate?
c. Overall, is the program delivering state community benefits commensurate with the level of investment?

After addressing these questions, it is concluded that the Natural Diversity Recovery Catchment Program:

- is consistent with statutory and policy obligations
- tackles two of the major threatening processes in the South West Land Division (altered hydrology and climate change/variability)
- is progressing the management of important biodiversity assets, and is based on a modest expenditure that is, if anything, less than might be expected given the proportional allocation of resources in the south-west
- delivers a broad range of state community benefits in addition to those related to statutory obligations.

Therefore, it is concluded that the program represents good value for money for the state community.

8. In terms of both direct and indirect stimulus for revegetation, DEC's mallee program, a component of the salinity initiative, represents the greatest contribution to carbon sequestration.
9. That is, life ultimately depends on individuals having enough air and water of a quality that will not cause death or serious illness. While acceptable mortality rates may be debated, these are threshold issues.

INTRODUCTION

SCOPE AND CONTEXT

This 10-year review (1996–2006) of progress with the department's Natural Diversity Recovery Catchment Program[10] updates that undertaken previously (Wallace 2001). This document forms part of a review of all departmental salinity programs; however, the recovery catchment section has been completed first to support strategic decisions in relation to natural resource management programs.

In undertaking this review, similar questions to those in 2001 are addressed, namely:

- Are we achieving our salinity initiative goals and associated outcomes, and should they be amended?
- Which management approaches have worked, which have not, and how does this affect our management of salinity in the future?
- What specific recommendations, based on our experience and new knowledge, should be implemented to improve effectiveness and efficiency?

In broad terms the salinity context for this review remains unchanged. The most recent predictions of salinity extent in the south-west of WA are that the area of agricultural land affected by salinity will increase from 0.82 million hectares to an estimated 2.9–4.4 million hectares, with a total area affected of up to 5.4 million hectares (McFarlane et al. 2004). Although the predicted extent of salinity is now less than earlier forecasts (for example, Department of Agriculture et al. 1996a), it still represents major, ongoing costs to the state community through degradation of infrastructure and natural land, water and biodiversity assets.

In the case of biodiversity, it is estimated that some 450 flowering plants and 400 invertebrates are at risk of global or regional extinction as salinity continues to unfold over the next 100 years or so (Keighery et al. 2002, 2004). The importance of better managing salinity is also emphasised in the most recent *State of the Environment Report Western Australia* (Environmental Protection Authority 2007) where land salinisation is ranked among the first priorities for action.

Those managing salinity still face the challenges outlined in 2001. Many ecosystem components and processes must be understood and their management integrated to halt salinity degradation. In the south-west, this complexity is exacerbated by the long timeframes—a minimum of several decades—over which on-ground management is generally required for sustainable success. An additional complication is that while salinity development and management are well understood in general terms, economically viable, environmentally sensitive tools for successful broadscale management are not yet available. Given the risks involved, there is also reluctance to invest in the development of the appropriate tools, a theme returned to in other sections of the departmental review.

Given the challenges listed above and the current emphasis on issues such as climate change and its interaction with food and water production, it is unsurprising that the public profile of salinity has declined. At the same time, saline groundwater tables have dropped in some areas with a drying climate. Therefore, while the timing of this review is consistent with standard planning cycles, it is also opportune to consider the value of salinity programs in the context of natural resource management priorities in general.

TERMS OF REFERENCE

The Department of Conservation and Land Management (CALM) previously reviewed its salinity initiative funded through the *Western Australian State Salinity Action Plan* (Department of Agriculture et al. 1996b) for the period January 1997 to 30 June 2000 (Wallace 2001[11]). By 30 June 2006 the salinity initiative had been implemented over 10 financial years, although increased funding began from a very small base late in the 1996–97 financial year.

This decade provides a convenient period for review, and sufficient time has elapsed for a new evaluation to be opportune. Consequently, the department's Director General has sought a new review of the salinity initiative. The terms of reference for this review are as for the original review, but amended to take into consideration more recent statements of policy. They are that this review will:

- review DEC's programs under the *Western Australian State Salinity Action Plan*[12] (Department of Agriculture

10. Referred to below as either the recovery program or recovery catchment program. Where another form of recovery program is discussed, full titles are used. For example, water resources recovery program.

11. Referred to as the *CALM 2001* Review throughout the following text.

12. Referred to as the *Salinity Action Plan* throughout the following text.

et al. 1996b) and its successors, the documents entitled *Natural Resource Management in Western Australia: Salinity* [13] (State Salinity Council 2000) and *Government Response to the Salinity Taskforce Report – Salinity: A New Balance* [14] (Government of Western Australia 2002); and

- make recommendations for the future of the department's programs under current government policy.

As with the previous review, this account deals primarily with the recurrent funds originally allocated to the department under the *Salinity Action Plan*. These funds were specifically for activities to better manage biodiversity assets threatened by salinity. Recurrent expenditure allocated to manage salinity prior to November 1996, and maintained throughout the period of this review, is not assessed except where it relates to either the activities of personnel allocated salinity management tasks, or to the delivery of specific government tasks allocated to the department in policy documents.

The Natural Diversity Recovery Catchment Program is one of several forming the overall departmental approach to the management of salinity—reviews of the other programs are either currently being completed or proposed.

On 1 July 2006, CALM and the then Department of Environment were amalgamated to form DEC. Given that this amalgamation post-dates the review period, this document deals largely with the work of CALM. However, given that four years have elapsed since the financial review period, new information up to early 2010 has been included to update the review.

13. Referred to as the *Salinity Strategy* throughout the following text.

14. Referred to as the *Response to the Salinity Taskforce Report* throughout the following text.

PROGRAM OBJECTIVES

The primary objective of the Natural Diversity Recovery Catchment Program is:

> *To develop and implement a coordinated Wetlands and Natural Diversity Recovery Program targeting at least six key catchments over the next 10 years to ensure that critical and regionally significant natural areas, particularly wetlands, are protected in perpetuity.* (Salinity Action Plan, page 23).

This objective remains unchanged through subsequent policy reviews of the program. However, an additional target that a total of 25 natural diversity recovery catchments be established by 2010 was identified in the *Government Response to the Salinity Taskforce Report in 2002*. In 2007, the *100-year Biodiversity Conservation Strategy for Western Australia: Blueprint to the Bicentenary in 2029 (Draft)* identified a target date of 2017 for the establishment of 25 natural diversity recovery catchments. The change in target dates reflects the lack of additional resources available for starting new recovery catchments.

A secondary objective has been recognised as part of the wider aims of natural diversity recovery catchments. This was accepted in principle through the CALM 2001 Review. This secondary objective was published in the *Buntine-Marchagee Natural Diversity Recovery Catchment Plan* (DEC 2007) as:

> *To develop knowledge and technologies to combat salinity throughout the agricultural region.*

This secondary objective acknowledges that:

a. success in conserving and recovering biodiversity assets threatened by altered hydrology depends on developing new knowledge and technologies that ensure the profitable, sustainable and environmentally sound management of other land uses, particularly agriculture

b. government investment in protecting public assets where the on-ground outcomes are long term and uncertain is best undertaken in a way that delivers a valuable return to community needs in the short term—in this case through development of applied knowledge, including new technologies. Other benefits are outlined in the Outcomes section below.

As noted in the CALM 2001 Review, it is also important that natural diversity recovery catchments:

- demonstrate that it is possible to stabilise hydrological trends within a large catchment that, if left unchecked, threaten land, water and biodiversity resources
- demonstrate to other land managers in Australia methods of protecting their biodiversity, land and water resources
- develop mechanisms which lead to community ownership of WA's natural resources, including management problems and their solution.

While not formal objectives, these additional outcomes will be achieved if the program is successful.

Consequently, although the Natural Diversity Recovery Catchment Program focuses on the conservation and recovery of important biodiversity assets, it contributes to a much wider range of important public benefits. Since 2003, there has been a greater emphasis within recovery program planning on identifying the priority values of biodiversity assets. A summary of the community benefits of biodiversity assets and related recovery works is provided in Appendix 1.

The six current natural diversity recovery catchments are described in Table 3 and their location is given in Figure 1.

Table 3. Six natural diversity recovery catchments, catchment area, date established and biodiversity assets. Unless otherwise stated, all threatened and priority listings are based on state records.

Name	Catchment area (ha)	Date established	Key biodiversity assets
Buntine-Marchagee	181,000	2001	• Threatened ecological community (TEC) 'Herbaceous plant assemblages on Bentonite Lakes' (Endangered) • Declared rare flora (DRF) *Caladenia drakeoides* and *Frankenia parvula* and 10 priority flora • A large variety of wetland types and valley floor vegetation assemblages and associated fauna including primary saline wetlands and braided channels, gypsum wetlands, fresh/brackish wetlands with *Eucalyptus camaldulensis* woodlands, bentonite wetlands, and freshwater claypans
Drummond	39,500	Oct 2001	Two claypan wetlands supporting: • DRF *Eleocharis keigheryi* and seven priority flora *Myriophyllum echinatum* P3; *Stylidium longitubum* P3; *Rhodanthe pyrethrum* P3; *Trithuria australis* P4; *Hydrocotyle lemnoides* P4; *Schoenus natans* P4; *Persoonia sulcata* P4 • High aquatic invertebrate species richness that lies within the top 10% of wetlands surveyed in the Wheatbelt survey • Priority ecological community (PEC) 'Claypans with mid dense shrublands of *Melaleuca lateritia* over herbs' (P1) Two other important biodiversity assets threatened by hydrological changes are: • PEC 'Wandoo (*Eucalyptus wandoo*) woodland over dense low sedges of *Mesomelaena preissii* on clay flats' (P2) • A second area of wandoo woodland within which occurs DRF *Acacia chapmanii* subsp. *australis*
Lake Bryde System	140,000	Jul 1999	• TEC 'Unwooded freshwater wetlands of the southern Wheatbelt of Western Australia, dominated by *Muehlenbeckia horrida* subsp. *abdita* and *Tecticornia verrucosa* across the lake floor' (Critically Endangered) • DRF *Muehlenbeckia horrida* subsp. *abdita* • Wooded yate swamp in Lake Bryde Reserve dominated by *E. occidentalis* and *M. strobophylla* • Wetland assemblages dominated by *M. halmaturorum*, *M. lateriflora*, *M. atroviridis* and *Tecticornia* sp. • Valley floor vegetation assemblages; the most dominant vegetation type being mixed melaleuca shrublands along the low lying flats dominated by *M. brophyi*, *M. lateriflora* subsp. *lateriflora* and *M. atroviridis*. The second dominant vegetation assemblage is *M. lateriflora* subsp. *lateriflora* in the lowest parts of the landscape. Adjacent mallee woodland over melaleuca shrubland is dominated by *E. sporadica*, *E. suggrandis* and *E. perangusta*
Lake Warden System	212,000	Nov 1996	• Listed as a Wetland of International Importance under the Ramsar Convention • Regularly supports more than 1% of the global population of hooded plover (*Thinornis rubricollis*) (P4) and chestnut teal (*Anas castanea*) • 73 species of waterbirds recorded. These include 42 EPBC[15] Act listed species, 40 are listed as 'Marine' species and 25 species are listed as 'Migratory' and are included under one or more of the following international migratory bird agreements: CAMBA (23), JAMBA (22), ROKAMBA (19) and CMS (20). One species is listed as 'Vulnerable' under the EPBC Act

15. Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*

Table 3. (continued) Six natural diversity recovery catchments, catchment area, date established and biodiversity assets. Unless otherwise stated, all threatened and priority listings are based on state records.

Name	Catchment area (ha)	Date established	Key biodiversity assets
Lake Warden System (continued)			• Two PECs 'Stromatolite like microbialite community of a Coastal Hypersaline Lake (Pink Lake)' (P1) and 'Scrub heath on deep sand with *Banksia* and *Lambertia*, and *Banksia* scrub heath on Esperance Sandplain' (P3) • Wide variety of wetland assemblages
Muir-Unicup	70,000	Nov 1996	• Listed as a Wetland of International Importance under the Ramsar Convention • 69 species of waterbird recorded. These include 30 EPBC Act listed species, 30 are listed as 'Marine' species and 17 are listed as 'Migratory' species and are included under one or more of the following international agreements: CAMBA (16), JAMBA (15), ROKAMBA (13) and CMS (14). Presence of the threatened Australasian bittern (*Botaurus poiciloptilus*) (Vulnerable) and the little bittern (*Ixobrychus minutus*) (P4) • DRF *Caladenia christinea*, *C. harringtonia* and *Diuris drummondii*, plus about 30 priority flora (numbers under review) associated with wetlands • Presence of two species of threatened fish, the western mud minnow (*Galaxiella munda*) (Vulnerable), Balston's pygmy perch (*Nannatherina balstoni*) (Vulnerable) and the black-stripe minnow (*Galaxiella nigrostriata*) (P3) • A rich suite of aquatic invertebrates, including those restricted to freshwater and salt tolerant species. Many species have restricted distributions (local to Muir-Unicup or local to the south-west) including some relictual taxa of Gondwanan origin. A couple of invertebrates are priority listed (*Pseudohydryphantes doegi* (P1) and *Acercella poorginup* (P1) with *Branchinella compacta* to be submitted for listing; others are being reviewed as well) and a microinvertebrate family has been identified that appears to be endemic to the complex • PEC 'Relictual peat community' (P2), which is generally rare and threatened within the West Australian landscape
Toolibin Lake	48,000	Nov 1996	• Listed as a Wetland of International Importance under the Ramsar Convention • TEC 'Perched wetlands of the Wheatbelt region with extensive stands of living swamp sheoak (*Casuarina obesa*) and paperbark (*Melaleuca strobophylla*) across the lake floor' (Critically Endangered), which is also listed under the Commonwealth EPBC Act as Endangered • 41 waterbirds recorded using the lake, of which 24 have been observed breeding – the largest number of species for any inland wetland of the south-west • Associated riparian vegetation – for example, York gum woodlands, that are poorly conserved in the south-west agricultural zone • An invertebrate fauna typical of brackish or mildly saline waters. The species present at any one time vary according to salinity and probably represent a transitional fauna between fresh and saline conditions rather than a stable brackish community • *Melaleuca strobophylla*, recorded as having a restricted geographic range • Flooded gum (*E. rudis*), a species near the eastern edge of its distribution

STATUS OF CALM 2001 REVIEW RECOMMENDATIONS

Recommendations 11 through 15 of the CALM 2001 Review relate to the Natural Diversity Recovery Catchment Program. Progress against each of these recommendations is summarised in Table 4. Proposed actions and responsibilities for further action, where warranted, are included with the recommendations of this review. An analysis of the department's progress against published government policy recommendations is being developed separately.

Where implementing recommendations has not been dependent on significant, additional resources, progress has been excellent. However, a key thrust of state policy documents and the review was the expansion of the program up to 25 recovery catchments. Without significant additional, ongoing resources, expansion of the current program is not practicable. Despite this, some progress in this regard has been made in partnership with several regional natural resource management groups through a collaborative approach which has enabled work on several potential recovery catchments, particularly in terms of data collection.

Figure 1. Location of six natural diversity recovery catchments in relation to IBRA sub-regional boundaries.

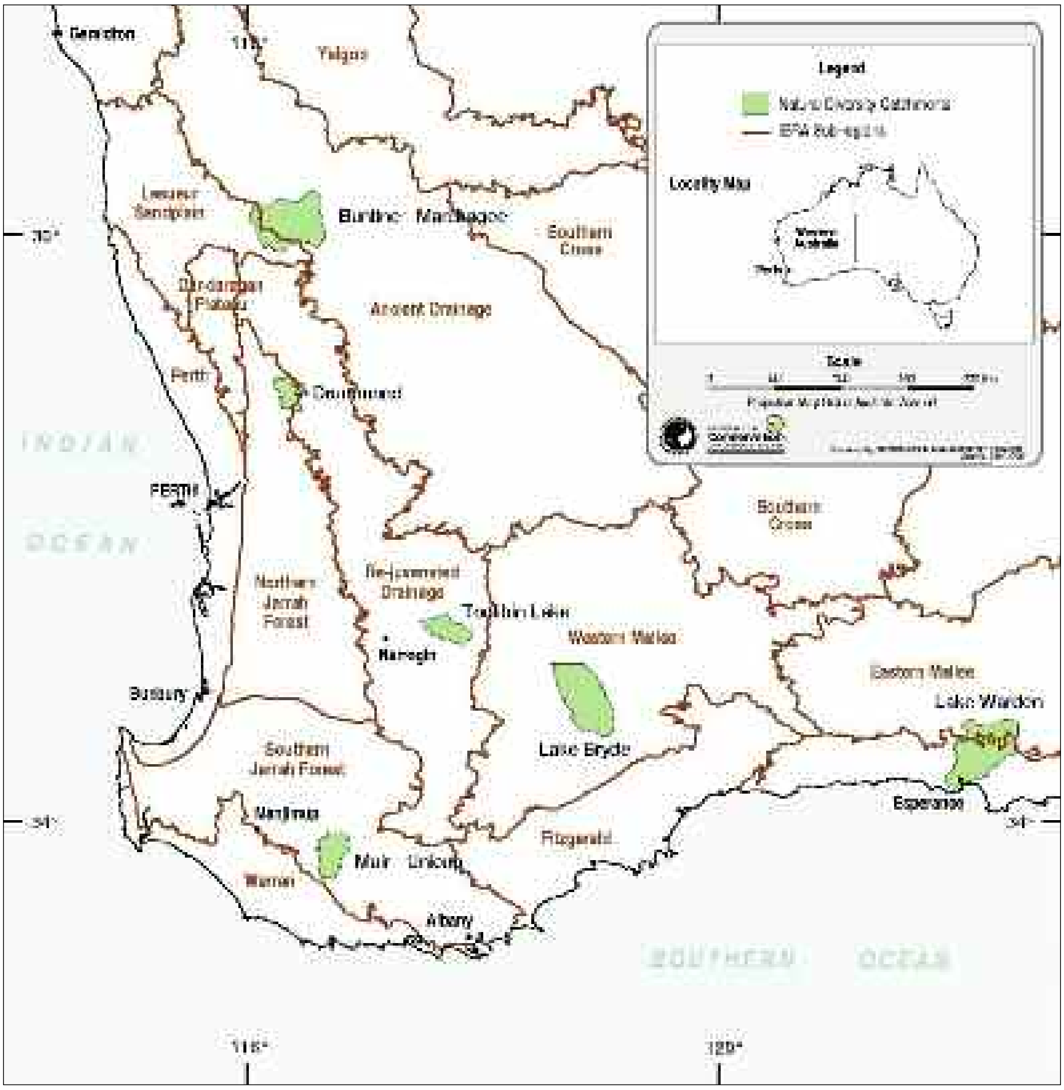


Table 4. Review of progress against the recommendations in the 2001 CALM Salinity Review – recommendation numbers are as given in the review.

Rec. no.	2001 Recommendation	Progress as at 30 June 2006	Proposed actions and responsibility (takes into consideration actions to June 2009)
11	The Natural Diversity Recovery Program should be expanded to cover areas that, while not necessarily containing wetlands, are of significant importance to biodiversity conservation and whose management will contribute to achieving positive downstream effects. Note that there is some capacity to achieve this through implementing the recommendations made under the Crown Reserves Program.	No additional recurrent funds have been provided to the Natural Diversity Recovery Program. Changing the emphasis within the Crown Reserves Program and the application of some funds received through the National Action Plan for Salinity and Water Quality (NAP) and regional natural resource management (NRM) groups have enabled targeted management of some areas covered by this recommendation. Examples include work at Dongolocking, Lake Gore, Wallatin and Tarin Rock in the 2001–06 period.	While the intent of this recommendation is still sound, work over the last eight years has emphasised that the Natural Diversity Recovery Program should retain its focus on the conservation of important biodiversity assets threatened by salinity and other aspects of altered hydrology. Targeting of funds to protect important biodiversity assets higher in the landscape, where this contributes to improved water management, should be retained as one element of an amended Crown Reserves Program, and funds to support this work should be sought through various sources including new Commonwealth and state government programs.
12	The Natural Diversity Recovery Program should be expanded to include the most important areas threatened by salinity identified through the Biological Survey Program. In doing this, it is also recommended that an effective environmental management system be developed that better integrates risk, costs and values than current procedures.	No additional recurrent funds have been provided to expand the Natural Diversity Recovery Program. However, resources obtained through the NAP/regional NRM groups have been used to support both existing recovery catchments, and undertake preliminary work on some potentially new recovery catchments. With regard to environmental management systems, DoE (2003), Wallace et al. (2003), and Sparks et al. (2006), and work on decision frameworks in recovery catchments provide a sound foundation for planning and implementing management taking into consideration risks, costs and values.	New funds should be sought to implement the expansion of the Recovery Program. Failing this, the Crown Reserves Program could be gradually wound down and the funds transferred to establishing new recovery catchments. (Recommendations concerning future funding are provided in the Recommendations section below). With regard to planning, it is important to build on past work, particularly that of the last eight years, to provide an increasingly robust framework for planning and implementing management. This will include the use of risk management approaches combined with Bayesian networks and other analytical techniques incorporating uncertainty to ensure that complex decisions regarding salinity management are soundly based and well-documented. This is essential to ensure that a proper adaptive environmental management process is maintained. A current (2009) project under the Future Farm Industries Cooperative Research Centre is committed to meeting this need.

Table 4. (continued) Review of progress against the recommendations in the 2001 CALM Salinity Review – recommendation numbers are as given in the review.

Rec. no.	2001 Recommendation	Progress as at 30 June 2006	Proposed actions and responsibility (takes into consideration actions to June 2009)
13	The Natural Diversity Recovery Program should be explicitly recognised for its importance in researching and developing solutions to salinity. Their role as living experiments that protect key public assets as well as contributing to research and development should be maintained and expanded. Works in recovery catchments will, if properly managed, underpin the achievement of both natural diversity conservation and sustainable land use objectives. This also underlines the program's role in maintaining the type of long-term monitoring required to develop and document effective practice in natural resource management.	The value of recovery catchments in relation to this recommendation has been maintained. Perhaps the best example is the continued synergy between DEC subsidised mallee plantings for land management, including salinity control at Toolibin, and the development of an oil mallee industry. Another example is the surface water management site within the Buntine-Marchagee natural diversity recovery catchment where DEC is contributing to works on farmland that will improve surface water management from both an agricultural and biodiversity conservation perspective, while at the same time developing a case study of surface water management for wider application. While this role of recovery catchments is promoted, there is still a need to better document and explain this function.	This continues to be a formal objective and is being incorporated into recovery plans. No further recommendation is required as this will form part of the recovery plan review process.
14	The Natural Diversity Recovery Program should be funded to implement effectively recommendations 11 to 13 inclusive. An additional $3 million (as recommended in the Salinity Strategy), scaled up over four years, should be allocated to natural diversity recovery catchments. It should be noted that this amount only substitutes for that which was to be sought from the Commonwealth Government under the Salinity Action Plan. Recommendations 11, 12 and 14 are consistent with the Salinity Strategy recommendation that the number of natural diversity recovery catchments be expanded. However, Recommendation 14 is an extremely modest step given the extreme risk to biodiversity values throughout the agricultural region. Consequently, it is recommended that: [see Recommendation 15 below]	No additional recurrent funds became available. Some additional funds obtained through projects under the Natural Heritage Trust (NHT) and National Action Plan for Salinity and Water Quality (NAP) helped extend works in some recovery catchments, and have allowed some investigations in potential recovery catchments.	For further actions refer to comments under Recommendation 12 above.

Table 4. (continued) Review of progress against the recommendations in the 2001 CALM Salinity Review – recommendation numbers are as given in the review.

Rec. no.	2001 Recommendation	Progress as at 30 June 2006	Proposed actions and responsibility (takes into consideration actions to June 2009)
15	The adequacy of funding for this program should be reviewed in three years (February 2004). This will allow time to fully digest the outcomes of the biological survey, implement additional recovery catchments, and assess whether one or more earlier recovery catchments are in a position where they may be wound down.	Not reviewed in 2004, and is part of this review. It is clear that current funding is not adequate to deliver the recommendations for recovery catchments. Also, none of the recovery catchments has developed to the point where funding could be significantly decreased.	For further actions refer to comments under Recommendation 12 above.
16	At an operational level, the issues highlighted in the Problems/Difficulties section should be tackled by the department, and action should be taken to maintain the positive outcomes listed within the highlights section and in the specific catchment accounts. This includes, but is not restricted to, developing and implementing: a) improved monitoring and GIS-based information systems b) guidelines for species selection in revegetation c) guidelines for cost-sharing and strategies to maximise adoption of actions sympathetic to conservation across the agricultural region d) improved public access to documents and reports generated through the recovery process that will help other groups to implement salinity management e) improved information exchange between officers involved with recovery works, both within the department and with other officers managing Water and Rivers Commission (WRC) and Agriculture WA recovery catchments	Progress against Recommendation 16 as follows: a) Covered in part under Recommendation 5 of this report. With the appointment of some hydrologists, physical monitoring in recovery catchments has improved, however, need to maintain improvement and develop better programs for monitoring biodiversity. b) Not done – need to complete this task. c) Strategies to maximise adoption of actions sympathetic to conservation are largely being undertaken through regional NRM groups. d) Website created, and some key documents have been placed there. Need to upgrade the site. e) Departmental officers involved in salinity now meet at least annually. In 2006, a one-day workshop was held between officers of DEC, Department of Water (DoW) and Department of Agriculture and Food (WA) (DAFWA) involved in recovery catchment work. It is proposed to maintain these meetings on a regular (not necessarily annual) basis. In addition, a Technical Advisory Group consisting of DEC officers has been formed to advise on technical issues pertaining to recovery catchments.	Progress against Recommendation 16 as follows: a) Physical monitoring in recovery catchments to be managed through recovery planning process plus a group of recovery catchment officers chaired by the supervising hydrologist (Natural Resources Branch). Biodiversity monitoring will, in the first instance, be developed through recovery plans. Situation to be reviewed within two years (see Recommendation 6 of this report below). b) Guidelines for species selection in revegetation is a low priority task, but will be developed if required. c) Given development of regional NRM groups, focus here will be on reviewing cost-sharing arrangements, and adaptation to a changing socio-political environment as required. d) NRB will re-develop the website and populate with appropriate material. e) Current arrangements satisfactory.

Table 4. (continued) Review of progress against the recommendations in the 2001 CALM Salinity Review – recommendation numbers are as given in the review.

Rec. no.	2001 Recommendation	Progress as at 30 June 2006	Proposed actions and responsibility (takes into consideration actions to June 2009)
	f) maintaining the very effective inter-agency links and collaboration that have evolved at the recovery project level, while noting the need to broaden this beyond the project level (see previous point) g) improved evaluation of proposed recovery catchments in terms of salinity hazard, values at risk, and costs to recover. In this regard it may be more fruitful, in some cases, to prevent areas higher in the landscape becoming saline than trying to implement expensive engineering in the valleys h) it is also recommended that these actions be tackled in consultation with other organisations involved in delivering highly targeted programs.	f) Cross-agency membership of committees involved in specific recovery catchments, and programs such as the Catchment Demonstration Initiative, Engineering Evaluation Initiative, Rural Towns Program and other salinity-related programs are maintaining a reasonable level of inter-agency linkage. g) Improved assessment and decision processes have ensured adequate progress in this regard. However, it is important that this is maintained– see actions. h) Interaction with regional NRM groups, Southwest Ecoregion planning, WWF and Greening Australia, for example, is ensuring broader consultation over approaches and technologies.	f) Current arrangements satisfactory, although as the listed programs cease, alternative approaches to maintaining cross-agency links will be established. g) Existing and proposed projects involving the Future Farm Industries Cooperative Research Centre will be implemented/developed to complete the current decision methods, including risk management components. h) Current interactions will be maintained.

PROGRAM IMPLEMENTATION

This section describes the management techniques applied in natural diversity recovery catchments. Although all catchments are managed using a standard approach, catchments vary considerably in terms of their social and biophysical characteristics. Thus, the standard approach is adapted to meet local circumstances. For example, while the main biodiversity assets in most recovery catchments are within nature reserves, many of those in the Buntine-Marchagee natural diversity recovery catchment are on private land, and this has implications for management including approval of plans and associated works.

In all recovery catchments, biodiversity assets are threatened by changes in hydrological processes arising from the replacement of perennial native vegetation with agricultural activities based on annual plants. A significant percentage of the recovery works must therefore be undertaken on private property. Under these circumstances, action only proceeds where there is strong mutual interest among the parties, or adequate incentives are available to encourage landholders to participate. In one recent study, the importance of incentives from the perspective of private landholders is clearly acknowledged by the landholders themselves (Munro and Moore 2007).

THE REGIONAL DELIVERY AND CENTRAL COORDINATION MODEL

Operational management of natural diversity recovery catchments is undertaken by the Regional Services Division of the department. In April 2003, the Natural Resources Branch was established within the Nature Conservation Division, and this group is now responsible for overall coordination of the salinity initiative. Indicative annual budgets for each recovery catchment are developed annually by the branch in consultation with personnel from Regional Services Division, and these are endorsed, or adjusted and endorsed, by the Director of Nature Conservation. In the language of purchaser-provider management models, the Director of Nature Conservation is the output purchaser, and the Director of Regional Services is the service provider.

RECOVERY PLANNING

Along with their operational role, personnel from the Regional Services Division are responsible for management plan preparation. This includes local consultation, which is generally managed through a recovery team or steering committee comprised of key stakeholders including representatives of local land managers, government agency representatives, and a range of other groups depending on the particular catchment.

Although recovery plans are developed with significant input from DEC regional personnel, staff from the Natural Resources Branch manage plan development, including the writing component and technical input, particularly in relation to hydrological expertise. While all recovery catchments have had at least an interim plan, only one formal plan (DEC 2007, Buntine-Marchagee) has been published in the last decade in addition to the formal plan for Toolibin Lake, which existed prior to the beginning of the program.

A departmental Technical Advisory Group also provides advice and input during the development of formal recovery plans. Ultimately, the final draft recovery plan is sent to DEC's Corporate Executive for approval, and to the Conservation Commission of Western Australia when key areas are vested in the Commission.

DATA REPOSITORY AND QUALITY CONTROL

The program involves regional officers collaborating with personnel from the Natural Resources Branch in the collection, collation and analysis of large amounts of data. Each of the individual recovery catchments has valuable and irreplaceable hydrological, geochemical, geological, geophysical and other significant datasets that, until recently, were largely managed inconsistently across the catchments. In July 2008 the department began developing a Hydstra database, the industry standard, to store and analyse hydrological information. Once all hydrological data are transferred to this system, the level of data protection, quality assurance, and capacity for corporate-wide analysis will be substantially improved. Use of Hydstra will also enable departmental data to be directly incorporated with the commonwealth and state datasets managed by the Bureau of Meteorology and the Department of Water respectively. Currently other biophysical data are stored and managed through regional and district offices, and there is considerable scope to improve data management. Science Division personnel also manage important datasets.

REPORTING

Systems for planning, budgeting and reporting are standard across all catchments and have been designed to ensure that management activities are closely linked to the management of a specific threatening process. Outputs and expenditure are, in turn, closely linked to management activities (see Appendix 2 for a detailed description). This ensures that the efforts to address specific threatening processes are fully documented, an important contribution to effective planning and project evaluation. The standard system also allows information to be collated and analysed across all recovery catchments.

SELECTION OF ADDITIONAL CATCHMENTS

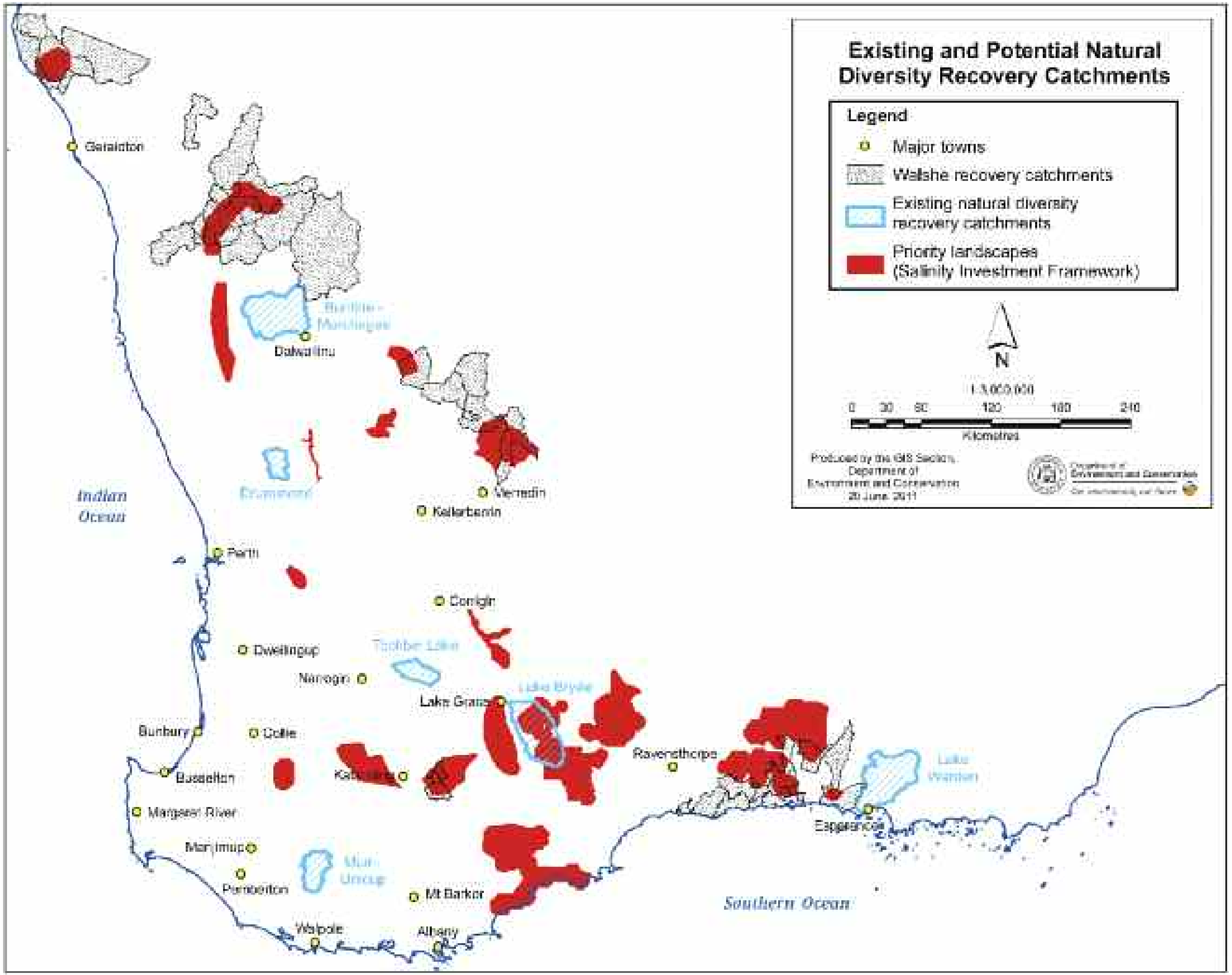
Only the Drummond and Buntine-Marchagee natural diversity recovery catchments have been added since June 2000. Selection of these used the criteria outlined in the CALM 2001 Review, augmented by expert knowledge developed during the biological survey of the south-west agricultural zone (Keighery et al. 2004).

However, a major new output from the biological survey of the agriculture zone (Keighery et al. 2004) was the identification of areas that should be investigated as sources for potential natural diversity recovery catchments (Walshe et al. 2004). This work highlights areas that are most likely to contain biological assemblages that best represent the biodiversity of the south-west agricultural zone threatened by salinity (see Figure 2).

Walshe et al. (2004) note in the abstract of their paper that the results of their analysis "identified a subset of core areas for conservation investment that efficiently represented [biological] assemblage diversity.
However, ... field reconnaissance and verification will be necessary to account for localised variation in species richness and for vagaries in the distribution of remnant vegetation patches, wetlands and salinity risk."

To improve the definition of sites for potential recovery catchments, this information was combined with expert and other analysis from the *Salinity Investment Framework Phase 1* (Department of Environment 2003). This has provided an important guide to the location of additional recovery catchments (see Figure 2). In December 2006, after undertaking some of the field reconnaissance proposed by Walshe et al. (2004), the next three natural diversity recovery catchments were identified and recommended for consideration within the department (Hutt, Lake Gore, Lort), and a further five areas were suggested for additional field work (Campion, Mollerin, Yarra Yarra, Coyrecup, Young-Stokes). With respect to the last group, it is particularly important to assess whether key biological communities threatened by salinity in the wheatbelt are adequately conserved in the rangelands to the east. A desktop analysis (Woodgis Environmental Assessment and Management 2009) suggests that many of the target wheatbelt communities are well represented in the rangelands, and thus some assemblages might not need to be conserved within the agricultural zone. In any case, at this stage, funding is not sufficient to initiate any further recovery catchments. Consequently, further work on selecting new areas has ceased.

Figure 2. Existing recovery catchments, areas selected under the Salinity Investment Framework (DoW 2003) and the work of Walshe et al. (2004).



ACTIVITIES, EXPENDITURE AND OUTPUTS

The overall expenditure and outputs from work on recovery catchments are summarised below. In this document, outputs are defined as measures of management activity—such as area revegetated, kilometres of drainage works—while outcomes are defined as measures of goal achievement, including threat amelioration.

OVERALL ANALYSIS

During the period July 1996 to June 2006, $16.2 million of state recurrent funds were expended on work in recovery catchments, an average expenditure of $1.6 million per year. Full details of this expenditure are provided in Appendix 2 and summarised in Table 5.

The following points need to be considered when interpreting these figures:

- Salinity expenditure is reported on an activity basis (project budgeting). That is, all costs including salaries, contracts and vehicles are allocated against a specific activity. This approach focuses attention on the cost of delivering a particular activity and its related outputs and outcomes.
- The expenditure recorded only tracks the use of recurrent funds allocated under the Recovery Program of the salinity initiative. An additional amount of about $0.3 million per year from the salinity initiative (starting in 2003–04) supports work through the Natural Resources Branch in recovery catchments, and some further recurrent funds are allocated within DEC to work in recovery catchments. However, the latter is a minor component of overall expenditure and is counterbalanced by use of recovery catchment personnel in bushfire suppression and other activities outside the recovery catchments (but with costs debited to the salinity program).
- Other agencies and private landowners fund research and on-ground works relevant to delivering outcomes in recovery catchments, but there is no mechanism currently for capturing this expenditure. Given that much of this expenditure is aimed primarily at achieving objectives other than the protection of biodiversity, it is arguable whether it would be appropriate to record this work against biodiversity outcomes, despite its importance in achieving them.
- During the period when the National Action Plan for Salinity and Water Quality was operating, the Avon Catchment Council [16], Northern Agricultural Catchment Council, South Coast NRM, and South West Catchment Council all made valuable contributions to on-ground works in recovery catchments. Again, it has proved difficult to accurately capture this expenditure (much of it does not come through departmental records). However, it is recorded in individual recovery catchment reports where data are available. Expenditure into recovery catchments from the Natural Heritage Trust, National Landcare Program and National Action Plan for Salinity and Water Quality is estimated to have exceeded $6 million for the period 1996–2008. After 2006, much of this expenditure has occurred via regional natural resource management groups. Note, also, that the primary purpose for a significant part of this expenditure has been directed primarily at, for example, sustainable agriculture, but has been targeted to recovery catchments to maximise multiple benefits.
- There will be some inaccuracies due to misallocation of funds due to human error. Corporate financial records were used as a check against catchment expenditure for each year, and there was an acceptable reconciliation at this level (<5 per cent error over all catchments for all years).

Over the past 10 years, three general phases of expenditure have become apparent to those working in recovery catchments and these are represented in the relative proportions of expenditure in Table 5.

In the first stage, with the exception of Toolibin Lake, all catchments began with completely inadequate local knowledge of hydrological and related processes. Even in the case of Toolibin, the emphasis had been on groundwater hydrology. Data on surface water and its impacts are only now beginning to be effectively captured. In general, 30 years is considered to be the minimum period over which data must be collected to characterise climate (Colls and Whittaker 1990), and in the Australian context some have suggested up to 150 years of data are required to describe the rainfall component of climate (Gibbs et al. 1978). It is therefore unsurprising that the first five to 10 years of work in each catchment has been dominated by investigations aimed at understanding how catchment hydrological processes affect the biodiversity assets under management. At the same time, continuous monitoring is required to maintain data collection and analysis at an adequate level to evaluate conceptual models and to develop the numerical models required for operational management of hydrology.

16. Now Wheatbelt NRM

Table 5. Summary of recovery catchment expenditure and outputs against core activities 1996–2006.

Activity	Outputs	Expenditure ($ million)	Expenditure (% of total)
Expansion of conservation estate through land purchase, including survey work	1,394 ha purchased	1.14	7%
Revegetation to buffer remnant vegetation, provide new habitat and provide hydrological control	2,672 ha revegetated 3.1 million seedlings	2.88	18%
Revegetation with commercially prospective plants to buffer native vegetation, provide habitat and provide hydrological control	2,249 ha revegetated 1.7 million seedlings	0.84	5%
Rehabilitation of degraded areas on Crown lands	310 ha rehabilitated	0.33	2%
Improved protection of remnant vegetation on private property	5,161 ha 350 km fencing	0.82	5%
Weed and feral animal control	Not applicable	0.09	1%
Engineering works on Crown lands to protect public assets	39 sites	2.94	18%
Engineering works on private property to protect public assets	Not applicable	0.66	4%
Monitoring, research and investigations, including impact assessments (other than funds allocated against specific management projects)	Not applicable	4.44	28%
Management of committees, recovery planning, communication and volunteer management	Not applicable	1.72	10%
Other (e.g. development of recreation/interpretation sites)	Not applicable	0.31	2%
Total		16.17	100%

All these aspects are reflected in the high percentage of expenditure against investigations and monitoring (28 per cent). As outlined below in the section titled, 'The challenge of managing catchments', we have generally aimed to have 10 years of data in recovery catchments before modelling catchment hydrology. Even this level of data has not always been achieved given the urgency of management action in some cases.

It would be poor management to embark on expensive engineering works without adequate biological and hydrological information. Therefore, the first phase of work is also characterised by on-ground works that are required for longer term success, but may or may not be the most urgent in the medium term. Typically these include strategic revegetation and improved protection and management of remnant vegetation in the catchment (30 per cent of expenditure). Such works are ultimately important contributions to achieving recovery goals, so represent 'no regrets' actions with very low risk of failure. In addition, these works protect biodiversity outside the biodiversity assets threatened by altered hydrology and are an important mechanism for engaging catchment landholders, an essential precursor to later actions such as cross-property engineering works. Revegetation works continue throughout the following phases.

The second phase involves engineering. Initially, such works usually focus on surface water management, which are typically extensive and sometimes complex. This work is required to better manage surface water moving through catchments—mainly to reduce waterlogging, decrease surface water residence time and minimise the surface expression of salinity from related recharge. Toolibin and Lake Bryde are well into this phase, with Lake Warden and Buntine-Marchagee also having entered this stage. In the case of Buntine-Marchagee, early works are centred on 'no regrets' actions at a sub-catchment scale (photographs 1 and 2), with substantial funding from external sources because the activities directly contribute to sustainable agriculture as well as (but more indirectly) to biodiversity conservation. Surface water management works may require substantial engineering, for example, the diversion at Toolibin and waterway at Lake Bryde (see photographs 3 and 4).

Ultimately, significant groundwater management works may also be required, such as the groundwater pumping program at Toolibin to reduce immediate threats, or the planned wetland dewatering at Lake Warden (first phase completed in 2008–09). Such works require much more sophisticated engineering, highly detailed environmental impact assessments and feasibility analyses including risk assessment (see, for example, the Bayesian analyses for Lake Warden (Table 6). Some 22 per cent of expenditure over the past decade has funded engineering works, and given the relative youth of the recovery catchments, this is certain to increase. Because of the high cost of capital works, this phase is typified by the need to seek additional resources from outside the annual recurrent funds of the program.

Finally, in the third phase of activity there is a consolidation of work into maintenance, monitoring and review. While in the case of Toolibin this phase has briefly proved less expensive, and one would expect this to be typical, it is also stimulating additional proposals for a new phase of engineering to modify and improve initial works based on experience and new information. This is associated with increases in expenditure. Furthermore, the task of monitoring, evaluation and reporting, critical to effectively manage and extend the knowledge from recovery catchments, is expensive in itself.

It is expected that work in each of the recovery catchments will broadly follow the sequence of phases described above. Although the various catchments cycle through these phases at different paces, this general pattern of effort is consistent with actual experience and provides a guide to forecasting workloads and budget requirements for new catchments.

DETAILED ANALYSIS

In addition to the broad analysis provided above, the data in Table 5 and Appendix 2 also allow more detailed evaluation. At this more detailed level the most interesting set of statistics relate to the relative costs of revegetation.

Analysis of revegetation costs shows that, overall, revegetation as biodiversity plantings costs on average $1,080 per hectare, or $0.93 per seedling. In contrast, revegetation with commercially prospective plants—mostly oil mallees in this case—costs on average $370 per hectare and $0.5 per seedling[17]. The significant cost difference for this key management strategy (23 per cent of 10-year expenditure) strongly underlines the potential savings in recovery costs if revegetation with perennial plants, integrated with agriculture, was commercially viable. A desktop study (reported in URS 2004 and Sparks et al. 2006) has estimated that recovery costs met by governments could be reduced by about 50 per cent if the perennial revegetation component was paid by commercial interests. This underlines the importance to nature conservation of departmental work to develop new commercial industries based on broadscale plantings of native plants.

A second point of interest is that all remnant vegetation protection, private land purchases, most revegetation (excluding the small proportion on Crown land), and all engineering works on private property directly and positively contribute to the management of private land. These include one or more of a wide range of benefits including improved management of salinity, waterlogging, stock and crop protection and erosion control. It is estimated that more than 35 per cent of recovery catchment recurrent expenditure directly benefits private landowners. This figure:

- excludes some 300 hectares of revegetation on private lands purchased for conversion to public reserves
- includes purchase of private land for reservation on the basis that all purchases are by mutual agreement and therefore of mutual advantage. In addition, land purchases invariably include large areas of saline or at risk land, consequently, they result in better alignment of land management and land capability
- excludes the benefits to private land arising from expenditure on Crown land; for example, improved management of surface water on reserved land that allows for the safe drainage of excess water from upslope farmland. Works at Toolibin and Lake Bryde are making an important contribution to upslope farmland in this regard.

Taking all these points into consideration, the benefits to private property of recovery catchment works will greatly exceed the calculation of 35 per cent of directly applicable recovery expenditure.

17. It should be emphasised that the area cited for the commercial plantings is based around hydrological area of impact. Given that many of the commercially prospective plantings are as mallee belts, rather than block plantings, the hydrological impact of the commercially prospective plantings is much greater than the more consolidated biodiversity plantings. This also explains the low number of seedlings per hectare for commercially prospective plantings.

OUTCOMES

Management success in recovery catchments needs to be reviewed over decades because the impacts of landscape scale management interventions to counteract secondary salinity can rarely be assessed in shorter time periods. Not only is it difficult to rapidly address problems that have developed over some 100 years, the pathway of recovery may be different and more difficult to the process of development. For example, recovering soil structural changes caused by salinisation may not involve a simple reversal of the salinisation processes. The positive effects of management are even more difficult to assess where, as in the case of salinity in the south-west, the landscape is still in decline. Thus management that either slows the rate of decline or decreases the final, full expression of salinity is, in many cases, a positive outcome.

As outlined above, nearly a third of expenditure in the recovery catchments has been directed to investigations that will underpin modelling, the results of which will drive complex management strategies. Apart from Toolibin Lake, until recent years there have been insufficient data and modelling to drive the more intense forms of management that are likely to provide outcomes in short timeframes. Therefore, outcome data are generally only available for Toolibin Lake, the area with the longest history of management intervention. In spite of this, there have been a range of positive outcomes from the recovery program to date. These are described below.

BIODIVERSITY CONSERVATION – ASSET PROTECTION AND RECOVERY

The success of the recovery program needs to be considered largely in terms of the conservation and recovery of biodiversity assets directly threatened by altered hydrology, particularly salinity. However, all recovery catchments also contain important biodiversity assets upslope and outside the wetland, riparian, valley floor and other ecosystems threatened by salinity. Recovery works, particularly revegetation, also contribute to the protection of these terrestrial biodiversity assets. Therefore, outcomes for the conservation of terrestrial biodiversity assets arising from recovery program works are also considered briefly below. Recovery outcomes are considered in relation to each of the six recovery catchments below (presented in alphabetical order), followed by a section on threatened ecological communities and threatened species in recovery catchments. The final part of this section describes upland biodiversity assets within recovery catchments that are better protected through catchment actions.

Buntine-Marchagee

The operational goal for the catchment is:

> *For the next 10 years, maintain the 2007 richness, distribution, abundance and condition of a representative sample of biodiversity assets threatened by salinity in the BMNDRC.* (DEC 2007)

Recent conceptual models of salinity development in the wheatbelt have given greater emphasis to the management of surface water before it reaches biodiversity assets in valley floors. This conceptual model is particularly important at Buntine-Marchagee where extensive surface-water control works are being undertaken on farmland. The model itself is based on the understanding that:

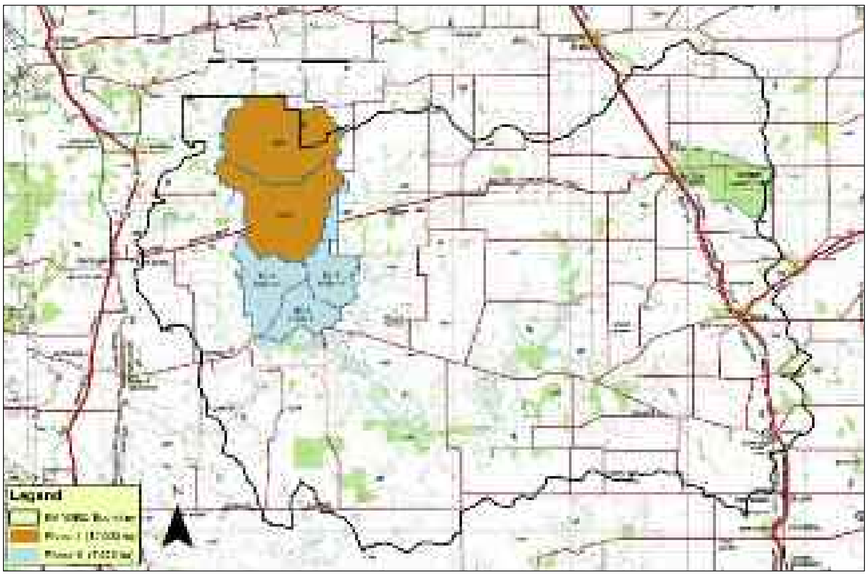
a. waterlogging is degrading some biodiversity assets in valley floors — for example, by drowning riparian vegetation
b. ponding of surface water in valley floors is leading to increased rates of recharge to groundwater, which will ultimately increase the area of shallow saline groundwater threatening biodiversity assets
c. ponding of surface water and associated recharge are also causing *in situ* salinisation of the soil surface, and this in turn is contributing to increasingly saline surface flows, which in turn are degrading biodiversity assets
d. ponding of surface water increases soil moisture content, hence increasing the likelihood of run-off during and shortly after ponding occurs
e. where sediment and nutrient stripping are incorporated as part of surface water management, the probability of downstream nutrient, turbidity and sedimentation impacts on biodiversity assets is greatly reduced
f. management that delivers (a) to (e) above at paddock scales is an important contribution to sustainable farm practice. In this regard, properly designed surface water management has long been recognised as a means of reducing water erosion, recharge, waterlogging and flood damage (McFarlane et al. 1993).

In this context, the broadscale surface water management being implemented at Buntine-Marchagee—which integrates surface engineering, revegetation and other improved practices—is an important success. Initial work focused on landholders in an 860-hectare demonstration catchment, with work beginning in the review period and mostly completed in 2006.

Success of this work (see photographs 1 and 2) has given landholders and DEC staff the confidence to expand this approach to a target area of 19,000 hectares (Figure 3) including the original demonstration catchment. Figure 3 emphasises the scale of works required to have a positive impact on natural resource management at landscape scales.

To date the outcomes have largely been more effective management of land to prevent erosion and downstream sedimentation, protection of a public road, and reduced surface salinisation on farmland. However, based on generic principles, it is expected that there will be positive outcomes for downstream biodiversity assets through improved quality of water reaching the valley floor, and decreased salinity outbreaks in the upper catchment. At the same time, revegetation integrated with the engineering works will at least partly offset the increased volumes of water reaching the valley floor as a result of surface water management.

Figure 3. The shaded brown and blue areas are the target integrated water management areas. The brown area includes works up to 2007–08. The blue areas encompass the proposed 2009, 2010, and 2011 treatments.



Photograph 1. Landholder Jack Stone inspects the surface water flow in the constructed grassed waterway and new culvert – immediately after the one-in-45 year rainfall event in December 2007.
Photograph courtesy of Kathy Stone.

Photograph 2. Downstream from the new culvert, the constructed grassed waterway performed well in the one-in-45 year rainfall event. Photograph courtesy of Kathy Stone.

The next phase of works will directly involve important wetland assets including a gypsum wetland and fresh-brackish wetland complex.

The significance of work in this catchment is underlined by its listing as a Highly Commended Australasian project by the Global Restoration Network (see http://www.globalrestorationnetwork.org/countries/australianew-zealand/). Given the comparatively short duration of this project, this is an excellent result.

Overall, the condition of biodiversity assets, apart from one wetland, in the recovery catchment has been comparatively stable, and none of the values for which the catchment was selected have been lost.

Revegetation works at Buntine-Marchagee have largely been undertaken in conjunction with the integrated surface water management project. Wherever practicable, revegetation aimed at improving the management of water in the landscape is implemented so that it also contributes to improved habitat for the conservation of biodiversity in general. The planning framework underpinning this work is based on a modified focal species approach for isolation-, area- and condition-sensitive birds (Huggett et al. 2004).

Drummond

The management goal is:

> *To maintain the existing (2007) natural species richness and viability of the freshwater claypans and associated habitats within the Drummond Recovery Catchment for the next 20 years (draft management plan).*

The Drummond natural diversity recovery catchment is the most recently established. The initial phase of revegetation and investigations are now (2010) drawing to a close, and the recovery plan will be completed once the hydrological assessments and modelling of management actions for the key biodiversity assets are complete. Currently, it is expected that some further revegetation, plus new engineering works to divert excess surface water, will be required to complete the main component of recovery works, for this, the smallest of the recovery catchments. Once these works are completed, it is predicted that the key biodiversity assets within this catchment, two freshwater claypans and their biological communities (including declared rare flora and priority flora species), will be secure in the short to medium term.

Much of the earlier activity for this recovery catchment comprised 'no regrets' actions throughout the 39,500 hectares of the Soloman-Yulgan Brook and Mt Anvil Gully catchments to improve retention and protection of vegetation, landscape connectivity, and hydrological function. To this end, these activities were aimed at demonstrating methods of protecting biodiversity, land, and water resources from threatening hydrological changes, and developing understanding and support for the Natural Diversity Recovery Catchment Program.

In terms of overall condition of the key biodiversity assets, the two threatened ecological communities (priority 1) and the declared rare flora (*Eleocharis keigheryi*) and three priority flora (*Trithuria australis* P2; *Hydrocotyle lemnoides* P4; *Schoenus natans* P4) remain intact. A second area of wandoo woodland, within which the declared rare flora, *Acacia chapmanii* ssp. *australis*, is threatened by hydrological change, is also being managed. It is anticipated that projected recovery works will maintain the current, good condition of biological communities on the freshwater claypans. However, further investigations will be required to assess management of the wandoo woodland.

Lake Bryde

The management goal for the catchment is:

> *For the next 20 years to slow the rate of decline of biodiversity across valley floor assemblages and to conserve specific high value biodiversity assets including:*
>
> - *threatened ecological communities on Lake Bryde, East Lake Bryde and in Lakeland Nature Reserve*
> - *the wooded yate swamp in Lake Bryde Reserve*
> - *wetland vegetation assemblages*
> - *valley floor vegetation assemblages dominated by* Melaleuca *spp.*

At Lake Bryde, major surface water management works (photographs 3 and 4) are still (2010) in progress and will protect large areas from waterlogging by moving water rapidly through the valley floor system into a series of termination lakes [18] in Lakeland's Nature Reserve. This is predicted to significantly decrease valley floor recharge and ameliorate subsequent groundwater rise, with significant benefits for vegetation communities that are currently degrading.

The waterway is a complex project and the first five years of catchment work have been dominated by the investigations underpinning this work, together with the purchase of private property, environmental impact assessments, feasibility assessment and engineering design, and liaison with local government and

Photograph 3. Section of surface water management waterway, Lake Bryde system.

Photograph courtesy of Wingsphotographics.

landholders. Hydrological and biological monitoring transects have been established to allow the biodiversity outcomes from this work to be documented over the next decade, and the application of remote sensing techniques is also being explored.

Although the primary aim of constructing the waterway is to protect important biodiversity assets, it should be emphasised that the work will ultimately contribute to resolving waterlogging and related problems on farmland upslope from the Lakelands Nature Reserve (see points (a) to (e) above under the section on Buntine-Marchagee). The improved water management and culvert upgrades will also significantly improve protection of vulnerable sections of public roads. These outcomes are significant in their own right, and underline the multiple benefits arising from the recovery catchment projects. It should also be noted that significant additional works are required before the waterway is fully functional.

18. The environmental impact assessment suggests that using these lakes will not result in unacceptable change. Recent observations indicate that the lakes are actually receiving fresher inflows than immediately prior to the waterway construction.

Photograph 4. Section of Lake Bryde waterway. Note the salinity and waterlogging expression along the boundary of the reserve—the waterway will help to prevent this waterlogging and further encroachment into the reserve. Photograph courtesy of Wingsphotographics.

As a consequence of the issues discussed above, in Lake Bryde there has been a much greater focus on assisting landholders with surface water management than at any other recovery catchment except for Buntine-Marchagee. Ultimately, extensions of the current waterway (photograph 4) upslope of Lake Bryde itself will contribute to management of the threatened ecological community on the floor of the lake, plus assist landholders to deal with similar problems on their own properties. Together with revegetation and remnant vegetation protection, these works have dominated the remainder of outputs at Lake Bryde, and have yet to be reflected in documented outcomes, as opposed to outputs.

The overall condition of some biodiversity assets has declined in the Lake Bryde Recovery Catchment over the past decade. However, no assets have been lost, and the declared rare flora and threatened ecological community persist.

Lake Warden

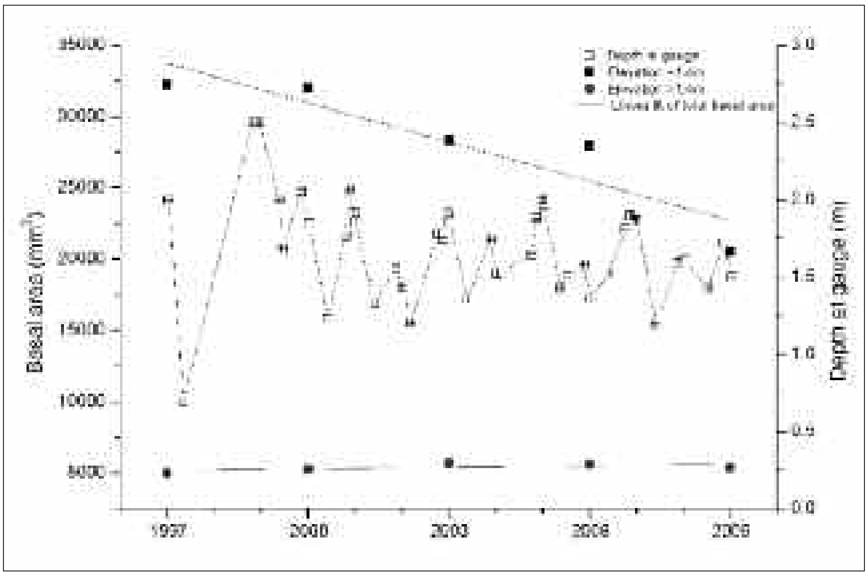
The management goal for Lake Warden is:

> *To recover the existing (2003) waterbird species richness and abundance and living assemblages of the Lake Warden Wetland System to a near natural state*[19]*, by the year 2030.*

Investigations have shown that the groundwater system directly affecting the Lake Warden Wetland System (LWWS) is quite local, and the upper catchment's groundwater system is separated from that of the lakes by a largely impervious geological structure. This emphasises that each catchment will have a unique set of characteristics that must be understood to underpin effective management. In the case of the LWWS, a desktop feasibility assessment based on general hydrological principles grossly overestimated the recovery costs. Other research has shown that the lake system is being 'drowned' by excess water from the upper catchment, which is causing loss of habitat including: shallow feeding areas, exposed feeding flats and fringing vegetation (Robertson and Massenbauer 2005).

19. A near natural state is benchmarked against early 1980s waterbird survey and lake hydrological data.

Figure 4. Basal area of *Melaleuca cuticularis* at Lake Wheatfield showing decline where flooded since 1999 (< 1.4 m elevation, squares) compared with the same species higher in the profile (>1.4 m elevation, circles). Transect 1 data are not included due to fire in 2009 prior to the survey (Lyons and McCormick, unpublished data).



The decline in basal area of vegetation due to excessive flooding is apparent from Figure 4 (Mike Lyons, pers comm. 2010). These data, collected by the department's Wetlands Monitoring Group, are for Lake Wheatfield in the Lake Warden system. A significant decline was observed in the basal area of *Melaleuca cuticularis* from 1997 to 2009 at elevations below 1.4 metres (adjusted $r^2 = 0.79$, $p<0.05$). Basal area of trees above this elevation showed no significant relationship with time (adjusted $r^2 = 0.25$, $p=0.23$). The correlations (Pearson's r) for the two elevation classes were also significantly different ($p<0.05$).

While revegetation and other management techniques will in time reduce the excessive run-off into the lakes, in the short term it is crucial to reduce the water in the wetlands to recover bird habitat and fringing vegetation. Thus, engineering interventions are proposed to counteract the current degradation in the short (10-20 years) term.

To underpin engineering works and give confidence in the selected management strategies, ecological models have been combined with Bayesian Belief Networks to provide a comprehensive understanding of how the wetland system functions, test management scenarios, and assess the probability of management success (Walshe and Massenbauer 2008; see also Table 6). This has provided the basis for biological and physical targets and thresholds in relation to reducing water in the lakes system. Feasibility assessment has canvassed both engineering and social aspects, explicitly dealing with aspects of the uncertainty and risk assessment, financial feasibility and offsite impact assessment for disposal of excess water.

The first of the engineering works, a gravity fed pipeline between Lake Wheatfield and Bandy Creek, was established in 2009. At the same time, conducting extensive revegetation and other works in the upper catchment is essential to minimise or halt salinisation of the surface soils which is leading to increasing salinity of surface inflows to the lake system. Greater than 50 per cent of the revegetation management action targets set for the next 25 years of recovery works has already been achieved. Revegetation works have also provided for increased community capacity [20] and promoted on-farm nature conservation.

The final engineering phase will include environmental impact assessments and design and construction of a pumping system to reduce water volumes in Lake Warden. If effectively implemented, not only will these works achieve recovery objectives, they will provide the town of Esperance with some additional flood protection.

In summary, the condition of the biodiversity assets has declined somewhat during the last decade, largely due to overfilling of the lake, which is the key process threatening the assets at this time. If the proposed engineering works prove to have acceptable environmental impacts and are funded, then overfilling of the lakes will be managed effectively.

Thus, provided the remaining phase of engineering works is implemented, there is a high probability of achieving recovery goals (Table 6). In the absence of management (the 'do nothing' option in Table 6), failure to achieve the recovery goal is almost certain (Walshe and Massenbauer 2008).

20. Capacity has increased through improved knowledge and understanding of the issues. This was achieved through a farm business planning approach that raised awareness of the defined threats, and management options required to meet a clear asset goal outcome. Offering technical support and a cost sharing subsidy that meets economic and conservation needs, combined with high levels of establishment success, has resulted in high landholder demand being targeted strategically at priority zones that will directly benefit the LWWS.

Table 6. Decision tables describing the utility of four alternative management actions under three climate states for a) shorebird abundances at Lake Warden, b) diver bird abundances at Lake Wheatfield and c) aquatic invertebrate species richness at Lake Wheatfield.

a) State	Probability of state p_i	Utilities: Option 1 (a_1) (engineering)	Option 2 (a_2) (perennials)	Option 3 (a_3) (eng. and peren.)	Option 4 (a_4) (do nothing)
Drier	0.6	69.5	6.0	70.4	1.8
Wetter	0.2	68.9	4.4	73.8	0.8
No Change	0.2	73.0	4.4	74.7	0.8
Expected Utility, *EV*		70.1	5.4	71.9	1.4

b) State	Probability of State p_i	Utilities: Option 1 (a_1) (engineering)	Option 2 (a_2) (perennials)	Option 3 (a_3) (eng. and peren.)	Option 4 (a_4) (do nothing)
Drier	0.6	34.0	12.7	35.6	4.6
Wetter	0.2	31.2	7.4	35.9	3.5
No Change	0.2	33.4	8.6	36.4	3.8
Expected Utility, *EV*		33.3	10.8	35.8	4.2

c) State	Probability of State p_i	Utilities: Option 1 (a_1) (engineering)	Option 2 (a_2) (perennials)	Option 3 (a_3) (eng. and peren.)	Option 4 (a_4) (do nothing)
Drier	0.6	57.8	42.6	77.9	28.2
Wetter	0.2	49.5	34.4	69.7	23.5
No Change	0.2	54.1	38.4	72.8	25.5
Expected Utility, *EV*		55.4	40.1	75.2	26.7

Note: the three climate states are 'drier', 'wetter' and 'no change' and utility is the probability (expressed as a percentage) of observing a threshold number of birds or species richness. Expected utility (EV) is the sum of the probability of utilities for each climate state calculated as the product of the probability of the state and the utility of the option. The higher the utility, the greater the biodiversity gain. In summary, the 'do nothing' option is predicted to result in goal failure, while implementing engineering and revegetation actions will maximise utility. If longer timeframes had been used for the calculations, the revegetation option may have achieved greater utility. Taken from Walshe and Massenbauer 2008.

Muir-Unicup

The primary management goal is:

> *To maintain existing (2006) biodiversity richness of the wetlands, sumplands, damplands, riparian zone, and seepage areas (including mid-slopes) threatened by salinity, acidity or waterlogging.*

In the Lake Muir-Unicup Natural Diversity Recovery Catchment, a surface saline scald on one drainage line leading to Yarnup swamp has largely been eradicated by revegetation and decreased annual rainfall. At this site, management attention is moving to other areas producing salt loads that are affecting the wetland. Further south in this catchment, the Geordenup/Neeranup Swamp system has benefited significantly from the re-diversion by private interests of surface waters back to their former flowpaths. Baumea reed beds have redeveloped in the Geordenup/Neeranup Swamp system as the volume of water flowing through them has been massively reduced (pers comm. Roger Hearn).

Although some management works can be implemented now with a high probability of conservation success, planning for many of the most important interventions depends on the development of sophisticated numerical and conceptual hydrological models. These will be constructed during the next phase of management, with new impetus coming from the appointment of a contract catchment hydrologist.

Muir-Unicup is a complex set of unique and highly important wetland assemblages with an equally complex hydrology. An important challenge over the next decade will be to successfully model and manage the key wetlands. Overall, no important biodiversity assets have been lost, however, there has been decline in asset condition in some areas and the status of bittern species is a concern.

Toolibin Lake

The primary management goal is:

> *to ensure the long-term maintenance of Toolibin Lake and its environs as a healthy and resilient freshwater ecosystem suitable for continued visitation and breeding success by the presently high numbers and species of waterbirds.* (1994 Recovery Plan)

At Toolibin Lake, engineering works have largely achieved physical recovery targets in relation to depth to groundwater beneath the lake and the salinity of surface inflows (George et al. 2004), two major accomplishments for the recovery catchment. In the case of groundwater control, since 2005 there have been two periods when many groundwater pumps have been out of commission due to technical problems. This was associated with much more rapid recovery of groundwater tables than expected. This is of concern, and underlines the importance of continued pumping for recovery.

In response to substantially improved groundwater and inflow control, mature vegetation of swamp sheoak (*Casuarina obesa*) has recovered in one section of the lake floor (photograph 5), vegetation condition has been maintained in some areas, but there has been decline in condition in many other areas (photograph 6). The stable and declining trends are captured in Figure 5, but not the recovery. Overall, the main trends in mature vegetation have been continued decline, or stabilisation, with some areas of recovery. The more deep-rooted paperbark (*Melaleuca strobophylla*) has been worst affected with most adult populations declining.

Overall, living vegetation has been retained across sections of the lake floor, which is an important recovery criterion. The reasons for continued decline at some sites are unclear given the achievement, for the most part, of key physical recovery criteria. However, it was always predicted that there would be some inertia between meeting hydrological targets and observing substantial biological recovery, although natural regeneration has fared much better (see below). Also, problems with managing the groundwater pumps noted above have led to higher than desirable groundwater levels during some periods, and would also have brought some salts back into the root zones of plants.

Only small amounts of pooling have occurred in the lake since 1996, due to: low annual rainfall, fewer intense rainfall events, and diversion of high salinity flows. Therefore, it is hypothesised that there has been little opportunity for soil-stored salts to be washed deeper into the soil profile beyond the root zones of the oldest plants, some of which have active roots at three metres below the soil surface (based on recent research data).

This hypothesis is being tested through a joint project with the Future Farm Industries Cooperative Research Centre. Considerable ecophysiological work is required to understand the current, variable response of vegetation and to interpret the interactions between pumping (both when on and off) and vegetation. In addition, further hydrological investigations and management works are required to manage the predicted increase in salinity of inflows as groundwater reaches the surface in drainage lines in the middle to upper catchment.

Figure 5. Vegetation trends in *Casuarina obesa* (plant numbers on Y-axis) at three sites on Toolibin Lake floor. Note that these transects miss the recovery area shown in photograph 5 below. A transect in this area including seedlings would show a substantial increase in basal area. (Data from the department's Wetland Monitoring Group.)

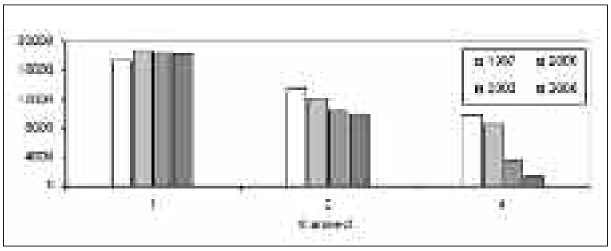
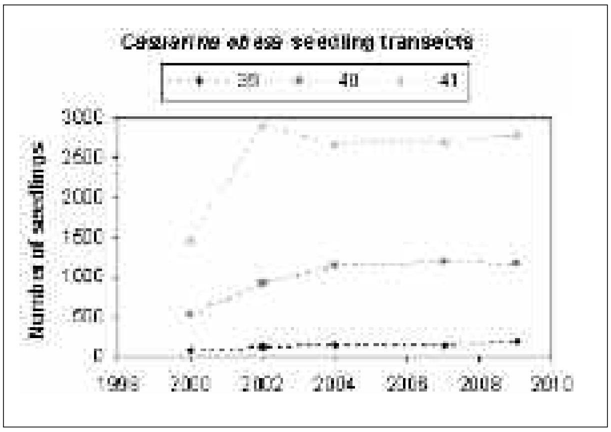


Figure 6. Population numbers of *Casuarina obesa* seedlings at three plots, each 100m x 5m, near Pump 9, the recovery site (Ecoscape 2009 p 102). The plot with the fewest seedlings had 177 in 1999. Note that in 1995 there were no seedlings at this site (K Wallace pers comm.).



In contrast with much of the mature vegetation, the situation with natural regeneration on the lake floor is much more positive. From 1997 there has been natural seedling regeneration of both swamp sheoak (*Casuarina obesa*) and paperbark (*Melaleuca strobophylla*) on many parts of the lake floor. A particularly positive sign has been the continued growth with very few deaths of this

Photograph 5. Strong recovery of *Casuarina obesa* at Toolibin Lake. Photograph courtesy of Sam MacWilliams.

Photograph 6. Groundwater pump at Toolibin Lake. Note that while *Casuarina obesa* canopy has largely been lost, green epicormic shooting is visible from stems. Photograph courtesy of Ken Wallace.

Photograph 7. Epicormic shooting from *Casuarina obesa* stems, Toolibin Lake.
Photograph courtesy of Ken Wallace.

regeneration. In 2008, one or two patches of paperbark seedling death were recorded. However this has not been observed again in 2009. Insect attack is associated with the 2008 deaths, but it is unclear whether they are a primary or secondary cause of mortality.

With regard to fauna, the limited data obtained when the lake partially filled in 1996 suggest that increases in salinity at Toolibin Lake have caused only small changes in invertebrate faunal composition and no significant change in the numbers and species of waterbirds that visit Toolibin Lake (Halse et al. 2000). Salinity and invertebrate richness are linked, and there has been no significant change in the salinity measured during partial fill events that have occurred at Toolibin between 1996 and 2006.

In 2006–07, 24 species of waterbirds, 11 displaying breeding behaviour, were recorded on Toolibin and Dulbining (upstream of Toolibin) lakes following a partial fill event (Peter Lacey pers comm.). A further six species of waterbirds were recorded during the same period immediately downstream at Walbyring Lake, and it is likely that these birds were also present in the project area. Given the partial nature of the fill, this is a substantial list and suggests that neither the invertebrate nor the waterbird fauna are likely to have changed significantly over the past decade when the lake is half or more full.

In summary, when the pumping system is operating effectively, the physico-chemical recovery criteria for Toolibin have largely been met, a major achievement recognised in part by the Recovery Catchment Team, Lake Toolibin Catchment Group (local community group) and the department being jointly awarded the Institution of Engineers Australia National Salinity Prize for 2002. Achievement of the biological recovery criteria has been much more varied with both some gains but also further degradation. Overall, the lake retains the core biological values for which it is noted—it would almost certainly have lost these without management intervention over the 1996-2010 period.

The physical and biological condition of the lake since 1990 is schematically described in Figure 7. The trends described are based on a combination of data and anecdotal observations, and are therefore qualitative and generalised. This diagram emphasises that indicators for complex systems will be moving in quite different ways through time. Although some indicators can be improved dramatically—for example, salinity of surface inflows controlled immediately with diversion systems in place—others are much slower to respond. In addition, interpreting monitoring data can be difficult given both the spatial and temporal variability of the systems themselves and the responses of organisms to interventions.

On balance, however, the Toolibin recovery goal has been met in terms of the composition of biota that is predicted to occur with a major filling event. However, the inferred abundance of native fauna must be achieved and the current condition of mature vegetation must be substantially improved to achieve full recovery. This will require ongoing management including revegetation and engineering works to stabilise and improve the quality of surface water flows from the catchment. One hypothesis currently being tested is that a major fill event and overflow are required to achieve sufficient downward flushing of salts to improve the trend to full vegetation recovery. The importance of maintaining groundwater as deep as practicable is emphasised by current research. A full review of Toolibin work as part of the planning process will provide a detailed analysis and evaluation of progress.

Threatened ecological communities and threatened species in recovery catchments

It is important to emphasise that the biodiversity assets within recovery catchments at risk from altered hydrology include a range of threatened ecological communities and threatened species.

These are listed in Tables 7 and 8. Thus, although the natural diversity recovery catchments are aimed at conserving key representative samples of natural biota threatened by altered hydrology, in doing this they are also managing a number of endangered and critically endangered species and communities.

Other conservation outcomes

Within all recovery catchments there are important biodiversity assets outside the areas that are threatened by altered hydrology on which the program is focused. This is most apparent in relation to threatened ecological communities and threatened and priority species in addition to those listed in Tables 7 and 8. Perhaps more importantly, many of the recovery catchments contain terrestrial biodiversity of sufficient importance that they would be selected as areas of management focus irrespective of their wetland and riparian values. This applies particularly to Muir-Unicup where the plant biodiversity is greater than that recorded for Mt Lesueur, a larger area and recognised centre for biodiversity (Gibson and Keighery 2000). Lake Bryde and Lake Warden catchments also contain terrestrial biodiversity of significant importance within the south-west.
In addition, there are a number of terrestrial assemblages at Toolibin and Buntine-Marchagee that are poorly conserved and not well represented in conservation areas.

Table 7. Threatened species within natural diversity recovery catchments at risk from altered hydrology.

Recovery Catchment	Threatened/ priority species
Buntine-Marchagee	*Caladenia drakeoides* *Frankenia parvula*
Muir-Unicup	Australasian bittern (*Botaurus poiciloptilus*) Mud minnow (*Galaxiella munda*) Balston's pygmy perch (*Nannatharina balstoni*) Christine's spider orchid (*Caladenia christinea*) *Caladenia harringtonia* Tall donkey orchid (*Diuris drummondii*)
Lake Bryde	Remote thorny lignum (*Muehlenbeckia horrida* subsp *abdita*)
Drummond	Keighery's eliocharis (*Eleocharis keigheryi*) *Acacia chapmanii* ssp. *Australis*

Figure 7. Schematic diagram of changes in biophysical indicators at Toolibin. General trends through time based on some monitoring and anecdotal information are shown—the diagram aims to capture the different patterns of change in achievement of indicators—it is not a quantitative representation. Time (year) is shown on the x-axis; percentage achievement of indicator target on the y-axis.
100% = target achieved.

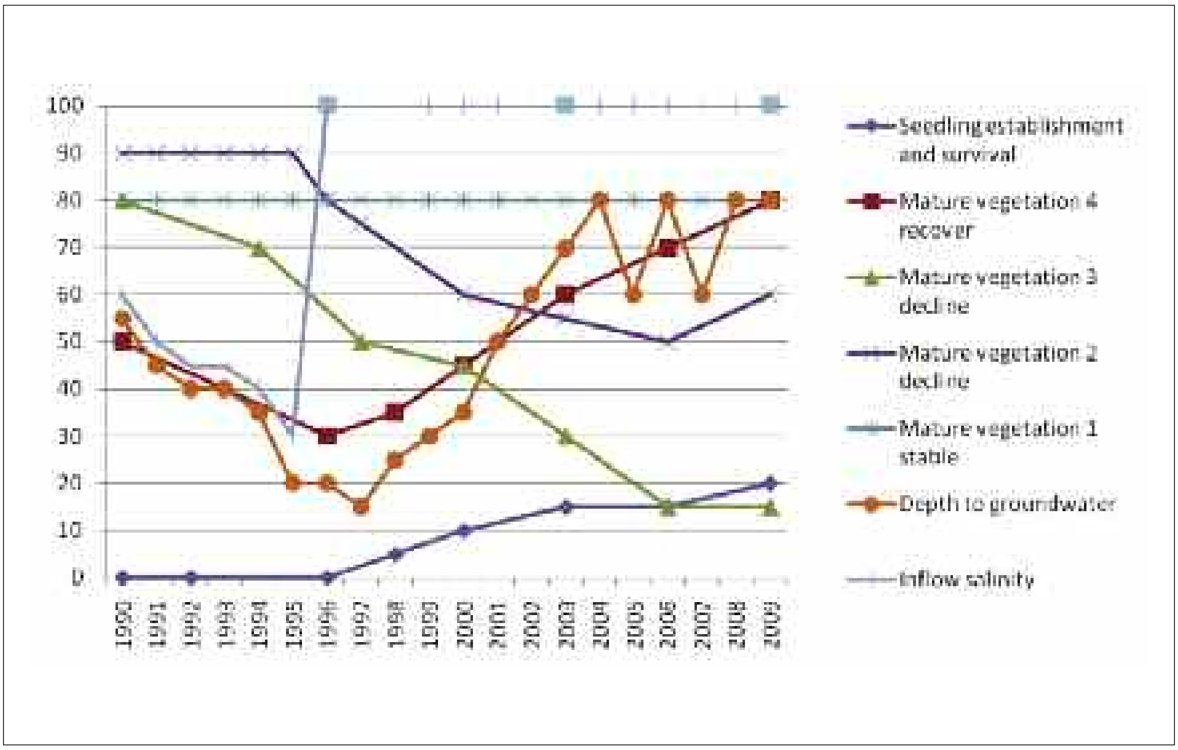


Table 8. Threatened and priority ecological communities at risk from altered hydrology within natural diversity recovery catchments.

Ecological community name	Status	Recovery Catchment
Herbaceous plant assemblages on bentonite lakes	Endangered (state list)	Buntine-Marchagee
Perched freshwater wetlands of the northern wheatbelt with extensive stands of *Eucalyptus camaldulensis*	To be confirmed	Buntine-Marchagee
Wandoo woodland over dense low sedges of *Mesomelaena preisii*	Priority 1	Drummond
Claypans with mid dense shrublands of *Melaleuca lateritia* over herbs	Priority 1	Drummond
Unwooded freshwater wetlands of the southern Wheatbelt dominated by *Muehlenbeckia horrida* subsp. *abdita* and *Tecticornia verrucosa*	Critically Endangered (state list)	Lake Bryde
Stromatolite like microbialite community of a Coastal Hypersaline Lake	Priority 1	Lake Warden
Scrub heath on Esperance Sandplain: Scrub heath on deep sand with *Banksia* and *Lambertia*, and *Banksia* scrub heath on sandplain	Priority 3	Lake Warden
Perched wetlands of the wheatbelt region with extensive stands of *Casuarina obesa* and *Melaleuca strobophylla*	Critically Endangered (state list and Endangered on EPBC list)	Toolibin Lake
Peat swamps	Priority 2	Muir-Unicup

For example, the *Banksia prionotes* and York gum/jam (*Eucalyptus loxophleba* and *Acacia acuminata*) associations at Toolibin Lake are poorly conserved, particularly in the wheatbelt. At Buntine-Marchagee 'Medium woodland - Salmon gum' is 'limited in extent' in the Northern Agricultural Region, and 'poorly represented' in the reserve system (0 per cent in the Northern Agricultural Region) (Richardson et al. 2004).

In this context, the revegetation and other management works undertaken as part of the recovery program not only contribute to improved water management at the catchment scale, they are important for the conservation of a range of terrestrial biota. Ecological resources from even commercially prospective revegetation, such as oil mallees, can be substantial and increase the probability that native biota will persist. For example, work by Patrick Smith from CSIRO has shown that while revegetation involving complex species composition and structures will better emulate natural bushland, oil mallee belts still add significant ecological resources for birds, invertebrates and even small mammals, such as western pygmy possums (*Cercatetus concinnus*) and red-tailed phascogales (*Phascogale calura*) (Smith 2009). Where revegetation serves to buffer remnant vegetation on upper slopes from the drift of fertilisers, pesticides and weed seeds, there are additional gains to biodiversity conservation.

This broader support for conservation has been formalised in a plan for revegetation in Buntine-Marchagee where a modified focal species approach for birds (Huggett et al. 2004) is used in conjunction with water management needs to maximise the conservation values from revegetation works. Although revegetation designs to best protect biodiversity from a hydrological perspective rarely coincide with priority areas for habitat expansion, catchment officers have found that they are able to implement more conservation works when conservation aims are ‘packaged’ with other land management aims, such as water management, than if they were offered independently to landholders.

Given that the total area of natural diversity recovery catchments (0.7 million hectares) is about three per cent of the south-west agricultural zone, work in recovery catchments is generating a significant ‘footprint’ in this important region for biodiversity conservation. If the recovery catchments expand to the 25 proposed in total, then a major contribution to landscape-scale conservation would be achieved.

WIDER BENEFITS AND OUTCOMES FROM RECOVERY WORK

New industry development

During the life of the program nearly $1 million have been used to subsidise the planting of commercially prospective plants, mostly oil mallees. In the low-medium rainfall zone of the south-west, the lack of a plant resource base is a key barrier to developing biomass industries based on woody perennials. Therefore, the strategic work in recovery catchments is, concomitantly, supporting the development of new industries. In addition, research at both Toolibin and Buntine-Marchagee on the interaction between mallee water use and groundwater is helping to establish both the range of soil types over which species may be planted, as well as helping to delineate their water requirements and contribution to salinity management (e.g. Noorduijn et al. 2009). At Toolibin, this relationship is being explored through a trial planted on private property in 1995, which is only now coming to fruition. The importance of long-term commitment to generate important results is emphasised by this and other research projects. However, the poor continuity of monitoring in this project diminished its value, which also emphasises the importance of a consistent, long-term commitment to monitoring and research.

Apart from oil mallees, melaleuca trial sites have been established at Lake Bryde and Toolibin, along with an *Acacia* phase cropping and a Search[21] trial at Lake Bryde. Although these projects are at a much lower level of intensity compared with oil mallee work, they nevertheless provide sites with documented species of known age, and thus lend themselves to general interpretation of plant performance.

Finally, a detailed feasibility study of salt harvesting in association with groundwater pumping, while underlining how difficult it would be to establish a profitable industry, continues to provide the benchmark against which new proposals for such an industry may be measured.

Improved management of other public assets and private property

As noted in the outcome statements, more than 35 per cent of expenditure has contributed directly to improved management and profitability of private property. URS (2004) estimated from their desktop calculations that direct commercial benefits to private landholders from reducing the area of farmland salinity would be about six per cent of public expenditure in recovery catchments. However, this calculation does not take into consideration on-farm benefits such as improved water and wind erosion control, increased stock and crop protection, and decreased probability of sedimentation and eutrophication of wetlands, including farm dams, where appropriate works are applied. In addition, the benefits calculated by URS were site benefits from salinity treatments. However, some works, such as large-scale waterways to manage excess surface water, provide a basis for on-farm works. This is because the constructed waterways provide one means for safe disposal of excess, freshwater ponding on farmland. Thus, there is a need to calculate more precisely the actual benefits to landholders—they will certainly exceed six per cent of total expenditure.

Not only have recovery works contributed to private property management, there have been a number of benefits for other land uses. For example, surface water management works at Buntine-Marchagee, Lake Bryde and Toolibin are helping to protect one or more public roads within their catchments from flooding and other water damage; and proposed works at Lake Warden will contribute to the flood protection of Esperance. Information has also been extended to other areas. For example, presentations to local governments and other agencies have used works at Lake Bryde as a basis for discussing water issues and roads, and methods for resolving them. A final example is that the recovery works at Muir-Unicup have contributed to the management (through revegetation) of lands held by the Department of Water.

As noted above, the current area of the existing six recovery catchments is about 700,000 hectares (over three per cent of the agricultural lands in the south-west which total some 20.8 million hectares). Provided the recovery programs are maintained and are successful, it would be expected that the majority of works required for hydrological management across this area will have been implemented. Improved hydrological management of this area represents a significant contribution to land management in general—particularly when the broader application of knowledge generated through the recovery catchments is also taken into consideration.

Management of climate change

In the south-west agricultural zone, revegetation in recovery catchments is the department's single largest on-ground contribution to carbon sequestration on agricultural lands.

More importantly, work in recovery catchments is a major source of knowledge concerning hydrological processes at landscape scales across the agricultural area. This knowledge is essential for successful management of native biota in the context of the potentially severe impacts of climate change. The comparatively long-term monitoring of a range of hydrological variables in recovery catchments represents an uncommon and increasingly valuable dataset for inland agricultural areas.

21. Search project is shorthand for the DEC/NHT funded work searching for commercially prospective native species in the late 1990s and early 2000s (CALM 2004).

Knowledge gained

In addition to examples mentioned above, there have been many other cases where knowledge and information from work in the recovery catchments has been directly applied or used in other salinity management projects. Examples include:

- application of new knowledge concerning groundwater pumping systems, including data on hydraulic properties and predicted impacts, from Toolibin to other sites in the wheatbelt
- use of contracts developed for recovery catchments for projects managed by other agencies and regional groups
- predictions of landscape and regional trends based on data from natural diversity recovery catchments and work in other catchments. This knowledge has also been used to predict the impact of salinity management options and the impact of unmanaged groundwater rise throughout the agricultural area. In this regard, it should be noted that under the *Salinity Action Plan* and *Salinity Strategy* there are 11 key catchments in the south-west, including six natural diversity recovery catchments, where there are sufficient data upon which to base predictions concerning salinity throughout the agricultural region. The importance of this knowledge, and of continuing the related monitoring and evaluation, is too easily underestimated
- strongly related to the previous point is the contribution of recovery catchments as detailed case studies of landscape-scale hydrological and other processes. This is important knowledge for guiding future land-use decisions. Recovery catchment contributions to knowledge in this regard will increase as further data are collected and analysed and the dataset is extended over decades, particularly given that catchments are distributed across a range of biogeographic regions
- assessment of the contribution of airborne geophysics—including radiometrics and electromagnetic data—to salinity management. This was undertaken by comparing, for catchments with substantial geophysical data, the analyses of airborne geophysics alone with standard field techniques (George et al. 1999, George and Woodgate 2002)
- ecophysiological knowledge that contributes to predictions of the likely success of revegetation (e.g. Noorduijn et al. 2009)
- multispectral imagery techniques developed for Lake Warden by the Lake Warden Recovery Team and Specterra have been applied to other areas such as Lake Gore and Gnangara Mound. Correlating the multispectral variations in vegetation condition with high resolution GPS ground truthing and aerial photographic texture of vegetation assemblages allows remote assessments of vegetation condition to be undertaken. Hyperspectral techniques are also being developed at Toolibin Lake, and mulitspectral imagery has been trialled at Drummond
- our understanding of palaeochannel genesis, evolution and stratigraphy has been improved through the Recovery Catchment Program. This is particularly the case from research in Toolibin Lake and Muir-Unicup, but also from Buntine Marchagee
- the source of acid groundwater in the wheatbelt is still a topic with many theories and few answers. However, a recent PhD study being finalised during 2010 (Margaret Smith) has determined sources of acidity impacting on the Muir-Unicup biodiversity assets. Most of the acidity had been generated within the regolith material and stored acidity is present in the wetlands. This knowledge has wider implications for acid generation in the wheatbelt, in the southern part in particular.

Values-based planning

The planning process in recovery catchments focuses effort by linking broad community values (developed through catchment steering committees or project advisory groups), goals, and biodiversity assets on the one hand, with management feasibility and actions, long-term monitoring and evaluation. It is widely accepted that the priorities of stakeholders must be considered in planning the management of natural resources. It is also critical that the goals of management reflect the relevant set of values (Wallace 2006).

As foreshadowed in the 2001 Review, the challenges (see next section) facing catchment-scale management necessitate an increasingly sophisticated analysis of the relevant cause-effect relationships and associated risks (see, for example, Walshe 2005, 2007). These planning processes are being further developed for natural diversity recovery catchments. This includes projects with the Future Farm Industries Cooperative Research Centre. Clearly documented assessments of the feasibility of management actions, alternative options, and the associated risks and likelihood of success are vital components of management in uncertain environments where large expenditures and long-term commitments are involved. This is exemplified by the work at Toolibin (Jones et al. 2009) and Lake Warden (Walshe and Massenbauer 2008).

LESSONS AND CHALLENGES

Over the course of more than a decade of work in recovery catchments we have learnt many lessons. This section describes the most salient lessons from the past and challenges for the future. In general, three broad challenges confront those managing hydrological processes for biodiversity conservation outcomes in south-western Australia. These are described by Wallace and Lloyd (2008) as follows:

> *Firstly, natural biodiversity assets are highly complex given the number and range of organisms at risk, a situation aggravated by inadequate knowledge of their life histories and related ecosystem processes. This contrasts with management of agricultural land and potable water resources where assets are more easily defined and tolerances are much better known.*
>
> *Secondly, the long timescales required for successful management within a variable climate are particularly taxing. The current extent of salinity has taken many years to develop, continues to spread, and may require decades to effectively address. While the regional climate is relatively stable, surface flows are erratic and underlying geology variable. Wetlands may be dry for long periods, or contain water for several consecutive years (Lane et al. 2004). Given also our inadequate knowledge, there is significant uncertainty regarding management outcomes.*
>
> *Finally, the above issues are exacerbated by a range of socio-cultural factors including inadequate understanding of biodiversity values and generally poor appreciation of management difficulties. These and other social factors—such as the difficulty of attracting and retaining personnel in rural areas—create an uncertain socio-political environment for conservation work. Taken together, these three challenges are a formidable barrier to effective biodiversity management.*

Lessons to date from managing recovery catchments, and future challenges are dealt with in more detail below under five headings:

i. *Institutional arrangements and catchment management*: summarises collective agency experience in catchment management
ii. *Landscape-scale management*: explores three critical aspects of management at this scale
iii. *Organisational management*: identifies key aspects of departmental arrangements that affect management success
iv. *Other technical and operational issues*
v. *The recovery catchment approach – value for money?*: addresses the issue of the ongoing and relative importance of continuing work in the recovery catchments, given the outcomes and lessons/challenges.

INSTITUTIONAL ARRANGEMENTS AND CATCHMENT MANAGEMENT

Viewed in a national context and compared with other states, WA has a long history of managing the hydrology of agricultural catchments in relation to salinity. These efforts have included research and development as well as generic operational approaches involving regulatory and incentives schemes. Apart from these activities, at the scale of specific catchments and sub-catchments government approaches to catchment management in WA have been directed either at assisting groups of land managers to better manage catchments threatened by salinity (Focus Catchment Approach, Rapid Catchment Appraisal, Catchment Demonstration Initiative[22]); or have been aimed at directly managing catchments to protect specific public assets (water resources recovery catchments, natural diversity recovery catchments, Rural Towns Program). Taking into consideration experience up to and including 2009, four conclusions may be drawn from this experience:

1. Comprehensive hydrological data need to be collated consistently over a long timeframe (minimum of 10, and preferably more than 20 years) to effectively develop even a modest model of catchment processes that is sufficient to underpin target setting and give confidence to significant financial investment. For example, initial hydrological planning was based on some 14 years of data (1973–1987) in the Collie Water Resources Catchment, and 15 years for Toolibin Lake Natural Diversity Recovery Catchment. In both these cases significant additional data have been required, and are still being collected and analysed, to improve models. Under the Catchment Demonstration Initiative, even catchments with more than 20 years history have struggled to develop effective models for target setting and monitoring due to the scale of the catchments and inconsistency of monitoring through time. This conclusion strongly affects the following three conclusions that describe the alternative approaches to catchment management.

22. For details on these catchment approaches see Agriculture Western Australia et al. (1996b), State Salinity Council (2000), and Robertson et al. (2009).

2. Implementation of management works at catchment scales, including the related investigations and planning works, will generally require annual expenditures of some hundreds of thousands of dollars plus additional funds for any major capital works. Such expenditures will normally be required over decades to achieve measurable targets. Resourcing this level of commitment requires the backing of senior executives in large organisations. For public assets, this effectively requires Chief Executive Officer support at the agency level reinforced by adequate socio-political backing amongst key communities of interest [23]. In theory public natural resource assets could be managed over long timeframes by corporate interests or non-government organisations. However, at least in Australia, there are no examples of this occurring for complex assets where delivery of multiple cultural values is involved. Even where projects have some of the required characteristics, they are generally supported by government funding.
3. It has not proved feasible to empower community groups, including groups of landholders, to effectively manage the hydrology of catchments to achieve long-term targets. Successful catchment management is difficult, and requires ongoing commitment of resources and expertise over timescales and at levels that is not practicable for most community groups at the catchment scale, especially given the typically short length of their funding cycles (generally one to three years). In contrast, community groups enjoy greater success managing shorter term, smaller scale natural resource management projects.
4. Planning and operational management at catchment scales are best driven by an organisation with a strong commitment to achieving a clear goal for the catchment as a whole over long timeframes. For example, the natural diversity and water resources recovery catchments are managed by agencies with long-term commitments to the recovery and conservation of important public assets (in this case biodiversity and water resources respectively). To date, this has proved the best model for achieving outcomes at catchment scales where consistent effort is required over long timeframes and where high levels of accountability are required for the management of public assets.

Thus, early expectations that agencies could provide landholders in priority catchments with sufficient advisory services to enable them to develop and implement management plans (Department of Agriculture et al. 1996b) have not been met. Even when $6 million was allocated to four catchments over four years (with considerable prior planning), there has been limited success in achieving substantial on-ground public benefits, at least within the one catchment for which there is published information (Robertson et al. 2009). However, the lack of broadscale, economically viable management options for salinity is also a significant barrier to success at catchment scales.

It is emphasised that applying all the approaches outlined above was essential to discover the most efficient and effective methods for managing the hydrology of catchments in agricultural areas. This experience provides important context for the description below of landscape scale management of salinity through natural diversity recovery catchments. It also contains important lessons for all those wanting to work at landscape scales.

LANDSCAPE-SCALE MANAGEMENT OF SALINITY

In addition to the conclusions outlined in the previous section, there are a number of other important points concerning successful salinity management at landscape scales [24].

Multiple partnerships

As described in Wallace and Lloyd (2008), the importance of cross-stakeholder and cross-disciplinary partnerships is well documented (in relation to recovery catchments see CALM 2001 Review, Halse and Massenbauer 2004, Munro and Moore 2005). Three consistent lessons described by Wallace and Lloyd from experience in recovery catchments are:

- One-on-one relationships with catchment landholders are essential for management success, even where there is a strong, socially coherent catchment group (which is rare—catchment boundaries often cross social and administrative boundaries).
- Cross-disciplinary and cross-agency collaboration underpins successful management. Networking is easier in WA given its relatively small population in comparison with the more populated states. However, relationships amongst agencies and individuals must still be nurtured, and partners must be willing to collaborate.
- Long-term relationships between local conservation officers and catchment landholders greatly facilitate

23. Natural resource managers in Australia have often used the term ‘community’ very loosely at significant cost to clarity. Here, the term ‘communities of interest’ is used in the sense defined by Harrington et al. (2008).

24. In this context, landscape-scale management is viewed as being in the order of 10–200,000 ha units.

positive working relationships between the two groups. In this context, selecting and retaining effective government personnel in rural areas is important, but often difficult (CALM 2001 Review).

As noted in the previous review, DEC has been fortunate in having willing collaborators and partners amongst catchment landholders and across a range of institutions (state and Commonwealth agencies, CSIRO, regional NRM groups, etc). Without such collaboration, there would be few successful works in recovery catchments, and none on private land.

Integrated packages of on-ground actions

We would all prefer that difficult tasks could be resolved with the land management equivalent of a single dose of antibiotics. However, the reality is that successfully managing salinity at landscape scales to deliver multiple benefits invariably requires an integrated package of management strategies. This has certainly been the experience in recovery catchments where most involve:

- strategic revegetation to improve water use and effect some hydrological control
- surface water management to reduce waterlogging and recharge on valley floors
- fencing and management of remnant native vegetation to help maintain water use, contributing to hydrological control
- intensive engineering works to manage the solute[25] and water balance of wetlands.

One valuable trait of recovery catchment managers in general has been their capacity to consider a range of solutions, including substantial engineering works, to maximise the probability of achieving biodiversity conservation objectives.

Priority setting

Institutions allocating grants for work in natural resource management generally give priority to on-ground works. While understandable from the perspective of achieving demonstrable, concrete outcomes, it encourages neglect of critical activities such as research, planning (including priority setting) and monitoring. Well-reasoned priority setting can be particularly important. For example, one lesson from the recovery catchment process has been the importance of planning management priorities in relation to a goal prior to engaging catchment landholders. This approach ensures that targeting of expenditure and the underlying reasons are clear at the outset to all stakeholders. In turn, this has avoided the creation of false expectations that can later threaten the achievement of outcomes.

Experience in recovery catchments has also shown that it is important to retain focus on project priorities in the allocation of resources, rather than some notion of stakeholder equity. For example, it can be tempting to offer subsidies for revegetation equally to all landholders, rather than targeting the specific sites (and landholders) that are most critical to achieving the recovery goal. Targeting of expenditure at any scale will inevitably lead to at least some criticism from those who miss out on funding—an issue discussed in the CALM 2001 Review. However, appropriate planning and consultative approaches do help people to understand the need to target expenditure.

Within the recovery program itself, there is also a need to improve priority setting and to better explain the internal allocation of resources. Although the business plans drafted for recovery catchments in conjunction with this review will help, full recovery plans for each catchment are an essential basis for effective priority setting.

ORGANISATIONAL MANAGEMENT – LOOKING WITHIN

In examining the lessons from recovery catchment work an important aspect is the effective functioning of the management organisation itself, in this case the department. This is explicitly explored in this section.

At an operational level, there may be tension between the needs of managing a complex asset, such as a recovery catchment, and the need of regional and district managers to meet immediate demands for activities such as bushfire suppression and environmental impact assessments. A constant challenge for all concerned is to ensure that the inevitable trade-offs between short-term urgency and long-term importance do not lead to the neglect of effective long-term planning and the strategic actions that will lead, ultimately, to goal achievement. This issue is exacerbated in situations where recovery catchment work can be seen by managers as an add-on to normal operational activities, rather than as part of core responsibilities. In this regard, the purchaser-provider model of organisational management, which will inevitably take second place in emergency situations, has not always been successful.

Related to the above, once a specialist operational group has been allocated tasks for a given area, there is a tendency for other operational personnel who have been involved in generic management activities, such as feral animal control, to shift their attention elsewhere.

25. Mainly salt (NaCl), nutrients and acidity.

Consequently, there may be a double loss to the specialist management activity in both time lost by recovery officers helping generic management (such as bushfire suppression) outside the catchment, and loss of operational resources that had once been allocated to work within the catchment.

To help address these issues it is important that recovery plans are completed, and there are more frequent joint reviews of progress between personnel from the Natural Resources Branch and regional personnel. These issues have been acknowledged, and steps are being taken to address these matters. The appointment of contract hydrologists rather than employing consultants will greatly assist in this regard.

The benefits of attracting and retaining good staff for five years or more are underlined by the generally improved liaison (see also section on Multiple Partnerships above), better skills development, and tighter linkages between research and operational work in catchments where officers have been retained for longer periods. The difficulty of achieving consistently effective interaction between research and management personnel has been well documented (Wallace 1995; Halse and Massenbauer 2005). Somewhat ironically, officers operating at a high level of performance may be inadvertently penalised by having greater expectations and demands placed on them —this may contribute to burn out and lead to inequity across work groups.

There are no simple means for improving the attraction and retention of rural-based staff. Short-term steps that can be taken include ensuring that recovery catchment officer positions are offered at a level commensurate with the demands and expertise required of them, continuing to improve technical support through the Natural Resources Branch, and investing adequate resources in selection processes. Longer term, there are important issues that need to be addressed to improve the attractiveness of employment in rural areas. Quality and availability of education, medical and social facilities remain important issues.

In concluding this section it is important to emphasise that achievements in recovery catchments depend on consistent, recurrent funding from government at an adequate level to support core recovery catchment work. In turn, for natural diversity recovery catchments this has depended on continuous support from three consecutive chief executive officers. No program of this nature could be successful without such a high level of intra-agency support. As might be expected, local landholders also prefer to interact with a long-term program with consistent resources and sufficient continuity of staff to allow them to evolve a predictable and positive relationship. Short-term projects with frequent staff changes and lack of an ongoing, coherent management approach are rarely successful, irritate local land managers and often use resources inefficiently.

OTHER TECHNICAL AND OPERATIONAL ISSUES

Since 2001 there has been considerable progress in relation to monitoring and evaluation and better standardisation of data collection and storage. However, there is still significant scope for improvement including more frequent and comprehensive evaluation and reporting to explicitly test management strategies and hypotheses. In addition, the high volume of data, reports and publications associated with each recovery catchment, combined with comparatively frequent staff turnover and weaknesses in information storage, have led to inadequate tracking and collation of reports and data. Successfully tackling this group of issues is critical to sustaining high quality, long-term management. Currently (2010) considerable effort is being applied to bring together hydrological data in a standard format across catchments, and to ensure that quality control and assurance are implemented. Recovery planning will ensure that strategies and hypotheses concerning catchment processes are explicit and thus more readily tested.

An important operational issue in recent years has been maintaining the pump network at Toolibin, where delays in repairing pumps and electrical systems have resulted in periods of groundwater rise. There are inevitable difficulties in servicing complex systems in rural areas, and specific monitoring and emergency systems are required to avoid unnecessary threats to recovery works. The difficulty of attracting and retaining personnel in rural areas considerably exacerbates these issues.

In two catchments in particular, government subsidised works on private property—such as revegetation and surface water management works—have been removed by landholders, generally after changes in property ownership. While formal agreements with landholders, including conservation covenants, have been considered as a mechanism for dealing with this issue, landholders are often reluctant to enter such agreements. To force this issue would almost certainly lead to an inadequate level of recovery works on private property, and the increased transaction costs would probably exceed any savings that might be generated. Thus, although the loss of catchment works is disappointing, the level of loss is sufficiently low that recovery programs are not threatened, and in any case there are no cost-efficient mechanisms for overcoming the deficiency.

Increased adoption of precision farming is itself a threat to past works given the desire of many landholders to operate over long, straight lines. This affects the uptake of revegetation and surface water management works in general and increases the likelihood that past works will be removed. Although sophisticated use of GPS would allow precision farmers to follow contours, most, to date, are using straight line methods. This poses significant problems for revegetation with belts and surface water management works aligned to contours—both important techniques for delivering a range of conservation and production benefits. There are no obvious solutions to this, although it is likely that the benefits of contour and precision farming will be integrated, particularly once the technologies are further developed and when major erosion events have occurred that affect precision farmers.

An important contribution to work in recovery catchments has been the availability of external funds. However, the main external funding source has been the various forms of the Natural Heritage Trust (now Caring for our Country). The five-year cycles of this program, with changing rules and approaches, is not conducive to sound long-term planning and the management of complex, natural resource management issues. In this regard, the continuity of state recurrent funds has been vital to ensure the continuity of planning and basic operational management, with boosts from external funds where they have been available. It would not be possible to run an effective, long-term catchment management program on a five-yearly basis with high uncertainty concerning future funding at the end of each funding cycle.

Finally, grazing by native species, particularly western grey kangaroos, and degradation by pigs and other introduced species are causing an unexpectedly high level of issues in more than one recovery catchment. The increasing level of pig introductions by illegal hunters, even into the wheatbelt, is of considerable concern from a number of perspectives.

THE RECOVERY CATCHMENT APPROACH – VALUE FOR MONEY?

As part of this review it is important to assess whether the natural diversity recovery catchment program provides value for money. Here, value for money is defined as government investment generating an acceptable level of overall, state community benefits where the assessment of benefits takes into consideration both negative and positive impacts. For a publicly funded program the judgement of 'an acceptable level' is ultimately socio-political and, in addition, requires evaluation against statutory requirements. Also, while some benefits can be evaluated using financial methods, many public benefits are not assessable in these terms. For example, supply of adequate potable water and air of a quality consistent with human health are threshold assessments[26], not financial ones.

Given the above, assessing value for money here involves addressing three questions:

a. Is the natural diversity recovery catchment program consistent with the department's statutory functions and published policies and goals?

b. If the answer to (a) is yes, does the program remain a high priority in relation to the relevant departmental goals, and if so, is the investment level appropriate?

c. Overall, is the program delivering state community benefits commensurate with the level of investment?

Each of these questions is considered below. Although the review focuses on the period 1996–2006, the following commentary includes some additional information up to and including March 2010.

Is the recovery program consistent with statutory functions and policies?

The role of DEC, as relevant to this review, is expressed through the functions of the Chief Executive Officer under section (33) of the *Conservation and Land Management Act 1984*. The natural diversity recovery catchment program is clearly consistent with these functions, in particular, those pertaining to:

- conserving flora and fauna throughout the state
- managing land (most of the biodiversity assets in the natural diversity recovery catchments are on land to which the Act applies)
- promoting and encouraging revegetation to rehabilitate land or conserve biodiversity
- research relevant to the other functions.

The most pertinent published policy document is the Corporate Plan where the applicable goal is:

> *To protect, conserve and, where necessary and possible, restore Western Australia's biodiversity.*

Again, the natural diversity recovery catchment program is consistent with this goal. This leads to the next question.

26. That is, life ultimately depends on individuals having enough air and water of a quality that will not cause death or serious illness. While acceptable mortality rates may be debated, these are threshold issues.

Does the recovery program remain a high priority for conservation, and is investment appropriate?

This question needs to be addressed in relation to the above goal, and can be broken down into three further questions—are the biodiversity assets threatened by altered hydrology of very high value; does addressing the threat of altered hydrology remain a high priority in the context of other threatening processes (and the response to the previous question); and is the current investment appropriate given program outputs and outcomes in the context of answers to the two preceding questions?

In relation to the first of these questions, the biodiversity assets threatened by altered hydrology in recovery catchments include:

- three Wetlands of International Importance under the Ramsar Convention
- more than 50 taxa listed as threatened or priority species of native biota
- three listed threatened ecological communities, and five priority ecological communities
- habitat for at least 27 species of migratory waterbirds protected under one or more of the international agreements with Japan, Republic of Korea and China
- a wide range of biological communities that provide important representation of biota threatened by altered hydrology across six IBRA sub-regions (eight counting small areas that overlap into a second sub-region). These samples are particularly important in the context of the predicted regional or global extinctions of up to 850 species of native taxa from the south-west due to salinity.

This list clearly demonstrates the very important array of biodiversity assets retained within the recovery catchments. Their international significance is underlined by the status of the south-west as a global biodiversity hotspot (Myers 2000), the only one in Australia.

This leads to a consideration of the second question, the relative importance of managing altered hydrology. In late 2004, a summary (Table 9) of the likely impacts of various threatening processes in the south-west was estimated based on the then current literature and expert assessments by departmental scientists. This assessment focused on the number of likely species[27] extinctions that would arise if threatening processes were not managed. Such estimates, given extant knowledge gaps, are necessarily coarse and involve important assumptions.

Nevertheless, the results (Table 9) provide a useful estimate of the relative intensity of various threatening processes and their likely impacts, and underline the continued importance of managing altered hydrology including salinity.

One important knowledge gap is that there was no basis for quantifying the likely number of extinctions due to climate change at the time of the assessment, although some scientists consider this perhaps the most important threatening process. Therefore, it is useful to briefly analyse the potential impacts of climate change in relation to the threat of altered hydrology.

Climate change—particularly a drying climate—would be expected to decrease the threats posed by increasing salinity and waterlogging. However, one possible scenario for the south-west is that extreme rainfall events will increase at the same time as overall rainfall decreases (Ruprecht et al. 2005). For example, over the last decade Lake Warden and Lake Bryde have received a remarkable number of high magnitude rainfall events which have caused flooding. Given that extreme summer events can be a very significant source of recharge driving the rise of saline groundwater, particularly in the eastern wheatbelt (George et al. 2008), climate change could exacerbate rather than diminish the threat of altered hydrology expressed as salinity. Not only would increasing extreme events increase recharge directly on valley floors, there will be increased runoff from slopes with associated recharge both *in situ* and on the valley floor.

In addition, 2010 assessments of groundwater data suggest that while the rate at which watertables are rising and land is salinising has slowed, the ultimate extent of areas with shallow waters tables is unlikely to be significantly less than forecast. What remains uncertain, as a result of enhanced climate variability, is how much of this area demarked as a hazard actually becomes salt affected (Richard George, pers comm.).

Thus, irrespective of how climate changes ultimately play out, ongoing hydrological management will be required in recovery catchments to conserve wetlands and their biota. For example, enhanced surface water management improves our capacity to manage water volumes reaching wetlands under either a drying or wetting scenario. At the same time, a vital requirement for managing climate change and variability is knowledge of landscape hydrology. At present, the natural diversity and water resources recovery catchments are the key means for establishing this knowledge base.

27. Of the widely recognised asset types—genes/alleles, taxa, biological communities, aggregations of biological communities and biomes—the species level is the most amenable for this type of analysis. However, analyses at the other levels of biological complexity are also important, but require substantial data. It is assumed here that managing species at risk of extinction will be an acceptable surrogate for communities.

Table 9. Predicted number of extinctions in the south-west within 50 years, based on data as at October 2004. These estimates assume that no management action is taken over the 50-year period.

Threat category (Dot point examples of key management issues)	Predicted no. of species extinctions
Altered biogeochemical processes • hydrological processes, particularly salinity • nutrient cycles, including eutrophication • carbon cycle and climate change Only hydrological processes considered in this analysis	750
Impacts of disease • dieback (*Phytophthora* spp.)	100+
Insufficient ecological and genetic resources to maintain viable populations/asset value • destruction of habitat (food, water, shelter, oxygen, access to mates) • land clearing • small population size and isolation	90
Impacts of introduced plants and animals • environmental weeds • feral predators • new introductions of damaging species • grazing by stock • competition for food and shelter (other than as above)	43
Detrimental regimes of physical disturbance events • fire • cyclones • flood • drought • erosion (wind, water, sedimentation)	20+
Impacts of problem native species • parrots • defoliation by scarab beetles, lerps, etc.	0
Impacts of pollution • oil, acid and other chemical spills • herbicide/pesticide use and direct impacts • secondary acidity (from drainage, canal construction)	0

In summary, successful management of altered hydrology, including salinity, continues to be a high priority task in the south-west to achieve biodiversity conservation goals. Climate change will undoubtedly influence how this unfolds over the coming decades, and developing and applying hydrological knowledge will be an increasingly crucial task for those managing natural resources.

In relation to the third question, the program outputs, expenditure and outcomes have all been summarised in the relevant sections above. Taken together they represent a substantial and well-documented body of work. To assess relative departmental expenditure an attempt was made to analyse departmental expenditure on each key threatening process. Unfortunately, the structure of departmental accounts made it difficult to accurately summarise expenditure for the South West Land Division against specific threatening processes.

Nonetheless, it was estimated that in the 2007–08 financial year the amount allocated to managing altered hydrology (including salinity) was about 10 per cent of the combined allocation to managing introduced animals, introduced plants, disease, fire and altered hydrology.

From a comparison with Table 9, it can readily be seen that the relative expenditure on salinity is, if anything, less than might be expected given the potential consequences of unmanaged salinity. In addition, as outlined above in the section dealing with outcomes, management for salinity makes an important contribution to the management of terrestrial species through habitat provision and through the central importance of landscape hydrology in management of climate change. However, it must also be emphasised that in the nature conservation area, DEC has many other commitments in addition to managing threatening processes. Thus, the relative allocation of resources is more complex than presented here.

In conclusion, the Natural Diversity Recovery Catchment Program is consistent with statutory and policy obligations, tackles two of the major threatening processes in the South West Land Division (altered hydrology and climate change/variability), is progressing the management of important biodiversity assets, and is based on a modest expenditure that is, if anything, less than might be expected (at least strictly on nature conservation grounds) given the proportional allocation of resources in the south-west. On this basis it is concluded that the program represents good value for money from the perspective of departmental functions and policy objectives, particularly nature conservation. This is particularly so given that progress is being made in a natural resource management arena where even slowing the rate of decline is an achievement (see Outcomes section above for more detail).

Delivery of state community benefits and summary of value for money

Apart from representing value for money in nature conservation terms, a wide variety of other community benefits arise from the Natural Diversity Recovery Catchment Program. Most have been outlined in the Outcomes section above, but see also Appendix 1 for a comprehensive summary. These additional community benefits include improved or additional:

- protection of public roads and other infrastructure
- contributions to industry development
- protection of farmland
- landscape aesthetics
- recreational opportunities
- health
- knowledge and educational opportunities
- opportunity values.

As noted in the introduction to this value for money analysis, many important public benefits are not amenable to financial evaluation, but are critical to human wellbeing. One method for analysing the benefits outlined in Appendix 1 is to compare the benefits arising from the program with those predicted to have arisen if there were no program. That is, one can compare the benefits arising from the program with those that are predicted to have occurred in the absence of the program. Table 10 summarises this comparison in qualitative terms for the period 1996 to 2009. Note that the comparative impact on benefits could be either positive or negative. However, in this case all the impacts of the program are positive in comparison with predicted outcomes without the program. These findings are uncontroversial. Given that the program is tackling altered hydrology over some 700,000 hectares of catchment, these positive impacts are, it is argued, significant and represent good value for the expenditure. For the period 1996–2006 this expenditure ($16.17 million) was, on average, $23 per hectare over the whole 10 years.

The delivery of broader benefits from the program is supported by other analyses. Specifically, it is estimated above in the Activities, Expenditure and Outputs section that more than 35 per cent of program expenditure (some $5.66 million) during the period 1996–2006 benefited management of private property. That is, about one third of the expenditure has private benefits in addition to the benefits arising from better management of the biodiversity assets that are the focus of departmental management. Additional financial gains will be realised through better protection of rural infrastructure, including sections of public roads.

Furthermore, Worley Parsons (2009), in a report for Verve Energy, calculated the present value of the broader regional benefits (that is, those arising from improved salinity management, aesthetics, additional employment, etc) from a biomass mallee industry in the Narrogin region to be about $95 million over 20 years, or an average of $4.75 million per year. This was based on there being about 5,000 hectares of mallees established in belts. The area of revegetation under the recovery program is about the same, but spread over six target areas rather than one. One would therefore expect a substantial benefit from recovery catchment revegetation. However, further investigation would be required to properly quantify the benefit. To deliver the benefits calculated by Worley Parsons, one would expect that revegetation would need to be highly targeted within one district, rather than six areas as under the recovery program. Also, the recovery catchment vegetation included block plantings for biodiversity, which has a smaller hydrological impact than mallee belts of equivalent area. Nevertheless, the recovery program is still much more targeted than most revegetation programs, and as work continues, can be expected to deliver additional benefits increasingly in line with the Worley Parsons assessment.

Based on the above analysis, and given also the benefits outlined in Appendix 1 and Table 10, it is concluded that the Natural Diversity Recovery Catchment Program not only represents good value for money in nature conservation terms, it provides a wide range of other community benefits that ensure the program provides substantial value for money to the state community.

Table 10. Contribution of works in natural diversity recovery catchments to state community benefits. Marginal improvement shown by +, significant improvement by ++. There are no negative impacts from the works. See Appendix 1 for detailed description of benefits.

Benefit	Brief description of benefit and, where relevant, sub-categories	Impact
Productive use	These are the benefits from biodiversity and associated recovery works that are derived either from direct commercial harvesting or indirectly through enhancing the production of commercial goods. In recovery catchments benefits include:	
	• food and fibre	++
	• structural materials (for example wood products)	+
	• energy, in the form of biofuels or bioenergy (e.g. wood pellets or electricity generation provided the mallee biomass project is successful)	+
	• medical and other oil products (provided the mallee biomass project is successful)	+
	• consumptive use	+
Infrastructure for travel	Includes positive effects on roads, railways, etc	+
Recreation	The importance of biodiversity for leisure activities is well known. In recovery catchments activities include bird watching, nature photography, bushwalking, canoeing and picnicking	++
Health (physical and chemical environment)	These are benefits from biodiversity that contribute to the quality of our chemical and physical environment	+
Health (protection from other organisms)	Biodiversity helps to maintain our health by protecting us from other damaging organisms	+
Aesthetics	Scenic and other aesthetic benefits from natural landscapes	++
Philosophical/spiritual/intrinsic	Biodiversity ethic values Land stewardship values	++
Knowledge and education	Natural biodiversity is widely used for scientific research and educational purposes. In a very real sense, natural areas provide a library of knowledge	++
Opportunity	The conservation of biodiversity provides for a range of future opportunities in any of the above categories	++

RECOMMENDATIONS

As noted by Wallace and Lloyd (2008):

> *After a decade, recovery catchments are valuable examples of tackling difficult natural resource problems at landscape scales. While there have been losses, progress towards biodiversity objectives generally has been positive, but not as rapid as hoped. However, this is consistent with the physical inertia in the local systems and the need to collect adequate data to underpin management decisions. At the same time, contributions to industry development, improved understanding of wheatbelt environments and gains for sustainable land use have added to the success of the program.*

In summary, the salinity initiative, including the Natural Diversity Recovery Catchment Program, will continue to be of high importance given the:

- high value of biodiversity assets at risk
- severe consequences to biodiversity conservation of leaving altered hydrology unmanaged
- vital contribution the program makes to our understanding of hydrology at landscape scales, which is essential to effectively manage climate change/variability and interactions among food supply, water supply, energy and biodiversity conservation
- ability to deliver wider community benefits in rural areas through the program's contribution to sustainable agricultural land use in particular, but also more broadly to the state community.

In this context, augmented recovery program funding would increase delivery of a wide range of community benefits. Also, the Natural Resources Branch already provides advice on hydrological and wetland management issues outside the recovery program, and has growing expertise in this area. This, and the contribution the branch offers in relation to climate change, provides important context for the following recommendations. Thus, concerning the future of the Natural Diversity Recovery Catchment Program and the role of the Natural Resources Branch, it is recommended that:

1. *The goal of the Natural Diversity Recovery Catchment Program becomes:*

   To develop and implement works within the South West Land Division that protect, and where practicable recover, the biodiversity of significant, natural wetlands and associated valley biological communities from the adverse effects of altered hydrology. Primary values underpinning this goal will be specified for each catchment project.

   Complex interactions between salinity and waterlogging have long meant that the recovery program deals with altered hydrology in general, not just salinity. This proposed change to the program objective also acknowledges the growing importance of climate change and variability as threats to biodiversity, and the important role of recovery catchments in modelling the impacts of hydrological change in general. The proposed goal would expand recovery work to include, for example, the thrombolite community at Lake Clifton, a threatened ecological community. Ultimately, it would be useful to expand the role of the program to cover Ramsar Wetlands in general as well as threatened ecological communities where altered hydrology is the paramount threat.

   The priority state community values underpinning goals are explored and documented with each new recovery plan. These values (for example, see Table 10) and their relative importance vary from catchment to catchment. To date it has been found that engaging advisory groups in assessing values of biodiversity increases the understanding and knowledge of all interest groups involved, including the department. This approach also provides one mechanism for assessing the value of outcomes for money invested.

   Officers working in the recovery catchments program, particularly the hydrologists, are already providing advice outside the salinity initiative, so that this recommendation is consistent with an existing trend. At current levels of funding, this will entail little change in the current program, but see also Recommendation (2) and (3) below.

2. *Consideration is given to re-allocating funds within the department's salinity initiative to bolster work in the natural diversity recovery catchments.*

   Completing the necessary work required to meet recovery goals, including engineering and replacement of capital infrastructure, is important and difficult with current resources. Consequently, it is recommended that consideration is given to some re-allocation of funds within the salinity initiative to bolster work in recovery catchments.

3. *All current recovery catchments have recovery plans to the final draft stage by June 2013.*

   Completion of recovery plans for each of the existing recovery catchments has proved to be a difficult task, largely given the need to collect and analyse essential information, but also due to the lack of central resources to undertake the necessary specialist writing and hydrological work. Implementation of the above recommendations will greatly speed the preparation of recovery plans.

4. *The department seeks to expand the Natural Diversity Recovery Catchment Program as resources become available. Priorities for consideration, should funds become available, will be biological communities threatened by altered hydrology in the Hutt River and Lake Gore catchments.*

   This is an aspirational proposal that acknowledges the desirability of expanding the current program.

5. *Key technical and operational issues within the recovery catchments are addressed.*

   At an operational level many issues highlighted above and in the previous review require additional work to improve effectiveness and efficiency. These include, but are not restricted to, developing and implementing:

   a. improved planning systems, including advances in feasibility analysis, and the assessment of risk and values. Some of this work will be delivered through a project with the Future Farm Industries Cooperative Research Centre, however, additional activities will also be required
   b. improved conceptual and numerical models combined with monitoring systems appropriate to support (5a) and to ensure continued development of knowledge and adaptation of operational activities. This will be particularly important in the context of climate change/variability and likely changes in catchment land use. Physical monitoring in recovery catchments to be managed through the recovery planning process plus a group of recovery catchment officers. Biodiversity monitoring will, in the first instance, be developed through recovery plans. Progress to be reviewed within two years (2012)
   c. improved communication of recovery catchment information and outcomes, including a redeveloped website
   d. the very effective interagency links and collaboration that have evolved with external partners, including regional natural resource management groups, universities and landholders, and to expand these links nationally (for example, through involvement with the Future Farm Industries Cooperative Research Centre)
   e. a process for ensuring that, where the success of recovery projects is threatened by changed circumstances (such as changing regional staff commitments), the issues should be discussed as early as practicable with appropriate managerial staff
   f. in relation to incentives schemes, consistent cost-sharing arrangements across catchments
   g. a review charged with the task of proposing mechanisms for attracting and retaining staff in rural areas.

6. *Work within the department to develop an industry based on mallees is maintained until June 2014, at which point progress should be reviewed. This date is consistent with DEC's formal commitments to the Future Farm Industries Cooperative Research Centre.*

   Currently the department maintains a woody crop development program based largely on mallees. In 2010 this is making steady progress towards a commercial outcome. This program delivers to a number of the department's statutory functions, but in particular "to promote and encourage the planting of trees and other plants for the purposes of the rehabilitation of land or the conservation of biodiversity throughout the state, and to undertake any project or operation relating to the planting of trees or other plants for such a purpose" (Section 33(1) (cc) of CALM Act).

   In relation to the salinity program, the development of a mallee industry or equivalent has the capacity to encourage broadscale revegetation at, once the industry is established, little government cost. This has major implications for managing salinity and other land degradation. URS (2004) estimated that commercially driven perennial revegetation could reduce government management costs in recovery catchments by 50 per cent. Early plantings of the program are already playing an important role in some recovery catchments, and at the same time such revegetation provides additional habitat for native species, and discourages planting of potential woody weeds.

   In addition, the mallee program is contributing to a wide range of other outcomes including the management of climate change. For example, plantings contribute to carbon sequestration and, if a bioenergy industry develops, will also assist in replacing non-renewable energy sources.

   Thus, it is particularly important that the program be maintained. The program should be reviewed prior to the cessation of the Future Farm Industries Cooperative Research Centre on 30 June 2014. There are ongoing departmental commitments until that date, and this therefore provides a convenient review point.

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GLOSSARY OF ACRONYMS

CALM	Department of Conservation and Land Management
CAMBA	China-Australia Migratory Bird Agreements
CMS	Conservation of Migratory Species of Wild Animals
DAFWA	Department of Agriculture and Food (WA)
DEC	Department of Environment and Conservation
DRF	Declared rare flora
DoW	Department of Water
IBRA	Interim Biogeographic Regionalisation of Australia
JAMBA	Japan-Australia Migratory Bird Agreements
LWWS	Lake Warden Wetland System
NAP	National Action Plan for Salinity and Water Quality
NHT	Natural Heritage Trust
NRM	Natural resource management
PEC	Priority ecological community
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreements
TEC	Threatened ecological community
WA	Western Australia

APPENDIX 1:

Benefits arising from biodiversity assets in recovery catchments and associated recovery works

Benefit	Description of benefit and dot point examples from recovery catchment works
Productive use	These are the benefits from biodiversity and associated recovery works that are derived either from direct commercial harvesting or indirectly through enhancing the production of commercial goods. In recovery catchments benefits include: • food and fibre, in this case improved hydrological management through surface water engineering, revegetation, and protection/management of remnant vegetation will decrease production losses due to waterlogging and salinity. In addition, strategically placed revegetation (particularly mallee belts) will also contribute to increased production [28] through decreased wind and water erosion, increased stock protection, etc. Elements of these benefits occur across all recovery catchments. • structural materials (for example, wood products) from some forms of revegetation – largely a potential, rather than realised, benefit. Lake Warden, Muir-Unicup and Toolibin Lake catchments in particular. • energy, in the form of biofuels or bioenergy (for example, wood pellets or electricity generation) derived from mallee plantings established for hydrological control with incentive payments from recovery catchment funds. Benefit will be realised provided the developing mallee industry becomes fully commercial. Toolibin, and to a lesser extent Lake Warden and Buntine-Marchagee. • medical and other oil products derived from mallee plantings established for hydrological control with incentive payments from recovery catchment funds. Benefit will be realised provided the developing mallee industry becomes fully commercial. Toolibin, and to a lesser extent Lake Warden and Buntine-Marchagee.
Consumptive use	These are the benefits from biodiversity and associated recovery works that are harvested for domestic uses and do not pass through a market. These include: • firewood and structural timbers harvested sustainably from revegetation established for hydrological control – currently a potential, rather than realised, benefit.
Infrastructure for travel	Includes positive effects on roads, railways, etc. • surface water engineering and revegetation protect and improve the maintenance of public roads and related infrastructure, such as culverts, in four recovery catchments (Buntine-Marchagee, Toolibin, Lake Bryde and Lake Warden).
Recreation	The importance of biodiversity for leisure activities is well known. In recovery catchments activities include birdwatching, nature photography, bushwalking, canoeing and picnicking. Research links recreation in natural environments to both physical and mental health. There are strong links between recreation and amenity (aesthetic) values. Loss of native plants and animals and loss in water quality in wetlands all have a negative impact on aesthetics and leisure. Specific examples of recovery catchment benefits with regard to leisure include: • tourist and local community sites at Lake Warden and Muir Unicup based on the wetlands • local community sites at Toolibin, Lake Bryde • general use of reserves for leisure in all recovery catchments, including annual visits by large groups in some cases.

28. Note that revegetation and structures can also occupy agricultural land, and may result in production losses. Outcomes need to be generated for a specific site.

Benefit	Description of benefit and dot point examples from recovery catchment works
Health (physical and chemical environment)	These are benefits from biodiversity that contribute to the quality of our chemical and physical environment. For example, remnant vegetation is often retained to provide shade or wind protection for people, revegetation with native species may be used to minimise dust in the atmosphere (and therefore allergic problems). Work in all recovery catchments: • in the case of revegetation, contributes to a more benign climate through carbon sequestration and lowering wind speeds at landscape scales where plantings are sufficiently extensive • dust reduction through retained vegetation and revegetation may have a positive effect on human health through decreasing allergies • maintaining biodiversity in the landscape increases the probability that bio-indicators will provide an early warning of problems in the environment (for example, experience with lead poisoning at Esperance where death of native birds highlighted the problem).
Health (protection from other organisms)	Biodiversity helps to maintain our health by protecting us from other damaging organisms. Includes: • maintaining biologically diverse wetlands and drainage lines reduces the probability of poisonous cyanobacteria blooms. Biodiversity may also contribute to suppression of disease organisms or disease-spreading organisms (inferred on the basis of general principles as outlined in Hooper et al. 2005). • medical products from eucalypts (see productive use above).
Aesthetics	Scenic and other aesthetic benefits from natural landscapes, beauty of wildflowers and birds. Includes sense of place values, although this could be incorporated into the next category. Maintaining recovery catchments in good condition is a major contribution to this value. For example, two farmers participating in an expert assessment of the impacts of belt plantings of mallees estimated that the resulting improvement in landscape aesthetics was 20–60 per cent compared with the landscape without belts (unpublished data).
Philosophical/spiritual/intrinsic	All humans operate within either an explicit or implicit set of philosophical beliefs that establish and explain the role of humans in the world/universe and these beliefs provide guidance for how people think they should live their lives and interact with other people, other organisms, and the inanimate world. Biodiversity is often an important part of our spiritual/philosophical and moral framework. Intrinsic values are incorporated here given that they are a statement of beliefs. Species extinctions and degradation of wetland communities would be a major negative in this regard, thus conservation of wetlands and their biodiversity contributes to benefits in this area.
Knowledge and education	Natural biodiversity is widely used for scientific research and educational purposes. In a very real sense, natural areas provide a library of knowledge about how more complex systems function, and this knowledge may be explored and used to inform human understanding and progress. A very simple example of this is the use of native bushland remnants as baseline sites for comparison with farmland to assess changes in soil structure and condition. Other examples include the widespread use of bushland to research natural processes, and as an educational resource used by schools to explore the relationships between living and non-living components of the environment. In recovery catchments, benefits include: • educational use of all recovery catchments, including constructed nature trails and/or information sites in three recovery catchments (Lake Warden, Muir-Unicup and Toolibin) • applied, scientific research across all recovery catchments is a major contribution to improving management of agricultural landscapes across southern Australia, particularly the south-west. This includes an important contribution to managing climate variability through building an understanding of the hydrological interactions with climate at catchment scales.

Benefit	Description of benefit and dot point examples from recovery catchment works
Opportunity	The conservation of biodiversity provides for a range of future opportunities in any of the above categories. The most obvious example is the genetic resource in native plants. Opportunity values include those values listed elsewhere in this table that are not currently realised. In recovery catchments, they will include maintaining the opportunity for: • discovery of currently unknown benefits in our native biota (including germplasm resource in native plants) • retained opportunities to utilise aesthetic and recreational values of natural areas as surrounding environments become increasingly degraded • future generations to make their own decisions concerning biodiversity values and their use.

APPENDIX 2:

1996–2006 Expenditure and outputs – all natural diversity recovery catchments

Threats	Work activities	Performance measures	TOTALS Statistics	TOTALS Expenditure
Lack of ecological resources to support viable populations	Expansion of conservation estate through land purchases. Current efforts in this area are generally focused on purchasing lands that enhance long-term viability of existing reserves and remnant systems.	No. of land parcels inspected	17	1,115,651
		No. of land parcels purchased	9	
		Total area of land purchased	1,394	
	Biological surveys to identify lands (but not those for private land purchase) that should be incorporated into the conservation estate, used for seed orchards, revegetated, or accorded better protection for salinity control.	No. of areas surveyed	38	19,546
		No. of recommendations completed (at regional level)	0	
		Total area agreed to come into conservation estate	0	
	Biological surveys (e.g. vegetation and floristics, mammal surveys, rare flora surveys and monitoring) as a basis for monitoring and planning.	No. surveys	69	823,142
	Creating buffers (including habitat expansion) for remnant vegetation, but not including use of commercially prospective species. Involves use of funds for works on private property to protect biodiversity values, and includes fencing of revegetation.	a. No. sites	185	808,270
		b. No. seedlings	1,161,527	
		c. Area of buffers	1,128	
		d. Total km of fencing	106	
		e. Total no. of landholders involved	83	
	Creating corridors (not including commercially prospective species) connecting remnant vegetation. Involves use of funds for works on private property to protect biodiversity values, and includes fencing of revegetation.	a. No. sites	95	743,863
		b. No. seedlings	753,300	
		c. Area of corridors	669	
		d. Total km of fencing	80	
		e. Total no. of landholders involved	34	
	Using commercially prospective species to buffer or create corridors.	a. No. sites	46	277,040
		b. No. seedlings	844,500	
		c. Area planted	331	
		Total km of fencing	45	
		Total no. of landholders involved	30	
	Rehabilitation of degraded areas on Crown lands.	No. sites rehabilitated	15	343,614
		Area rehabilitated	310	
		No. of reserves involved (note, individual reserves should only be recorded once)	9	
			0	

			TOTALS	
Threats	**Work activities**	**Performance measures**	**Statistics**	**Expenditure**
Lack of ecological resources to support viable populations (continued)	Improved protection and management of native vegetation on private properties including: • Fencing of remnant vegetation on private property. • Coverage of private remnants by conservation covenants.	Km of fencing	350	765,626
		No. of remnants	136	
		Area of remnants	5,161	
		No. of landholders involved	91	
		No. of sites covered	25	
		Area of sites covered	46	
	Research other than listed above.	List (separately) of reports and investigations	9	186,160
Detrimental regimes of physical disturbance events, such as fire, cyclone, drought, flooding. At this stage, fire is the only disturbance proposed for management. All activities relate to fire management.	Planning and liaison.	Separate written list of plans and other documents	1	672
Impacts of introduced plants and animals.	Weed control – other.	No. sites treated	16	67,897
		Area treated	309	
		No. reserves treated (note, individual reserves should only be recorded once)	11	
		No. private property sites	0	
	Rabbit control.	No. sites treated	9	3,998
		Area treated	20	
		No. reserves treated (note, individual reserves should only be recorded once)	1	
		No. private property sites	1	
	Pig control.	No. sites treated	0	9,592
		Area treated	0	
		No. reserves treated (note, individual reserves should only be recorded once)	2	
		No. private property sites	10	
	Fox control.	No. sites treated	1	8,250
		Area treated	2,000	
		No. reserves treated (note, individual reserves should only be recorded once)	4	
		No. private property sites	0	

Threats	Work activities	Performance measures	Statistics	Expenditure
			TOTALS	
Altered biogeochemical processes. ***Note that salinity and waterlogging control is the only activity shown. Nutrient stripping and carbon sequestration have not been included, but may be later.***	Contribute to the development of improved drainage assessment, practice and policy.	No. NOIs processed	4	10,374
	Revegetation (generally of cleared areas on private property) with main objective of hydrological control. Includes fencing. Not including commercially prospective species.	Land conservation plantings a. No. sites	99	1,248,771
		b. No. seedlings	1,217,330	
		c. Area planted	875	
		d. Km of fencing	157	
		e. No. of landholders involved	75	
	Revegetation with commercially prospective species (generally of cleared areas on private property) with main objective of hydrological control. Includes fencing.	a. No. sites	46	605,146
		b. No. seedlings	853,937	
		c. Area planted	1,918	
		d. Km of fencing	18	
		e. No. of landholders involved	44	
	Engineering works on Crown lands to protect public asset values.	List (separately) of investigations, reports	11	3,115,271
		No. of sites treated	39	
		Length of structure; or	37	
		Area treated	1,300	
	Engineering works on private property to protect public asset values.	List (separately) of investigations, reports	10	681,848
		No. of sites treated	40	
		Length of structure; or	42	
		Area treated	225,000	
		If appropriate, number of de-watering bores	0	
	Monitoring and research/investigations (other than listed for particular project areas above).	List (separately) of investigations, reports	22	3,536,490
Inappropriate culture	Management of recovery and related committees, input to catchment planning, liaison with local authorities and all other groups.	No. meetings	212	828,339
		No. of groups dealt with	99	
	Communication, education, general training of external audiences.	No. of groups dealt with	324	802,444
		No. of interpretive items	307	
		No. of media releases	121	
	Volunteer management.	No. volunteers	59	39,080
Competing resource use	Notices of intent to clear.	No. dealt with	5	6,995
	Recreation.	See Parks and Visitor Services	0	125,006
				16,173,085

ISBN 978-1-921703-21-8

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2010268-811-1000