Environment Western Australia

1997

Draft State of the Environment Report

Draft Report for Public Discussion

Environment Western Australia 1997
Draft State of the Environment Report for Western Australia

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How to comment on this report

We would welcome your comments on this report. We are particularly interested in receiving comments on the information in this report, and on the appropriateness of the suggested responses.

After the comments on the draft report have been considered, the Government will release the final State of the Environment Report with its response.

Please send your comments by 30 October 1997 to:

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Foreword

The Government of Western Australia initiated the process to report on the state of Western Australia's environment. The Environmental Protection Authority was instrumental in triggering this reporting process. The Western Australian Government adopted the format for state of environment reporting used by other states and the Commonwealth who have followed the Organisation of Economic Co-operation and Development's pressure–state–response model for reporting on the state of a region's environment. That model has been used as the basis for this report. A major challenge in using this approach is that it requires involvement of all sections of the community to report accurately and fairly.

To meet this challenge, the State of Environment Reference Group was established. Members of this group were drawn from the principal natural resource agencies, the Soil and Land Conservation Council, the National Parks and Nature Conservation Authority, the Lands and Forest Commission, and major community catchment management groups.

To provide an overview of WA the State was divided into regions and Focus Groups were established for most regions. This regional approach to reporting on the environment allowed important environmental issues in each region to be identified and discussed by local people and State agency staff. Hundreds of individuals have had input to this report either as a group member or as a specialist in some aspect of the environment. State agencies have not only reviewed the performance of their current programs but also provided advice on ways to respond to identified issues.

There are many important features about *Environment Western Australia 1997*. These include the following.

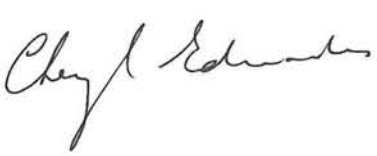
- Specific environmental issues are described concisely and given a priority in terms of environmental status.
- The condition of the environment, pressures acting on it and responses to these are presented.
- Rather than being a snapshot of the performance of current government programs as in 1992, this State of the Environment Report is designed as a guide to future policy.
- Important natural resource use sectors are described in terms of their progress towards sustainability.
- The foundation for an ongoing program to monitor and report on the condition of the environment and the effectiveness of our responses is provided.
- First generation environmental indicators are developed for each of the important environmental issues discussed in the draft report.
- This is a draft report and public comment is welcome. This will ensure the accuracy of the information and enable discussion about the suggested responses to these issues.

Many of these features are new to state of environment reports in Australia and reflect the Government's desire to include the community in bringing about a more focussed and effective approach to managing the environment.

After the public comment period the draft report will be finalised and the Government will indicate its response to the issues and suggestions contained in it.

I acknowledge the efforts of all those involved and thank them. In particular I congratulate and thank the State of the Environment Reference Group for steering the production of the draft report.

I commend this draft report to you and encourage you to comment on it.



HON. CHERYL EDWARDES (MRS) MLA
MINISTER FOR THE ENVIRONMENT, EMPLOYMENT AND TRAINING

Preface

Environment Western Australia 1997 Draft State of the Environment Report, provides an overview of the key environmental issue facing Western Australia. The approach taken to produce this report is different from that used to produce the 1992 *State of the Environment Report*. It involved community and government representatives working together to identify environmental issues, provide input and suggest responses. The overall approach has been to integrate scientific and local environmental knowledge to inform decision-makers within government and the broader community. This builds on the notion that environmental management is more successful when jointly addressed by government and community.

Production of this report was co-ordinated by the State of the Environment Reference Group, made up of community and government representatives. The Reference Group was established by the Minister for the Environment and its members include:

- Dr Bryan Jenkins, Chief Executive Officer, Department of Environmental Protection;
- Mr Rex Edmondson, Chairperson, Soil and Land Conservation Council;
- Mr Leon Watt, Chairperson, Lands and Forest Commission;
- Mr Tom Day, Chairperson, National Parks and Nature Conservation Authority;
- Mr David Reid, Chairperson, Blackwood Catchment Co-ordinating Group;
- Mr Noel Robins, Chairperson, Swan Avon Integrated Catchment Management Co-ordinating Group;
- Mr Keiran McNamara, Director, Nature Conservation, Department of Conservation and Land Management;
- Mr Kevin Goss, Executive Director, Sustainable Rural Development, Agriculture Western Australia; and
- Mr Harry Ventriss, Director, Regional Services Division, Water and Rivers Commission.

The Reference Group has made a conscious effort to ensure that the report is easy to read and understand. As a consequence, their has been an emphasis on general rather than technical terms. In some instances this means an issue is less precisely described from a scientific view point.

More detailed information, and first generation environmental indicators, are provided for each issue in the *Draft State of the Environment Reference Group Working Papers*. The draft working papers also contain suggested responses to each environmental issue; these have largely been put forward by each of the Regional Focus Groups.

On behalf of the Reference Group I would like to thank the many people who assisted in preparing this draft report, in particular the members of the Regional Focus Groups who volunteered their time and expertise. I would also like to acknowledge the members of the State of Environment Unit within DEP;

- Ms Denise Allen
- Ms Jookie Wong
- Mr Michael Rowe
- Mr Andrew Higham and
- Dr Ray Wallis

A full list of acknowledgments is on page 69.

DR BRYAN JENKINS
CHIEF EXECUTIVE OFFICER
DEPARTMENT OF ENVIRONMENTAL PROTECTION.

Contents

STATE OF THE ENVIRONMENT REPORTING IN WESTERN AUSTRALIA

Process

Western Australia's first *State of the Environment Report* was produced in 1992. At that time there was a general assumption that another report would be produced in about four years time.

In June 1995 the Western Australian Government agreed to the production of a second state of the environment (SoE) report based on the Organisation for Economic Co-operation and Development's (OECD) pressure–state–response model (Figure 1).

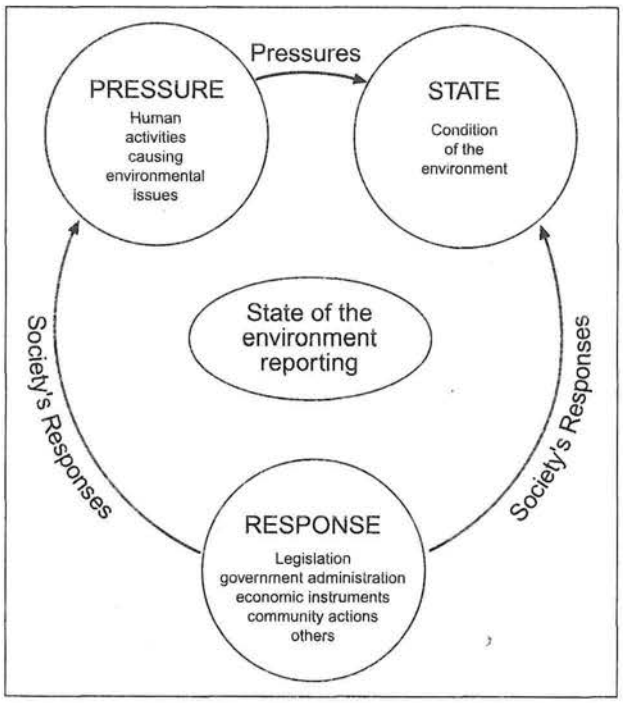


Figure 1 *The Pressure–State–Response model used in State of the Environment Reporting.*

The Government felt that it was important to report regularly on the environment and provide up-to-date information to all Western Australians. This draft report is also intended to inform debate and stimulate action on environmental issues.

This report differs from the first *SoE Report* in a number of ways. In particular, the current report provides advice to government in setting priorities on key environmental issues and suggests appropriate responses to these issues. It is focussed on environmental issues rather than broad 'parts' of the environment. It also proposes an ongoing framework for environmental monitoring and reporting, including progress towards sustainability for each of the key natural resource sectors.

In October 1995, the Minister for the Environment established a Reference Group to steer the SoE reporting process. The Department of Environmental Protection (DEP) co-ordinated the reporting process.

It is important to note that the report does not consider all of the many issues facing Western Australia's (WA's) environment. Rather it focuses on key environmental issues identified by the SoE Regional Focus Groups and Reference Group.

Regional Focus Groups were established based on environmental regions across the State. These regions were chosen to reflect the unique diversity of WA's environment and are broadly based on the Interim Biogeographic Regionalisation of Australia. The State is divided into 23 SoE regions: eight marine and 15 terrestrial (Figure 2).

The establishment of Regional Focus Groups allowed the report to be prepared with input from individuals from the general public, industry and government. Where this was not possible because the region was too remote, e.g., the Gibson Desert region, a network of correspondents was asked to participate.

Each group or network identified the key issues for their region and reported on them. The information was discussed by experts in relevant fields and formed into the *SoE Reference Group Draft Working Papers*.

In addition to key environmental issues, the main natural resource agencies have reported on progress toward ecologically sustainable development in the following sectors:

- agriculture;
- fisheries;
- forestry;
- mining and petroleum production;
- tourism; and
- water supply.

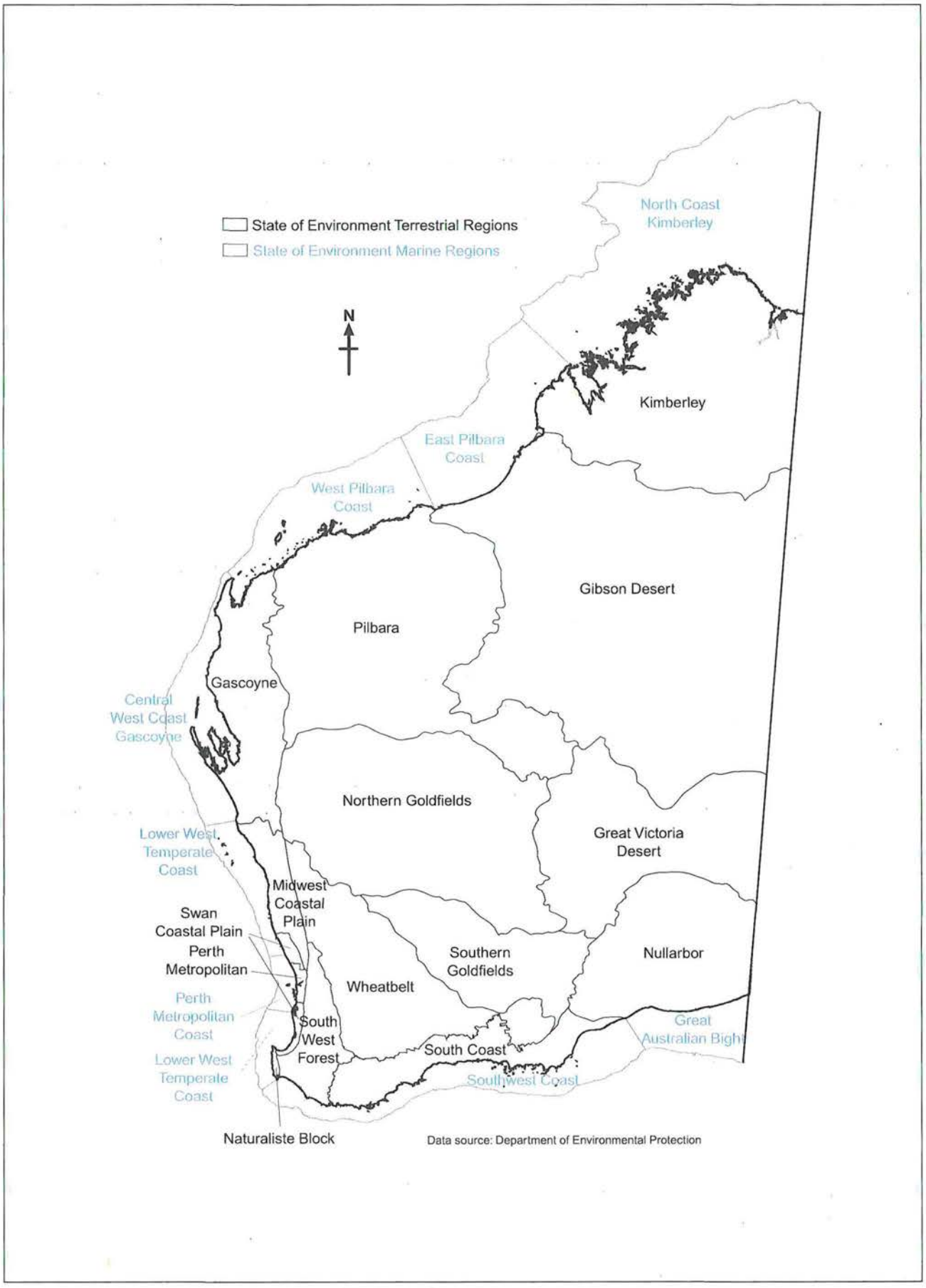


Figure 2 *State of the environment reporting regions for Western Australia.*

The report is based on a modified OECD pressure–state–response model so that it is useful at a sub-national level. This retains the benefits of an internationally agreed framework for environmental reporting.

First generation environmental indicators for each issue and sector have been developed. Indicators have been included in this draft report where possible. The full set of first generation indicators is included in the *SoE Reference Group Draft Working Papers*.

The SoE Reference Group has ranked in priority the environmental issues according to a set of criteria which took account of:

- maintenance of ecological integrity;
- the precautionary principle; and
- inter-generational equity.

This was a qualitative assessment.

Future action on environmental issues should follow these priorities.

About this draft report

This draft report is divided loosely into three sections. It provides information on two fundamental pressures on the environment which impact on most components of the environment: *Population and Environment*; and *Consumption and Waste Management*. The draft report then discusses 23 priority environmental issues facing WA. The format for this section is described below. The sustainability of the main natural resource sectors (agriculture, fisheries, forestry, mining and petroleum production, tourism and water supply) is also described.

The 23 priority environmental issues are grouped into five broad categories which reflect the main components of the natural environment on which the issues have an impact:

- the atmosphere;
- land;
- inland water (groundwater, rivers, wetlands and estuaries);
- the marine environment; and
- the maintenance of biodiversity.

To some extent this is an artificial grouping as many of the environmental issues are interconnected and affect different parts of the environment, e.g., rangeland degradation includes aspects of erosion, sedimentation and biodiversity. However, this approach allows the issues to be discussed and explained easily. Where an issue is directly related to other sections of the report those sections are cross-referenced in the text and in the bottom right hand corner of each page.

The format for discussion of each environmental issue is shown in the blue text below.

The environmental issue is named and the regions where the issue is relevant (as identified by Regional Focus Groups or the SoE Reference Group) are identified and mapped.

Each issue is then addressed in the following form.

Environmental status

A rating (out of five) shown by markers indicates the significance of the issue based on several environmental criteria. A rating of five indicates the highest level of significance.

Conclusion

A statement by the SoE Reference Group which critically assesses the issue.

Objective

Provides a broad environmental objective for the issue.

Suggested response

Nominates possible approaches to managing the issue. The Regional Focus Groups and Reference Group have been key contributors in suggesting these responses.

Description

Explains the issue.

Condition

Summarises what is known about the impact of the issue on the environment and where possible a comparison is made with the 1992 *SoE Report*.

Pressure

Identifies key causes for each issue.

Current Response

Summarises most of the significant current and ongoing community and government responses to each issue.

Implication

Identifies social, environmental and economic implications of the issue.

Cross-referencing

A reference to the *SoE Reference Group Working Papers* is provided for more information. Sometimes cross-referencing will indicate where the issue interacts with another issue in the report.

Future Reporting

The SoE Reference Group has developed an environmental objective for each issue in this draft report.

These objectives will guide ongoing SoE activities including policy development and the establishment of definitive environmental indicators. The objectives are derived from the State Conservation Strategy (Government of Western Australia, 1987), the National Strategy for Ecologically Sustainable Development (Anon., 1992) and the Intergovernmental Agreement on the Environment (Council of Australian Government, 1992).

The Reference Group has also determined a set of principles for environment reporting which will provide a framework for ongoing environmental reporting. The framework for ongoing SoE reporting in WA should:

- provide for all relevant government agencies, community-based organisations and the private sector to be part of the process (policy development, monitoring, reporting etc.);
- ensure co-ordination and integration in monitoring, analysis and reporting and avoid omission, duplication and repetition;
- enable a report for Government on priority environmental issues and associated indicators including recommendations for priority action and funding;
- establish an identifiable agent responsible for co-ordinating SoE activities;
- be compatible with, and actively provide links to, the reporting processes developed through the various tiers of government, i.e. local, catchment, regional, state and national;
- deliver annual outcomes in line with audit requirements and incorporate appropriate indicators into existing annual reporting mechanisms;
- provide opportunities for a number of reports to be produced according to various attributes, e.g., region, issue, theme, and report on issues as information becomes available or as an issue becomes relevant;
- provide relevant and useable information to all decision-makers.
- use information in a valid and accurate manner, recognising the limitations of the information;
- identify community response to environmental issues in terms of attitude and behaviour and barriers to behavioural change;
- allow for the State's environmental objectives to be monitored and progress reported to the community; and
- be continuously updated and be accessible to all members of the community.

After the public review period it is anticipated that this framework will provide the basis for future reporting.

The *SoE Reference Group Draft Working Papers* will form the starting point for further discussion on the appropriateness of each environmental indicator. The *Working Papers* will also provide input to the strategic development of responses to each environmental issue.

The effectiveness of these responses will be measured by the degree to which it brings about change in the environmental indicators for that issue. By linking objectives, indicators and responses in this manner, the community can be confident that actions to manage the environmental issues will be better targeted, more efficient and cost effective.

If the SoE reporting process is followed it will be possible to evaluate the effectiveness of society in improving the state of the environment, and will assist in ensuring that the environmental performance of government agencies is accountable to the Auditor General.

See Section 1 of the SoE *Reference Group Draft Working Papers* for a fuller description of the SoE Regions.

Physical Features

Western Australia is the largest Australian State. It covers a land area of about 2.5 million km^2 (one-third of the nation's land area) and includes 12,500 km of coast line. There is also an adjacent area of the ocean under Australia's Exclusive Economic Zone (EEZ) of approximately 12 million km^2.

The land mass is dominated by the ancient Western Shield plateau, which is generally 300–600 m above sea level. The main mountain ranges of the State are located in the Pilbara region, e.g., Hamersley Ranges. The landscapes of the central and northern portions of the State are some of the oldest in the world and have been stable and largely above sea level for about 400 million years. In the south west of the State, despite ancient and nutrient poor soils, the land supports extensive agriculture, forest, woodland and heath. Large tracts of south west coastal plains are formed from more recent sand deposits, e.g., Swan Coastal Plain. The south east of the State is dominated by the flat limestone Nullarbor Plain.

Climate

The sheer size of the State means there is a number of distinct climatic regions. These range from the moist tropical climate of summer monsoons in the north west Kimberley, the hot dry climate with summer cyclones of the Pilbara and Gascoyne, the hot dry arid interior of the Gibson and Great Victoria Deserts, to the temperate climate of winter rain and dry summers in the south west of the State. Figure 3 shows the rainfall distribution in WA.

State of Environment Regions

Due to the size of the State and its environmental diversity it has been divided into a number of regions as illustrated in Figure 2. These SoE regions are closely related to the Interim Biogeographic Regionalisation for Australia (IBRA) (Thackway & Cresswell, 1995), with larger SoE Regions being combinations of IBRA regions. Each SoE region is based on geology, landform, vegetation and climate. In some cases the boundaries vary to accommodate other factors such as catchment boundaries.

Human Settlement

Aboriginal presence in WA is considered to be amongst the oldest in Australia, probably dating back more than 50,000 years. As they led a hunter–gatherer lifestyle, Aboriginals used a number of campsites. The use of fire as a hunting tool is thought to have caused significant changes to the vegetation, flora and fauna of the State.

European settlement began in Albany in 1826 and the Swan colony in 1829. Today WA supports 1.7 million people with over 70 % of the population living in the Perth metropolitan region. The rest of the State is sparsely settled with the south west corner (other than Perth) and the Kimberley the only areas showing significant population growth rates.

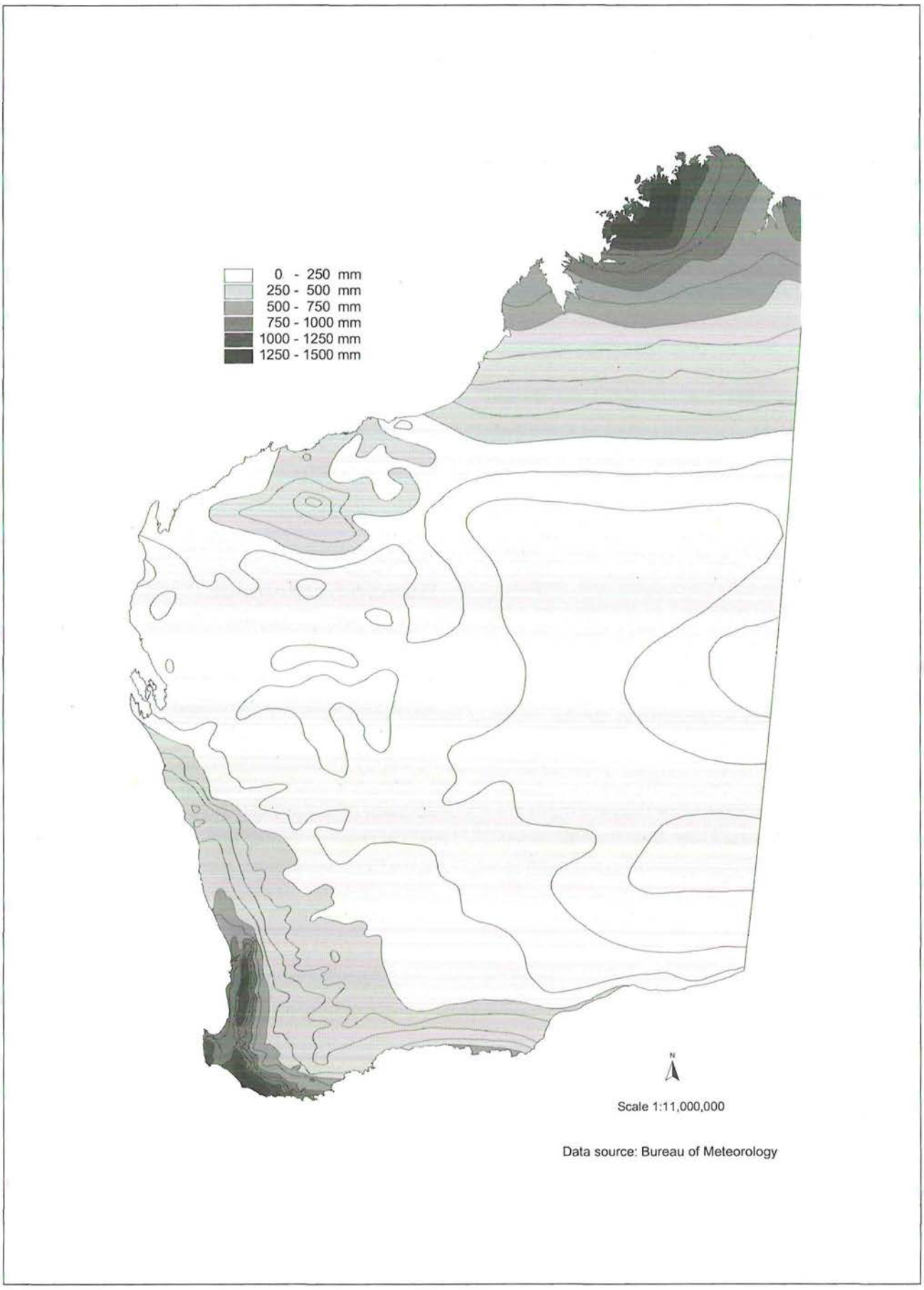


Figure 3 *Average annual rainfall distribution for Western Australia (Data since 1940).*

CONCLUSION AND STATEWIDE PRIORITIES

Conclusion

Since the 1992 *SoE Report* there is now more information on the environment. This 1997 report uses the most recent available information. However, there are still significant shortcomings in the available data for environmental management. For many of the issues in this report the lack of information means that it is not possible to present long-term trends. The report emphasises the importance of establishing agreed indicators and monitoring mechanisms for the future.

In general, available information shows a steady decline in the condition of the environment and an increase in the pressure humans place on the environment. However, with effective environmental management some issues are improving, e.g., reduced levels of atmospheric lead and sulphur dioxide, declining chlorine levels in the stratospheric ozone layer and recovery of some threatened mammal species.

The continued decline in the condition of the environment will result in increasing social costs. With few exceptions the social costs are not being accounted for and therefore are not discussed in this report.

A substantial amount of effort is being applied by the community, government and industry to ensure that social and economic development is ecologically sustainable. At present most of the measures show sustainable resource use, e.g. fisheries, and forestry, but there are few if any agreed measures of ecological sustainability for these resources. Consequently all major natural resource agencies are putting effort into developing measures of ecologically sustainable development consistent with national and international work in this area.

Statewide Priorities

All of the environmental issues considered in this draft report are important. The SoE Reference Group has assigned priority by rating each issue in terms of its environmental status. The purpose of the rating is to provide advice to Government on the relative priority of the environmental issues for action.

Environmental status was determined by the Reference Group based on the core principles of ecologically sustainable development (ESD):

- the maintenance of ecological integrity;
- the precautionary principle; and
- inter-generational equity.

The Reference Group used a number of criteria to qualitatively analyse and compare very different and complex environmental issues. The criteria included:

- the irreversibility of the environmental impact;
- the rate at which each issue is worsening;
- the degree of impact on other parts of the environment;
- the extent of impact across the state; and
- the impact on the choices of future generations.

The Reference Group has provided an environmental status rating from one to five for each issue. Five markers indicates the highest priority for government and community action based on the above criteria.

❖ ❖ ❖ ❖ ❖ (Highest priority environmental status)
Maintaining biodiversity
Land salinisation
Salinisation of inland waters

❖ ❖ ❖ ❖ Enhanced greenhouse effect
Stratospheric ozone depletion
Land contamination
Loss of fringing vegetation
Eutrophication

❖ ❖ ❖ Photochemical smog
Haze from particulates
Erosion
Soil acidification
Sedimentation
Contamination of inland waters
Degradation of marine habitats
Contamination of the marine environment
Introduction of exotic marine species
Fish stocks

❖ ❖ Carbon monoxide
Sulphur dioxide
Waterlogging

❖ Lead
Dust

FUNDAMENTAL PRESSURES

Population and Environment

Background

Description

Western Australia's population is projected to rise from the present 1.75 million to 2.7 million by 2029. This will put increased pressure on the environment, particularly in suburban Perth and coastal regions in the south west. Most of us live in low density, mainly coastal settlements and are among the highest users of motor vehicles in the world. We currently enjoy a high standard of living and have expectations of maintaining this in the future.

However, without careful management we could face huge costs in providing clean air, land and water for our population. Present planning processes cater for continued economic and population growth in WA. Strategies to stabilise growth have not been developed.

Population and the environment are inextricably linked, so we need to have more information on these in order to plan for a sustainable future. We also need to realise that as individuals our actions impact on the environment. If we are to sustain our quality of life as WA's population grows, then our individual and collective impacts on the environment will need to be reduced.

Condition

Population Dynamics

Changes in the State's population are determined by three factors: the rate of natural increase of our population; the death rate; and the rate of migration into and out of WA. In 1996 WA's population was 1.75 million, with 1.28 million (73 %) of those people living in Perth. Perth stretches 90 km along the coast and 40 km inland, and is characterised by low density, car dependent suburbs. The city's population has resulted in increased air, water and land pollution, as well as loss of biodiversity through habitat destruction caused by demand for transport, housing, industry and recreation.

Rural populations have fluctuated, with the wheatbelt region experiencing gradual decline, while the south west is showing sustained growth. Busselton is one of Australia's fastest growing regional centres.

Coastal and wetland areas of the Swan Coastal Plain are vulnerable to population growth; already 70–80 % of wetlands in this area have been irreversibly degraded (Government of Western Australia, 1992).

Migration Trends

Interstate and overseas migration continues to be an important factor in WA's population picture, with over 100,000 people arriving in the State between 1986 and 1991. Over the same period, 30,000 people moved to other locations in the State, the majority moving to Perth and the south west (Western Australian Planning Commission, 1996a).

Settlement Patterns

Seventy-five per cent of urban Western Australians live in detached houses with space for garden and outdoor activities, ideally close to the coast. We are very dependent on cars, using them more than average Australians. In 1995 there was almost 600 passenger vehicles per 1000 people in WA, compared to the national average of 530 vehicles per 1000 people (Australian Bureau of Statistics, 1996b).

Planning Processes

Land use planning in WA has evolved rapidly over the last 50 years, often driven by bursts of population growth and development booms which have provided employment and encouraged migration. Until recently the most intensive planning has centred on Perth, catering for its strong population growth and resulting urban expansion. Since the mid-1950s planning has directed Perth's growth along corridors, feeding strategic regional centres mostly to the north and south of the city centre. These factors have generally increased the city's reliance on motor vehicles and which, in turn has increased air pollution, noise and urban congestion problems (see *Carbon Monoxide* on page 23). The corridor plan and earlier planning frameworks have had unintentional benefits by preventing urban development on Perth's valuable groundwater supply areas allocating these areas to forestry reserves.

Current, long-term planning builds on earlier corridor principles in addition to encouraging

population growth in regional centres (Western Australian Planning Commission, 1996b). Recent changes to planning law now allow for statutory planning schemes to be prepared in regional WA, and for them to be subject to environmental review.

Pressure

Population and Resource Consumption

People create pressure on the environment. We depend on the environment to provide the majority of the resources we need to live, e.g., food, water, shelter and warmth. The environment is also a place of recreation and a source of inspiration, but must also absorb our wastes. Much of the environment is easily degraded and its resources depleted if overused. This applies to use by both humans and other species. Generally, the more populated an area, the more resources are used and the greater the potential environmental impact. The wealth of a population is also a key factor; usually the richer people are, the more they consume.

The 'ecological footprint' model has been developed to measure the effects of human consumption patterns on the environment. Its aim is to give an idea of human carrying capacity; how many people or what human activities the environment can support indefinitely and still remain healthy.

A population's ecological footprint is determined by calculating how much land and water is required to produce our resources and absorb our wastes. This includes those resources consumed and wastes disposed outside of a population's immediate living area. Developed countries like Australia have large ecological footprints because of the resources they consume from other parts of the world and the wastes they effectively export as a part of trade in raw materials (Rees & Wackernagel, 1994).

The Australian Bureau of Statistics quotes an estimate of Australia's ecological footprint, comparing it to those of Canada, USA and India. The people of Australia, USA and Canada respectively use 4.4, 5.1 and 4.3 ha of productive land each to sustain their standards of living, while India uses only 0.4 ha, i.e. the average Australian consumes 10 times that of an average person from India (Australian Bureau of Statistics, 1996b).

Environmental degradation is a sign that we are exceeding our carrying capacity in some areas, which has major implications for our quality of life, not to mention that of future generations. Under current conditions, the capacity of the land to maintain production is diminishing.

Response

There is currently no mechanism to examine fundamental questions of how sustainable our population and consumption patterns are. The current State Planning Strategy provides a framework for managing growth. In providing this framework the State Planning Strategy accepts that population will increase at 1.3 % per year for the next few decades. Similarly, the Department of Commerce and Trade's (Dawkins, Lang & Thorpe, 1996) examination of WA's future to 2029 only considers two scenarios: current and 'quantum' growth levels; quantum growth being an even more dynamic rate of growth than present.

So, some difficult questions need to be asked:–

- Are there limits to growth in WA ?
- Is there an optimum population size for the State ?
- Should we be planning to limit the size of our cities ?
- Does WA need a population and consumption strategy ?
- How can we reduce our individual and collective impacts so that increasing population may be accomodated without increased impact ?
- Should society incorporate full environmental costings and population options into its development decisions ?

Given the strong growth ethos in WA these are difficult issues for some even to contemplate. Issues of population size and composition will always be contentious. We need to be able to engage in rational debate about even the most controversial issues. The State Planning Strategy suggests population growth be monitored and an Interdepartmental Forecasting Committee investigate the relationships between economic growth, population and environment and formulate a policy position. Other mechanisms that involve the community should also be considered.

With the great strength of feeling associated with some of these issues, local, state and federal governments have a pivotal role to play in ensuring that the issues are examined in a balanced manner and that all Western Australians can have access to the best information available.

See Section 2 of the SoE *Reference Group Draft Working Papers* for more information on *Population and the Environment.*

Consumption and Waste Management

Conclusion

Western Australia, in common with most other developed societies, exhibits a pattern of increasing per capita consumption and an associated increase in the production of waste.

Increasing consumption is depleting essential and finite natural resources and impacting adversely on the environment.

Inappropriate creation and disposal of waste has the potential to pollute ground and surface waters, contaminate and quarantine land, add to the greenhouse effect, squander resources and energy, and reduce social amenity.

There is an urgent need to change our society's culture of consumption and replace it with one based on conservation and re-use of resources.

Objectives

- To reduce WA's per capita consumption of resources through programs which discourage unnecessary consumption and manage all waste in accordance with the waste management hierarchy (avoid, reduce, recycle, recover, treat and dispose in ascending order of alternative action).
- To halve the amount of waste per capita to landfill by the year 2000 based on the 1991 benchmark.
- To protect the environment, health and social amenity by appropriate waste management practices and promotion of waste avoidance and reduction strategies.

Suggested response

- Develop and implement a State waste management strategy and associated programs.
- Develop and implement a State waste reduction and recycling strategy and associated programs.
- Develop and implement a State cleaner production strategy and associated programs.
- Develop and implement a State resource conservation strategy and associated programs aimed at reducing consumption and reducing the environmental impacts of necessary consumption.

Background

Description

Historically, the majority of Government and community effort in the area of waste management has been aimed at ensuring safe disposal of waste. Programs are now in place which should ensure that by the year 2000 the majority of wastes created by society in WA are treated or disposed of in accordance with best practice and in a manner which should have minimal environmental impact.

Only recently have limited resources been devoted to avoiding the production of waste and recycling and re-using it where feasible. Negligible resources are put towards producing the cultural change necessary to change WA from a society reliant on high levels of consumption to one embracing conservation of resources.

Condition

As a result of increasing population and consumption, Western Australians are producing more solid, liquid and gaseous wastes than at any time in our history and there is no obvious sign that this trend is slowing. In addition, the nature of the wastes produced by society is increasing the environmental impact of waste disposal.

It is estimated that almost 3 million tonnes of solid waste is disposed of within landfills each year in WA. Many of these landfills are unlined and are polluting ground and surface waters in an uncontrolled fashion. To date, monitoring suggests that this pollution is confined to contaminants such as nitrogen which can be assimilated in the environment by natural processes. However, increasing quantities of hazardous materials are being directed to landfill and this will eventually cause adverse environmental impacts unless action is taken to divert waste away from land disposal.

The volume of liquid wastes produced for disposal in the sewer or other forms of treatment facility have also increased and this is increasing the contaminant loading entering the marine environment, groundwater systems and inland surface water systems. These contaminants contribute to environmental problems

such as eutrophication and also act to increase the burden of toxic materials such as mercury and cadmium. In addition, liquid waste disposal sites for those wastes which could not be disposed of to sewer have been a significant polluter of groundwater. Fourteen sites have been identified in Perth, many of which were located near current groundwater supply areas. Since the 1980s these sites have been closing with these wastes now being directed to the Forrestdale liquid waste treatment plant.

The gaseous wastes we produce in the production of power, manufacturing of products and for transport are also increasing and this is contributing to local impacts such as the impact of sulphur dioxide in Kalgoorlie, regional impacts such as photochemical smog in the Perth metropolitan region and global problems such as the enhanced greenhouse effect and stratospheric ozone depletion.

At this stage there is little evidence that we are approaching the limit of available natural resources in WA, mainly due to the relatively small population and large land area in the State. However, the environmental and economic costs of extracting these resources are now becoming significant issues.

There is an increasing awareness of the need to recycle and reduce waste, however there is also little evidence of any real desire in the community to reduce the level of consumption.

Pressure

Increasing population and the community's demand for a continuing high standard of living based on increasing levels of consumption will require the consumption of increasing quantities of natural resources and the production of more wastes. Information on consumption and waste behaviour in WA is only beginning to be collected. This lack of information is hindering the development of effective policies to manage the pressures on the environment resulting from increasing levels of consumption.

While we are beginning to collect information on consumption patterns, many of the factors that influence consumptive behaviour must be managed at a national and international level because of the nature of the economy.

Excessive consumption of resources and increasing production of wastes will eventually result in unacceptable environmental impacts.

Current Response

Successive governments have, and continue to implement a range of legislation, policies and studies which provide a framework for ensuring that solid, liquid and gaseous wastes are disposed of in manner which prevents unacceptable local impacts and which aim to minimise the contribution of waste emissions to regional and global environmental impacts. There are, however, very few examples of actions and resources directed at encouraging resource conservation, waste minimisation and cleaner production.

At the State government level, work is well advanced on the development of a State waste reduction and recycling policy and work has begun to develop a cleaner production policy.

Local governments have implemented kerbside recycling programs but the standard of these varies greatly and at this stage they divert less than 10–20 % of kerbside waste from landfill. Clear policies and leadership from Government and the community can assist local governments in delivering an effective kerbside recycling service.

A number of companies and local authorities are now starting to explore the use of alternative processes for treating waste such as composting and biodigestion in order to reduce the volume of organic wastes which is directed to landfill. In addition, individual companies have implemented cleaner production programs with great success but there is no co-ordinated program which is aimed at significantly reducing the production of waste.

Implications

Current consumption patterns are putting increased pressure on the environment. This is epitomised by depletion of natural resources and emission of waste to atmosphere, land and water. Society needs to examine consumption patterns in order to develop effective strategies to reduce pressure on the environment.

Consumption and Waste Management can be direct pressures on the environment, resulting in *Land Contamination* and *Contamination of Inland Waters*. See these sections within this report.

See Section 2 of the SoE *Reference Group Draft Working Papers* for more information on *Consumption and Waste Management*.

ATMOSPHERE

Enhanced Greenhouse Effect

Environmental Status: ❖ ❖ ❖ ❖

Conclusion

In December 1995 the United Nations Intergovernmental Panel on Climate Change concluded that greenhouse gas concentrations in the atmosphere have continued to increase and that the balance of evidence suggests 'a discernable human influence on global climate' (Houghton *et al.*, 1996).

While aspects of this conclusion are still uncertain and debated, the control of greenhouse gas emissions has become an international issue with environmental, social and economic implications. In this regard Australia and WA need to contribute to managing domestic and industrial greenhouse gas emissions.

Many activities emit greenhouse gases, e.g., residential and commercial users of energy, transport, mining and agriculture. The rate of production of greenhouse gas emissions in WA will increase. Therefore all sectors must work towards reducing these emissions.

Objective

To reduce net greenhouse gas emissions in accordance with Australia's obligations under the Framework Convention on Climate Change.

Suggested response

- The Western Australian Government should develop a Greenhouse Strategy which builds on earlier strategies and includes a range of initiatives to reduce greenhouse gas emissions. Performance in greenhouse gas limitations needs to be monitored and audited. The Government should establish a process to achieve this.

Background

Description

The greenhouse effect is a naturally occurring phenomenon which regulates the surface temperature of the earth, allowing life to exist.

Greenhouse gases occur naturally in the atmosphere and include carbon dioxide, water vapour, methane, nitrous oxide and ozone. These gases retain heat absorbed from solar radiation, and from radiation scattered back into the atmosphere from the Earth's surface and from clouds. This warms the Earth's surface and lower atmosphere. However, greenhouse gas concentrations in the atmosphere have been increasing since the industrial revolution as a result of human activity.

This increase has resulted in the 'enhanced greenhouse effect.' There is now discernable scientific evidence suggesting that the 'enhanced greenhouse effect' may cause global climate to change.

Condition

Globally, since the late 1700s, greenhouse gases in the atmosphere have continued to increase with carbon dioxide rising by about 30 %, methane by 145 % and nitrous oxide by 15 %.

Climate change as a result of the 'enhanced greenhouse effect' is difficult to measure because of natural climatic variability. However, global mean surface air temperature has increased and global sea levels have risen by between 10 and 25 cm over the past 100 years. Much of this sea rise may be related to the increase in the global mean temperature.

Some estimates have been made about the possible impacts of the enhanced greenhouse effect on WA's climate (Hennessy & Whetton, 1994) and the environment more generally (Bouma *et al.*, 1996). The 'enhanced greenhouse effect' may result in:

- an increase in fire frequency in many parts of the State;
- temperature rise and changes in rainfall and concentrations of carbon dioxide which could favour some plants at the expense of others, affecting agricultural production and affecting species distribution;
- changes in habitat distribution which could threaten native animal and plant species, particularly those that are geographically isolated or adapted to very specific climatic regimes; and
- coastal areas being vulnerable to changes in the intensity and frequency of storms as well as rises in sea level.

For example, early estimates are available for changes in temperature by the year 2030 as a result of the 'enhanced greenhouse effect'. Using the highest estimates of possible temperature change and greenhouse gas emissions, the frequency of summer days over 35°C is estimated to increase by at least 50 % at Albany, Broome, Busselton, Kalamunda, Kuri Bay and Manjimup. Similarly the frequency of summer days over 40°C is estimated to increase by at least 50 % at Broome, Derby, Donnybrook, Esperance, Geraldton, Kalamunda, Kalgoorlie, Perth, Port Hedland, Wiluna and Wyndham (Hennessy &Whetton, 1994).

Pressure

Australia with 0.3 % of the world's population contributes 1.5 % of global greenhouse gases, of which WA currently contributes about 10 %. The methodology to report on greenhouse gas emissions has changed since the 1992 *SoE Report*. The National Greenhouse Gas Inventory (NGGI) has provided estimates of WA's greenhouse gas emissions for 1988 and 1990. During this period WA's greenhouse gas emissions increased by 12 %. No more recent estimates are available using this methodology.

The NGGI uses five broad categories to report on greenhouse gas emissions based on the categories defined by the United Nations Intergovernmental Panel on Climate Change (Houghton *et al.*, 1996). These represent the main human activities that contribute to the release or capture of greenhouse gases into or from the atmosphere (see Table 1) and are as follows.

- *All energy* includes activities which cover the full fuel cycle, including mining, transmission, storage, distribution and conversion of fuels. It also includes the use of energy for transport. This category was the largest source of greenhouse gases in WA in 1990, contributing about 50 % of the total emissions.
- *Industrial processes* includes by-products of various production processes not including the combustion of greenhouse gases produced by industrial processes. This category contributed least to WA's emissions, contributing only 1.3 % of the total emissions.
- *Agriculture* includes emissions from livestock (such as methane), nitrous oxide from soils, burning of agricultural residue and some cropping activities. Emissions from agriculture were significant at 20.4 % of the total emissions.
- *Land use change and forestry* includes emissions as a result of land clearing which causes carbon stored in the soil to be released as carbon dioxide. In Australia, forestry is a net sink of carbon dioxide because the carbon dioxide used as a result of forest growth exceeds the carbon dioxide emitted as a result of timber harvesting. It should be noted that there is a large degree of uncertainty associated with estimating emissions in this sector. In 1990 this sector was estimated to contribute 22.1 % of WA's total emissions.
- *Waste* includes methane and other gases generated from waste management activities such as emissions that result from the decomposition of material in landfill sites and as a result of wastewater treatment. In 1990 this category produced 5.3 % of WA's greenhouse gas emissions.

Most of these sectors will continue to emit greenhouse gases. The rate of greenhouse gas emissions from mineral processing is set to increase rapidly over the next few years as several major projects begin in the north west of WA. Figure 4 shows projected carbon dioxide emissions as a result of energy use in WA.

Table 1 *Contributions to gross greenhouse gas emissions by sector for Western Australia in 1990 (National Greenhouse Gas Inventory Committee, 1996).*

Sector	Emissions in carbon dioxide equivalents	Percentage of Total Emissions
All energy	30,900	50.9
Industrial processes	776	1.3
Agriculture	12,386	20.4
Land use change and forestry	13,447	22.1
Waste	3203	5.3
Total	**60,712**	**100**

Current response

In 1994 the Greenhouse Co-ordination Council developed a *Revised Greenhouse Strategy for WA*, which built on earlier work in this area.

A range of Government and private programs exist to establish woody vegetation and protect remnant vegetation. Vegetation absorbs carbon dioxide and indirectly contributes to reducing greenhouse gases in the atmosphere.

The Environmental Protection Authority (EPA) can require proponents to consider greenhouse gas emissions from new proposals as part of the environmental impact assessment process.

Research on the implications of the greenhouse effect on WA's environment and industries is occurring.

A range of initiatives have been developed to increase energy efficiency and to further promote and develop renewable energy initiatives (notably energy efficient residential development has been promoted by both State and local government).

Co-operative programs are in place between industry and the Commonwealth Government under the Greenhouse Challenge Program to reduce greenhouse gas emissions. Several leading WA companies are involved.

Implications

The exact implications of possible climate change arising from the 'enhanced greenhouse effect' are unclear. However, climate change could impact on human health and the natural environment, as well as natural resource-based industries. The increased severity of natural events such as cyclones, bushfires and floods may also have significant implications.

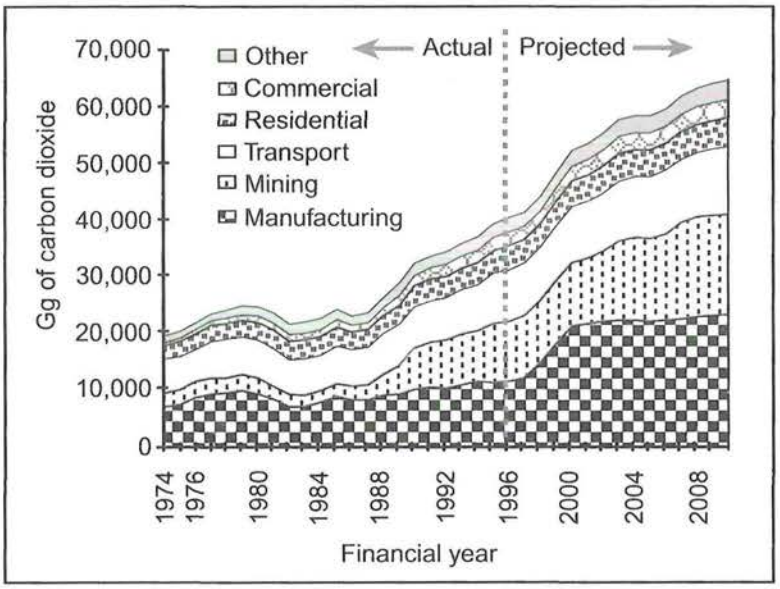


Figure 4 *Carbon dioxide emissions from end-users of energy in Western Australia, 1974–2010 (Source: Office of Energy).*

See Section 4 of the SoE *Reference Group Draft Working Papers* for more information on the *Enhanced Greenhouse Effect*.

Stratospheric Ozone Depletion

Environmental Status: ❖ ❖ ❖ ❖

Conclusion

Like the greenhouse effect, the depletion of the stratospheric ozone layer is an international environmental issue.

While ozone-depletion occurs mainly over Antarctica it also occurs to a lesser extent over most parts of the world. The ozone hole allows more ultraviolet radiation to reach the earth which can affect human health and the environment. Australia as a nation, and each State, must work together to manage this issue.

Objective

To phase out the use and emission of ozone-depleting substances in WA.

Suggested response

- Continue to implement Australian and New Zealand Environment and Conservation Council National Strategy for protection of ozone through WA's existing *Environmental Protection (Ozone Protection) Policy 1993*.

Background

Description

Ozone occurs naturally in the atmosphere and forms the stratospheric ozone layer about 15–30 km above the earth. Ozone absorbs ultraviolet radiation from the sun, shielding the earth from extreme ultraviolet radiation.

The natural balance of stratospheric ozone has been disturbed by the production and emission of ozone-depleting substances. These ozone-depleting substances include: chlorofluorocarbons (CFCs); halons; methyl chloroform; carbon tetrachloride; hydrochlorofluorocarbons (HCFCs); and methyl bromide. These substances have been used as refrigerants, foam blowing agents, industrial cleaning solvents, fire retarding chemicals and pest fumigants.

Condition

Due to the global nature of ozone-depletion, the condition of the ozone layer will be discussed for Australia as a whole.

Each spring over the Antarctic the ozone layer is severely reduced, when the total ozone declines by about 60 %. This is referred to as the 'ozone hole'. The ozone hole is replenished at the end of spring when ozone-rich air from the tropics and subtropics moves southward with the ozone-depleted air bringing ozone levels over Antarctica almost back to normal.

Since 1981, the global ozone layer has decreased by 6 %. In Antarctica, this has been much higher, with an estimated loss of 1 % per year since the mid-1960s (Fraser, 1996). ozone-depletion now affects the most populated parts of Australia all year.

The concentration of ozone in a column of air above the earth's surface is measured in Dobson Units (DU).

In 1995–96 average ozone levels recorded at Halley Bay in Antarctica were the lowest on record (average of 210 DU) compared with ozone levels from 1957–72 (average of 310 DU). The minimum level of stratospheric ozone for 1995–96 was 105 DU, recorded in early October, compared with the lowest ever recording of 98 DU in mid-October 1993.

The aerial extent of ozone-depleted air measured in 1993–95 averaged about 20–21 million km^2 whereas the aerial extent for 1987 and 1989–92 averaged 18–19 million km^2.

Decreased stratospheric ozone allows more ultraviolet radiation (particularly ultraviolet-B) to reach the surface of the earth. A 1 % decrease in stratospheric ozone has been calculated as equivalent to a 1–2 % increase in ultraviolet radiation at ground level (State of the Environment Advisory Council, 1996). No country has carried out reliable long-term ultraviolet radiation monitoring, but Australia has recently started taking regular measurements.

Exposure to this radiation can affect human health and increase the incidence of sunburn, skin cancers and cataracts and damage the immune system (McMichael *et al.*, 1996). It can also reduce the yield of crops and disrupt marine food chains.

Pressure

While a total ban on the import of ozone-depleting substances into Australia was enacted from 1 January 1996, some of these substances are still being used. The amount of these chemicals being released in WA is unknown. Because of a total ban on imports, the amount available for use is progressively decreasing (State of the Environment Advisory Council, 1996).

Available information on individual ozone-depleting substances for Australia as a whole is summarised below.

Methyl bromide

Methyl bromide is used primarily as a fumigant in agriculture. Since it has been used the average global concentration of methyl bromide has increased from 6–7 ppt to 10 ppt.

Hydrochloroflurocarbons

Although HCFCs have a much lower ozone-depleting potential, they are in greater use because they are a transitional substance, used in place of CFCs.

The atmospheric abundance of HCFC–141b, –142b, –22 are growing rapidly. HCFC–22 levels are growing steadily at 5 % per year though it appears the rate of growth has started to slow down.

Chloroflurocarbons and Halons

At the beginning of the decade, concentrations of CFCs were rising at between 4 % and 10 % per year, depending on the type of CFCs.

Chlorine levels from CFCs, methyl chloroform and carbon tetrachloride started to fall in 1992, and although there are growing levels of HCFCs, total chlorine levels have also started to fall. In addition, the growth rates of bromine from halons have started to slow down.

The 'levelling off' of the rising concentration curve is attributed to global action to decrease the emission of ozone-depleting substances.

Current response

Australia, together with some 130 other nations has signed the Montreal Protocol; an international agreement to control the emission of ozone-depleting substances.

Australia has phased out most ozone-depleting substances using legislation at both Commonwealth and State level as part of its commitments under the Montreal Protocol. This has been co-ordinated through the *Australian Strategy for Ozone Protection*. While the Commonwealth controls the manufacture, import and export of ozone-depleting substances, State and Territory governments control the sale and use of these chemicals.

Since 1992 the use of CFCs in WA has been controlled by the *Environmental Protection (Ozone Protection) Policy 1993*. All of the substances regulated by this policy have been banned for new uses. However some ongoing use is still allowed, e.g., halons in fixed flood systems for fire control such as those used in computer rooms. The *Environmental Protection Policy* (EPP) is the only such instrument in Australia which includes provisions for controlling HCFCs. This approach has put WA at the forefront of controlling ozone-depleting substances as it was developed in consultation with industry, and has resulted in a minimal use of ozone-depleting substances including HCFCs.

Appropriate representative bodies, which have been granted 'issuing body' status under the EPP ensure the requirements of the legislation are followed by managing the phasing out of ozone-depleting substances within their industries. The DEP continues to check on compliance with the conditions stipulated in the policy.

Training opportunities in reducing the use of ozone-depleting substances in various industries is provided by technical and further education, private companies and industry associations.

Implications

It will take several decades to restore the natural balance between ozone production and destruction because of the time taken for ozone-depleting substances to break down. During this time, a large part of the world will probably be subject to increased ultraviolet radiation.

Australia already has one of the highest incidence of skin cancer in the world. It is estimated that more than two-thirds of Australians will develop some form of skin cancer (Environmental Protection Agency, 1996).

See Section 4 of the SoE *Reference Group Draft Working Papers* for more information on *Stratospheric Ozone Depletion*.

Photochemical Smog

Environmental Status: ❖ ❖ ❖

Conclusion

Photochemical smog can damage human health and the environment. If Perth's smog levels increase by modest amounts, the present objective will be exceeded more often.

The growth of emissions of smog precursors from vehicles and industry will need to be reduced to avoid increasing health effects.

Objective

That ambient ozone levels be below the National Health and Medical Research Council (NHMRC) goal of 100 ppb (1-hour average). In the longer term, ambient ozone levels should be kept below the World Health Organisation (WHO) goal of 80 ppb (1-hour average).

Suggested Response

Responses to reduce photochemical smog should focus on reducing the reliance on motor vehicles for personal travel and improving technology to reduce vehicular and industrial emissions of smog precursors:

- ensuring new vehicles have minimum emission levels, and that these are maintained over the life of the vehicle;
- reporting, inspection and repair of defective motor vehicles or defective vehicles taken out of service;
- better management of car parking in the City of Perth to improve air quality;
- promoting higher car occupancy;
- promoting travel alternatives, including public transport, cycling and walking;
- ensuring industrial emissions are as low as possible, given ongoing technological improvements;
- ensuring urban development patterns and densities promote short trips and public transport, walking and cycling.

Background

Description

Photochemical smog is one of the most significant pollution problems in many cities. It is characterised by high levels of ozone. Ozone in the lower atmosphere is not natural and is formed when nitrogen oxides and reactive organic compounds (ROC) from motor vehicles and other sources react together for a few hours under the influence of strong sunlight and high temperatures. Smog formation is limited to the period from late spring to early autumn.

Ozone at high concentrations can reduce lung function, make asthma worse and cause tissue damage deep in the lungs.

Condition

Perth's air quality is of a very high standard compared with many other cities, however the Perth region regularly experiences photochemical smog during, and around, summer. Over the three-year period from July 1992 to June 1995, there were, on average, 10 days per year on which the ozone concentration exceeded the WHO goal somewhere in the Perth region. Similarly, the NHMRC goal is exceeded on about two days per year somewhere in the Perth region (see Table 2). Since the 1992 *SoE Report* the *Perth Photochemical Smog Study*

Table 2 *Exceedances of Ozone Goals in the Perth Region (Source: Department of Environmental Protection).*

Year	No. of Days		
	> 80 ppb (1-hour average)	>100 ppb (1-hour average)	No. of Sites
1992–93	9	3	8
1993–94	9	2	8
1994–95	12	1	9
1995–96	17	3	6

(Department of Environmental Protection & Western Power, 1996) has provided much information on the cause, sources and nature of smog in Perth. However, it is still difficult to determine whether there is a distinct trend in relation to ozone levels.

High ozone events occur within, and beyond, the metropolitan area. Nevertheless, Perth's air on most summer days is relatively clean due to the windy climate and isolation from other cities.

Pressure

The main sources of emissions which lead to the formation of photochemical smog include motor vehicles, industrial emissions, area sources, e.g., service station vapour losses, paints and thinners, and biogenic emissions (vegetation emits reactive organic compounds). Motor vehicles contribute 51 % of the total nitrogen oxides emitted and over 40 % of ROC. Industry contributes 44 % of nitrogen oxides and 19 % of ROC. Area sources contribute 5 % and 37 % of nitrogen oxides and ROC respectively.

Current responses

The *Perth Photochemical Smog Study* has recently been released.

Public transport systems have been improved and there is greater encouragement of public transport, cycling, walking and car-pools.

Australian Design Rule 37/01 further limiting emissions from new vehicles has been implemented. Industry licensing systems have been overhauled and regulations to control ROC from service stations are in place.

The State Government has given a commitment to the development and implementation of an Air Quality Management Plan for Perth. This process will be initiated through a Parliamentary Select Committee.

Implications

The current health effects of photochemical smog in Perth are limited. However, in the absence of control strategies, increasing motor vehicle usage and industrial discharges are likely to result in more frequent exceedances of air quality objectives.

See Section 4 of the SoE *Reference Group Draft Working Papers* for more information on *Photochemical Smog*.

Haze from Particulates

Environmental Status: ❖ ❖ ❖

Conclusion

Haze levels in the Perth region are likely to increase. Arguably, fine particulates pose the greatest air pollution-related health risk to the Perth community.

Objective

That haze levels do not cause local visual distance (LVD) to fall below 20 km (1-hour average) and do not exceed the DEP's interim objectives for particulate matter concentration.

Suggested Response

- Appropriate legal standards for particulate haze should be determined.

Background

Description

Haze refers to the presence of very small airborne particulates in concentrations large enough to impede vision, making the air appear brownish in colour. Visibility reduction can be measured directly using nephelometers and converting the recorded backscatter of light to measure LVD.

With respect to health effects, airborne particle concentrations are measured in two size ranges: PM10 for particulates less than 10 μ in diameter (referred to as inhalable particulates); and PM2.5, less than 2.5 μ in diameter (referred to as fine particulates). There is debate about the appropriate air quality standard for both fractions of particulates.

A concern associated with haze is an apparent association between airborne particulates and premature mortality, especially among elderly people with a pre-existing chronic respiratory illness. Overseas studies have found links between airborne particulates and reduced life expectancy across urban populations.

Studies have also established associations between airborne particle concentrations and higher than normal levels of hospital admissions, respiratory illness and asthma attacks (Gras, 1996).

Condition

The Perth Haze Study has provided information on the cause and sources of haze in Perth. However, it is not possible to determine any distinct trends in particulate levels.

Haze levels are highest in winter due to the increased emissions from wood heaters and periods of overnight to morning inversions accompanied by light winds, which restrict dispersion. The goal for LVD is regularly exceeded in the Perth region from autumn through to spring (see Table 3).

High haze events are sometimes associated with incursions of smoke from open burning activities outside the Perth metropolitan area, which add to wood smoke which has accumulated over-night.

Pressure

The main sources of winter haze in Perth are: smoke from domestic wood heaters; particulates emitted from motor vehicles (mostly those run on diesel); particulates formed from combinations of other pollutants; and naturally occurring airborne particulates such as dust and sea salt.

The demand for and use of wood heaters is likely to continue. Open burning during autumn and spring is a common activity to reduce risks of wildfires, regenerate forests and plant communities, and for disposal of vegetation. Agricultural burning of stubble and for weed control is likely to continue. The use of diesel vehicles is likely to increase and particulate emissions will correspondingly increase without measures to reduce them.

Current responses

Educational campaigns to encourage householders to operate wood heaters to minimise emissions of smoke and other toxic gases have been implemented.

Changes to legislation and regulations to address wood heater design standards, appropriate use, new installations, air quality objectives and enforcement are being developed. The DEP has issued guidelines which recommend techniques to minimise air pollution from the burning of vegetation cleared for land development.

Predictive computer modelling is used to reduce the smoke impacts from hazard reduction burning upon

populated areas.

The State Government is committed to the development and implementation of an Air Quality Management Plan for Perth. This will be initiated through a Parliamentary Select Committee.

There has been considerable work on setting standards for haze internationally.

Implications

In the absence of effective control strategies, excessive haze levels will become more frequent. The Perth Haze Study estimates from measurements of PM10 and PM2.5, that airborne particulates are responsible for premature deaths in high risk groups, higher than normal levels of hospital admissions, and increased respiratory illnesses including asthma attacks.

Table 3 *Exceedances of haze goals in the Perth region (Source: Department of Environmental Protection).*

Year	No. of Days			
	LVD < 20 km (per hour)	No. of sites	PM10 > 50 µg/m^3 (per 24 hour)	No. of sites
1993–94	63	4	3	3
1994–95	80	5	5	5
1995–96	76	6	2	4

Particulate haze over Perth. Photograph by Dr John Rogers.

See Section 4 of the SoE *Reference Group Draft Working Papers* for more information on *Haze from Particulates*.

Sulphur Dioxide

Environmental Status: ❖ ❖

Conclusion

Sulphur dioxide impacts are highest in the airsheds around Kalgoorlie, Kwinana and Collie. The Kwinana region is under considerable pressure. Excessive levels at Kalgoorlie are expected to fall in the near future.

Objective

That sulphur dioxide (SO_2) levels be below agreed standards:

- for Kalgoorlie, SO_2 not to exceed more than 1400 $\mu g/m^3$ (1-hour average) and 700 $\mu g/m^3$ more than 8 times per year;
- for Kwinana residential areas, SO_2 not to exceed 350 $\mu g/m^3$ (1-hour average) more than 8 times/year and never exceed 700 $\mu g/m^3$ (1-hour average); and
- elsewhere SO_2 not to exceed 570 $\mu g/m^3$ (1-hour).

In the long-term SO_2 levels should be kept below the NHMRC goal of 570 $\mu g/m^3$ (1-hour average) at all residences.

Suggested Response

- Due to the high level of SO_2 emitted around Kalgoorlie, public education about sulphur dioxide emissions and environmental and health effects is needed in this region.
- Industries in the Kalgoorlie area should be in full compliance with the EPP criteria.
- The current program of abatement should be sustained along with the monitoring network.
- There is concern over the Kalgoorlie EPP standard of 700 $\mu g/m^3$ being greater than the NHMRC goal. Therefore the Kalgoorlie EPP should be reviewed sooner than its scheduled review in 2000.
- The proposed National Environmental Protection Measure and complementary State Air EPP should provide for regional differences and national standards for air quality in WA.
- The possible acidification of soils in the Kalgoorlie region should be investigated and quantified.

Background

Description

Sulphur dioxide is a significant air pollutant in WA, particularly around industrial centres such as Kalgoorlie, Kwinana and Collie. It is a strong respiratory irritant, a trigger for asthma and can damage vegetation.

Sulphur dioxide is produced by burning substances with a high sulphur content such as coal, through the removal of sulphur from ores or industrial feed-stocks, or from the production of sulphuric acid.

Sulphur dioxide in the air oxidises to sulphur trioxide which, when dissolved in water droplets, forms sulphuric acid. This process is accelerated in the presence of particulates. The sulphate ion may appear as a particulate. The phenomenon of acid deposition (or acid rain) caused by acidic reaction products of SO_2 and other pollutants common in parts of Europe and America, has not been examined in WA.

Condition

Since 1992 the SO_2 levels around Kalgoorlie have declined although they have still occasionally exceeded the criteria established in the relevant EPP (see Figure 5). Kwinana levels have stabilised (see Table 4) though the Kwinana area is under significant industrial and residential development pressure. Collie is under significant pressure from industrial development.

Pressure

Sulphur dioxide levels around Kalgoorlie are likely to fall significantly following the recent installation of scrubbing equipment at the largest industrial source.

Sulphur dioxide levels around Kwinana are under considerable pressure due to the expansion of existing industries, the availability of land for more industry and the construction of new homes in the buffer zone.

Collie's SO_2 impacts are under less pressure relative to the other areas, though this is increasing with the construction of a new coal-fired power station.

Current responses

Computer models used for predicting SO_2 dispersion at Kwinana have recently been upgraded to reflect state-of-the-art scientific knowledge.

A redetermination of the Kwinana EPP is being planned for 1997 which will include the use of statistical discharge limits.

Licensing procedures have recently been changed to incorporate discharge-based licence fees and inducements for best practice to provide greater encouragement for industries to reduce SO_2 discharges.

The company that has the largest emission of SO_2 in Kalgoorlie has installed equipment to convert SO_2 to sulphuric acid to reduce its gaseous discharge.

Implications

It is likely that the high SO_2 levels around Kalgoorlie has had periodic health impacts on the local population. With decreasing levels, it is likely that only sensitive members of the population will continue to be affected.

The increasing use of the remaining air space for SO_2 dispersion at Kwinana, while meeting the existing EPP requirements (or possibly the more stringent NHMRC goal) is going to require more intensive regulatory management.

Table 4 *Exceedances of sulphur dioxide standards in the Kalgoorlie and Kwinana regions (Source: Department of Environmental Protection).*

Year	No. of Days			
	Kalgoorlie (700 µg/m^3)	No. of Sites	Kwinana (350 µg/m^3)	No. of Sites
1993–94	84	10	0	4
1994–95	89	10	1	4
1995–96	91	10	0	4

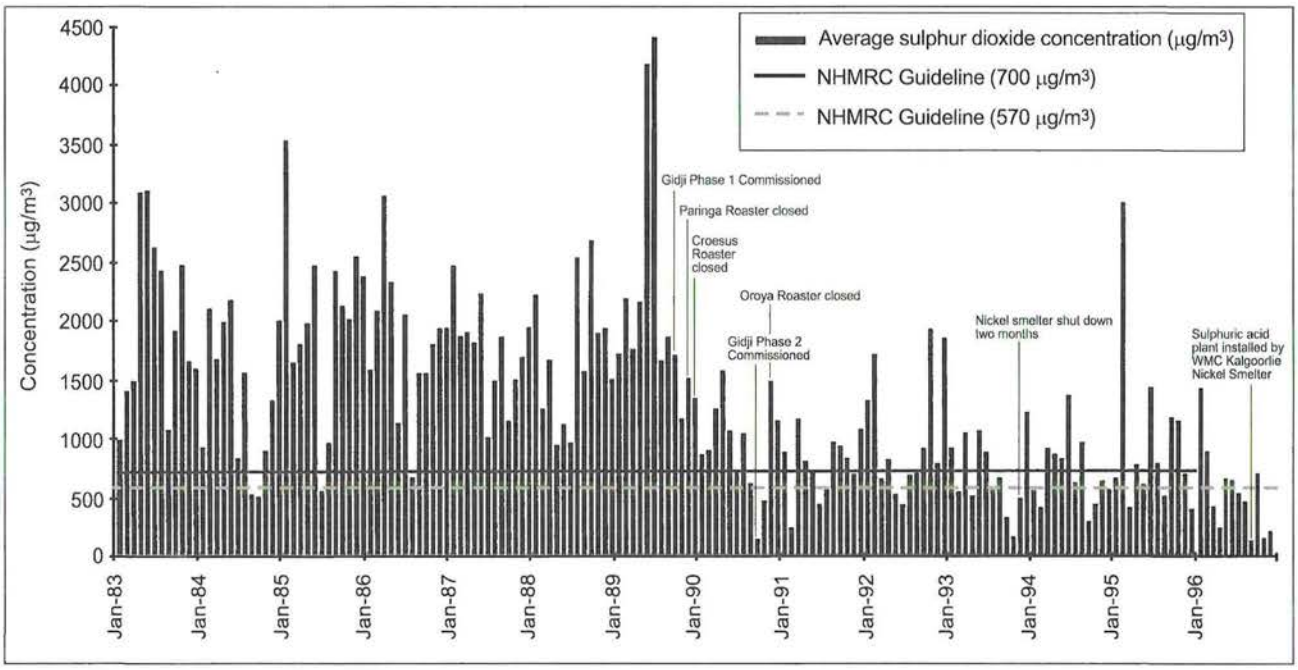


Figure 5 *Maximum average hourly sulphur dioxide levels at Kalgoorlie Hospital with significant events resulting in changes to the ambient sulphur dioxide concentration (Source: Department of Environmental Protection).*

See Section 4 of the SoE *Reference Group Draft Working Papers* for more information on *Sulphur Dioxide*.

Carbon Monoxide

Environmental Status: ❖ ❖

Conclusion

Carbon monoxide is an urban pollutant caused mostly by vehicle emissions. Currently it is not known whether carbon monoxide levels in Perth will increase as vehicle traffic increases. Increasingly stringent vehicle emission design standards in new vehicles may offset expected increases in vehicle numbers.

Objective

That ambient carbon monoxide levels be below the NHMRC goal of 9 ppm (8-hour average) and the WHO goal of 25 ppm (1-hour average).

Suggested Response

Responses to reduce carbon monoxide should focus on reducing the reliance on motor vehicles for personal travel and improving technology to reduce vehicle emissions and wood heater and combustion stove emissions and include:

- promoting higher car occupancy;
- promoting travel alternatives, including public transport, cycling and walking;
- ensuring new vehicles have minimum emission levels, and these are maintained over the life of the vehicle;
- ensuring urban development patterns and densities promote short trips and public transport, walking and cycling; and
- ensuring emissions from wood heaters and combustion stoves are as low as possible given ongoing technological improvements.

Background

Description

Carbon monoxide is a common urban air pollutant. It is a toxic, odourless gas which can enter the bloodstream of living things, reducing the oxygen carrying capacity of blood.

Carbon monoxide is a product of incomplete combustion. Motor vehicles account for about 75 % of carbon monoxide in Perth's air. The highest levels are recorded near areas of dense vehicle traffic.

Wood fires and combustion stoves in suburban areas can also contribute to high winter-time concentrations of carbon monoxide.

Condition

Since the 1992 *SoE Report*, the NHMRC goal of 9 ppm and the WHO goal of 25 ppm (1-hour average) has not been exceeded (see Table 5). There is insufficient evidence to conclude that carbon monoxide levels are falling. Perhaps because of increased use of motor vehicles, the highest recorded levels have remained close to the objective.

Pressure

Increasing vehicle traffic is likely to add to carbon monoxide emissions potential. However, the rise in emissions might be offset to some extent by the increasingly stringent motor vehicle emissions design standards and vehicle fleet turn-over, which together should reduce emissions. Carbon monoxide emissions from the use of wood heaters may increase.

Current responses

Public transport systems have been improved and there is greater encouragement of public transport, cycling, walking and car-pools.

Australian Design Rule 37/01 (which came into effect from 1 January 1997) will lower the new vehicle carbon monoxide emissions standard to 2.1 g/km from its present level of 9.3 g/km.

Implications

The implications of increasing vehicle traffic and the impact of the new motor vehicle emission standards are not known.

Table 5 *Highest Carbon Monoxide Concentrations in the Perth Region (Source: Department of Environmental Protection).*

Year	Highest Recorded Level		
	1-hour average Conc. (ppm)	8-hour average Conc. (ppm)	No. of Sites
1992–93	13.8	8.2	3
1993–94	12.8	8.9	3
1994–95	9.4	7.6	3
1995–96	10.6	8.7	3

See Section 4 of the *SoE Reference Group Draft Working Papers* for more information on *Carbon Monoxide*.

Lead

Environmental status: ❖

Conclusion

Lead pollution from motor vehicles is no longer considered a significant issue.

Objective

That ambient lead levels are below the NHMRC goal of 1.5 $\mu g/m^3$ (3-month average).

Suggested Response

- Monitoring of ambient atmospheric lead levels should continue.

Background

Description

Exposure to excessive amounts of airborne lead can affect the intellectual development of young children.

The major source of lead in Perth's air is motor vehicle emissions. This is because lead has been added to petrol since the 1920s to increase the efficiency of combustion.

Since 1986 all new petrol-engine vehicles sold in Australia have been required to run on unleaded fuel. Educational campaigns have also encouraged the use of unleaded fuel in pre-1986 vehicles where possible. In addition to this, regulations have progressively reduced the lead level in leaded fuel from 0.4 g/l in 1993 to 0.2 g/l from 1996.

Table 6 *Highest recorded lead concentration (3-month average) in the Perth region (1991–96) (Source: Department of Environmental Protection).*

Year	Highest Recorded Level	
	3-month average Conc. ($\mu g/m^3$)	No. of Sites
1991–92	1.22	1
1992–93	1.14	1
1993–94	0.83	1
1994–95	0.59	1
1995–96	0.37	1

Condition

Since 1992 atmospheric lead levels have continued to fall in response to reductions in the content of lead in petrol. This is one example of where the quality of the environment has actually improved since 1992. It is likely that this trend will continue although at a lesser rate. Lead levels are within the NHMRC goal (see Table 6).

Pressure

Since the late 1980s, airborne lead levels have declined and are now levelling off.

Current responses

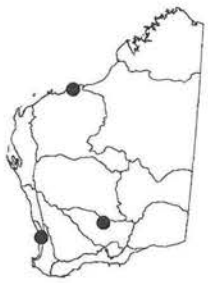
Regulations continue to require that new vehicles use unleaded fuel and limit the maximum lead content in petrol.

Implications

The concentration of atmospheric lead is not expected to return to levels that would cause health effects.

Cars on the Kwinana Freeway: the use of unleaded petrol has reduced the level of atmospheric lead in Perth's air. Photograph by Department of Environmental Protection.

See Section 4 of the SoE *Reference Group Draft Working Papers* for more information on *Lead*.



Dust

Environmental Status: ❖

Conclusion

Atmospheric dust resulting from industrial activity, urban land clearing and development can have severe effects on amenity and can cause short-term nuisance events and local ecological impacts. Health impacts from atmospheric dust have not been detected.

Management programs can be used as part of best management practice to control dust within Department of Environmental Protection (DEP) guidelines. Currently there are no uniform standards across the State, however regional standards are established for key localities.

Objective

To protect the health and amenity of the public and local environments by:

- reducing dust levels below DEP guidelines or standards, where appropriate; and
- ensuring that best management practices are achieved in existing and future development.

Suggested Response

- Future development should consider dust management as an integral component of environmental management strategies.

Background

Description

For the purposes of this report, dust includes all airborne particles that are greater than 10 μ in diameter (PM10). Dust can be carried in wind gusts, and is either directly eroded from exposed surfaces or emitted during industrial activities, ship loading and unloading, excavation, or soil disturbance from land development sites. The issue of wind erosion on agricultural land is considered in *Erosion*.

Condition

A significant level of community nuisance is being caused by industrial emissions of dust and dust from land clearing and development. Although dust occurs naturally in all country areas, dust is of greatest concern in Perth, Port Hedland, Kalgoorlie–Boulder and Kwinana. In Perth some land development has occurred with little concern for dust emissions. At ports such as Port Hedland, the loading of iron ore has caused dust problems in the past for local residents and the local environment. In mining areas such as Kalgoorlie–Boulder, stockpiling, excavation and blasting operations can cause short-term dust emissions.

Environmental impacts are likely to have been greatest in Port Hedland due to past management practices, planning decisions and the microclimate of the area. Currently, dust causes minimal ecological damage, and impacts of dust emissions on human health have not been detected.

Mangroves may be affected by dust accumulation on leaves, causing dieback of vegetation. Iron ore dust can damage and cause mortality of mangrove vegetation (Semeniuk, 1994). There is, however, limited information to confirm the extent of damage caused by dust emissions.

Dust from industrial sources often contains heavy metals that may accumulate and cause contamination of inland waters. There is no evidence that dust has led to contamination of inland waters at a level that exceeds EPA guidelines for the protection of aquatic ecosystems.

Pressure

The main sources of dust emissions are stockpiles of iron ore and mining wastes, handling and shipping of ore at major ports, excavation for earthworks and development, land clearing for urban development, handling of large volumes of other products such as wheat in agricultural areas and ports.

In 1995, 1.2 million tonnes of iron ore was loaded at Esperance Port, leading to minor dust problems in the local area. This facility now complies with most environmental requirements and does not cause significant dust pollution. It is an example of best management practice for dust management. In 1995, 58 million tonnes of iron ore were exported from Port Hedland, where dust problems have been much more severe. The Environmental Protection Authority has recently assessed a plan for dust management at Port Hedland.

Poor dust management can lead to dust pollution in urban areas. The main pressure causing dust to be a nuisance issue is a lack of consideration about the need to manage this issue.

Current response

Land developers and industry are required, and in some cases, taking the lead, in implementing best management practices for dust suppression and management. For example, at Port Hedland significant improvements have been made to ore handling equipment and site management. In the short-term, water is used to control dust, in the long-term, dust is controlled by progressive rehabilitation and rock armouring.

The DEP has set guidelines for developers to ensure that dust pollution does not occur during clearing and earthworks for urban development

The EPP for Kwinana provides the framework for managing dust emissions within the Kwinana airshed. This policy has controlled dust within set criteria.

Before mining approval is given industry is required to provide details on management of dust covering both occupational health and environmental aspects for all phases of mining operations.

Implications

There is little information on the health effects of ambient dust exposure. However, in Port Hedland, where iron ore dust exposure has been the most significant, no health impacts have been detected (Environmental Protection Authority, 1996). Dust can cause significant community nuisance and reduces the quality of life in urban areas. Minor losses of biodiversity may have resulted from iron ore dust. No causal link for this has yet been demonstrated.

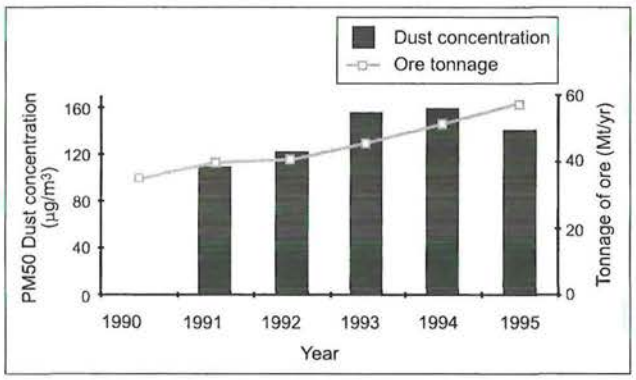


Figure 6 *Tonnage of ore handled through Port Hedland versus annual average townsite dust concentration (Environmental Protection Authority, 1996).*

See Section 4 of the SoE *Reference Group Draft Working Papers* for more information on Dust.

LAND

Land Salinisation

Environmental status: ❖ ❖ ❖ ❖ ❖

Conclusion

Land salinisation is one of WA's most significant environmental issues. It has severely damaged the natural environment, and has reduced agricultural productivity.

It occurs over a significant part of the agricultural area and also in irrigated areas. The amount of land affected by salinity will continue to increase until a new hydrological balance is reached. Without action the area affected is likely to almost double to 17 % of the total farm area, in 15–25 years and eventually double again as groundwater levels continue to rise.

Land salinisation offers a direct challenge to traditional farming systems. These need to be fundamentally altered in order to redress the hydrological imbalance.

Government has a role in encouraging this change, and in investing funds to protect areas of high conservation value and water supply. The majority of investment in revegetation and other activities will need to come from the private sector. Unprecedented effort from all sectors is required to manage land salinisation.

Objective

The *WA Salinity Action Plan* (Government of Western Australia,. 1996) has set multiple objectives for the management of salinity. Those which relate specifically to the salinisation of land include:

- to reduce further deterioration of agricultural land and where possible recover or rehabilitate existing salt-affected land; and
- protect and maintain natural (biological and physical) diversity within the agricultural areas of WA.

Suggested Response

- Re-establish large areas of deep-rooted perennial vegetation and continue to improve high water-using farming systems throughout the agricultural landscape to address the hydrological imbalance.
- Implement the *WA Salinity Action Plan* immediately in consultation with the community.
- Protect existing remnant vegetation on public and private lands from the effects of rising saline groundwater.

Background

Description

Land salinisation is caused by the disturbance of natural ecosystems, primarily through land clearing, and the replacement of perennial deep-rooted, native vegetation with annual crops and pastures. Crops and pastures do not use as much water as native vegetation. The 'excess' water that is not used by vegetation either moves off the land as runoff or moves into the ground becoming groundwater (recharge). This recharge causes groundwater tables to rise, bringing with it salt stored in the soil. Irrigation can also cause land salinisation in some areas. Recharge from excess irrigation and leakage from irrigation channels can cause groundwater to rise, contributing to salinity.

When salty groundwater comes close to the surface it can enter the root zone of plants. Salinity can kill agricultural and native vegetation, causing a loss of productivity, habitat and populations of plant and animal species. This biological decline is accompanied by deterioration in the physical environment producing an array of related problems. Waterlogging, erosion, sedimentation, the salinisation of land, rivers and wetlands are all related to groundwater rise.

Managing salinity is dependent on managing water in the landscape so that recharge and groundwater are brought under control at the farm and whole catchment scale.

Condition

Approximately 9 % of WA's agricultural land is currently affected by salinity (Table 7). The area of salt-affected land could double within the next 15–25 years, and double again before a new equilibrium is reached (Ferdowsian *et al.*, 1996). Since 1992 considerable effort has gone into more accurately estimating the area of land affected by salinity. Clearly, with better

information the extent of land salinisation is much greater than that reported in the 1992 *SoE Report*.

Salinity has markedly decreased biodiversity, particularly at the local and regional scales. Up to 80 % of susceptible remnants of native vegetation on farms and 50 % on public lands (including nature reserves) in WA could be lost within the next century. This process will continue for many years even if practices to combat salinity are implemented immediately.

Pressure

Past land clearing, and replacement of native vegetation with crops and pastures, have been responsible for disturbing the hydrological balance. This imbalance is the dominant pressure causing the spread of salinity. Land clearing is controlled in WA to prevent land degradation. It is still occurring in some areas.

There is also a continuing reduction in the quantity and quality of native remnant vegetation due to the impact of grazing and feral animals, incursion of weeds and some land clearing.

Current response

A comprehensive *Salinity Action Plan* has been adopted by the State Government which includes monitoring and reporting on the extent and severity of salinity.

Research to quantify the nature and extent of salinity has occurred over many years.

The Commonwealth and State Governments provide funding for various programs directed at managing salinity.

Research has been conducted on more productive and higher water using farming systems and these are being adopted. Many catchment groups and farmers have focused on salinity management. However, salinity management through widescale revegetation has occurred in few catchments. Research and development is also being conducted to assist in the broadscale introduction of commercial tree crops on cleared agricultural land and integrating these tree crops into farming systems.

Clearing controls exist to protect remnant vegetation. In some catchments, there are total clearing bans. Remnant vegetation is being protected under the Remnant Vegetation Protection Scheme and clearing controls by Agreements to Reserve.

Implications

The implications of land salinisation for WA's environment and society are enormous (Chief Executive Officers of Agriculture Western Australia, Water and Rivers Commission, Department of Conservation and Land Management, Department of Environmental Protection, 1996). The estimated capital value of the land lost to salinity is in the order of $1445 million. If the current rate of salinity expansion continues, the resulting loss of land capital value will be $64 million each year until a new hydrological balance is reached.

Environmental costs associated with salinity largely relate to losses in biodiversity. This has associated costs in terms of lost plant and animal resources, including lost opportunities for economic development. Agricultural production will be reduced through the loss of shelter for livestock and soils becoming salty.

Forty-six million dollars has already been spent in compensating farmers for not being able to clear land in selected Clearing Control Catchments which protect water resources. There will also be capital costs associated with the use of more saline water.

Salinity threatens local recreation resources and diminishes the inland region's tourist potential. Several wheatbelt towns are experiencing encroaching salinity problems. Much existing infrastructure, e.g., roads have been located and designed without considering risks associated with increased salinity and waterlogging. Waterlogging will dramatically increase the magnitude of run-off volumes and peak flood events.

Table 7 *The estimated area affected by salinity in the South West Land Division of WA for 1994, 2010–20 and potential (depending on rainfall) (Ferdowsian* et al., *1996).*

Region	Area surveyed (ha)*	1994 area (ha)	Area affected (%)	2010/20 area (ha)	Area affected (%)	Potential area (ha)	Area affected (%)
South West Land Division**	19,231,400	1,804,000	9.4	3,296,300	17.1	6,109,000	31.8

* Includes some land partly covered by native vegetation.
** The South West Land Division includes the Midwest Coastal Plain, Wheatbelt, Swan Coastal Plain, Naturaliste, South West Forests and South Coast SoE Regions.

***Land Salinisation* is a direct pressure causing *Salinisation of Inland Waters*. It also impacts on *Waterlogging*, *Loss of Fringing Vegetation* and *Biodiversity*.**

See Section 5 of the SoE *Reference Group Draft Working Papers* for more information on *Land Salinisation*.

Land Contamination

Environmental status: ❖ ❖ ❖ ❖

Conclusion

Although land contamination is a serious environmental problem, detailed information on the extent and severity of contaminated land in WA is not available.

Over 1500 contaminated sites are thought to exist in WA (Department of Environmental Protection, 1995a). It is not known how many contaminated sites exist outside of Perth, although a significant number of rural properties are contaminated by organochlorine pesticides and arsenic from old sheep dips.

Clearly, there is an urgent need to better understand the nature and extent of land contamination in WA.

Objective

To identify contaminated sites and manage land contamination.

Suggested response

- Amend existing legislation to provide an integrated contaminated sites management framework.
- Establish an inventory of contaminated sites.

Background

Description

Land contamination can be defined as land where hazardous substances occur at concentrations which pose, or are likely to pose, an immediate or long-term hazard to human health or the environment. The problems associated with land contamination vary with each site in character, hazard potential and importance to human health or infrastructure.

Land contamination can lead to contamination of inland waters, particularly in sandy soils (see *Contamination of Inland Waters*).

Condition

Since 1992 more contaminated sites are being re-developed and the focus has shifted from landfill sites to inner-urban redevelopments. This has substantially increased the number of contaminated sites that have been identified to the DEP. Of the potential 1500 contaminated sites in WA, 1200 of these occur on the Swan Coastal Plain. It is not known how many sites occur in the Perth Metropolitan Region. Most were caused by poor chemical storage, waste containment and disposal practices. Over 100 of these sites currently require active management. The nature of contaminating substances at many potentially contaminated sites in the metropolitan area is largely unknown.

Some land used for industry or agriculture has been turned into residential land. In some cases this land may be contaminated from past activities and practices, e.g., below McCabe St, Mosman Park.

There are currently 12 operating, and about 100 abandoned landfill sites in the Perth Metropolitan Region. Increased ammonia is the only major change in groundwater quality caused by landfill sites (see *Consumption and Waste Management*). Elevated levels of heavy metals or pesticides have not been detected (Department of Minerals and Energy, 1995).

In rural areas the application of some agricultural pesticides (particularly organochlorine pesticides) has caused land contamination, e.g., some potato growing areas near Manjimup. The 1992 *SoE Report* indicated that 12,700 ha is subject to management notices under legislation. More recent estimates are in preparation. Of the 1200 properties subject to management notices, a substantial portion occur on the Swan Coastal Plain. However, contaminated agricultural properties have largely been identified and do not pose a direct threat to the environment or human health as organochlorine pesticide residues adhere to soil particles and generally are not mobile in the environment.

Low-level heavy metal (primarily cadmium) contamination from fertiliser application also occurs in agricultural areas. The affected areas have not been clearly identified.

Pressure

Activities which can cause land contamination include:

- disposal of waste;
- accidental spillage;
- leakage during plant operation;
- storage or transportation of raw materials, finished

products or wastes;

- the spreading of sewage sludge;
- migration of contaminants into a site from neighbouring land-use, either as vapour, leachate or movement of liquids through the soil; and
- the use of agricultural chemicals (Australian and New Zealand Environment and Conservation Council & National Health and Medical Research Council, 1992).

The main sources of potential contamination in the metropolitan area are underground storage tanks, e.g., petrol tanks beneath service stations, and industrial sites.

Current response

The DEP has released a position paper on contaminated sites following public comment on a discussion paper released in August 1995. The position paper will form the basis of the framework to manage contaminated sites.

Implications

One of the key implications of land contamination relates to potential health impacts. Research has been conducted on the health impacts of heavy metals and some organochlorine pesticides.

However, little information is available on the other implications arising from land contamination, except where it has a direct impact on primary production, e.g., contaminated meat arising from pesticide use.

The Swan River foreshore adjacent to the McCabe Street redevelopment in Mosman Park is one example of a contaminated site in the Perth Region which is currently being cleaned-up. Upon completion of the clean-up program, the foreshore area will be covered with clean fill and rehabilitated to ensure that it is left in a stable condition. Photograph by Dr John Rogers.

See also *Contamination of Inland Waters* within this report.

See Section 5 of the SoE *Reference Group Draft Working Papers* for more information on *Land Contamination*.

Erosion

Environmental status: ❖ ❖ ❖

Conclusion

While soil erosion is not the problem of say 10 years ago, it continues to affect the productivity of agricultural and pastoral lands. It can also lead to offsite environmental effects, such as sedimentation and eutrophication of inland waters.

Soil erosion is a sporadic event and difficult to monitor on a statewide basis. Emphasis is being placed on the prediction of unseasonal events to assist in the management of erosion. However, some information is available for pastoral lands and selected agricultural areas.

Although methods to manage erosion are well established more effort is required to promote best management practice for this issue. Improved hazard assessment, in the face of unseasonal conditions and better defined management responses are required.

Objective

To minimise the extent and severity of soil erosion.

Suggested response

- Further development of better management practices for erosion and communication of these to land managers.
- Development of more effective indicators of erosion for agricultural lands.
- Development of an 'early warning system' which can trigger land managers to take steps to prevent wind erosion.

Background

Description

Soil erosion occurs when soil is exposed and disturbed, e.g., by the clearing of land for cultivation, or through grazing by stock. Both wind and water can cause soil erosion by detaching soil particles from areas not protected by vegetation and moving these down-slope or down-stream.

Erosion causes a loss in agricultural productivity through the loss of fertile topsoil and exposure of hard subsoils. It also leads to a loss of biodiversity.

Eroded soil can move into rivers and streams causing sedimentation as well as eutrophication due to nutrients being carried into waterbodies on soil particles.

Condition

The extent of erosion is difficult to measure across the State because it is dependent on management practices of landholders and seasonal conditions which vary from year to year.

No recent estimates of erosion are available for the agricultural area other than data presented in the 1992 *SoE Report*. This indicated that some 50,000 ha were affected by wind erosion, and some 750,000 ha were affected by water erosion. However, these estimates have been questioned and it has been suggested that these figures significantly underestimate the area affected by erosion in WA.

For the South West Land Division the historical pattern has been severe wind erosion events about every 10 years (affecting hundreds of thousands of hectares), moderate erosion about every 5 years (affecting thousands of hectares) and some erosion can occur every year (affecting hundreds of hectares). As much as 20 mm of top soil has been lost from parts of some paddocks during a single storm. Damage done in severe events has taken many years to recover.

Severe wind erosion events have occurred along the South Coast and the Midwest Coastal Plain Regions in recent years (1987, 1990, 1991, 1994, 1995 and 1996).

The extent of agricultural land currently affected by water erosion is not known. Most water erosion occurs with severe rain events, often in summer or early winter.

Estimates of the extent of erosion on pastoral land are available from rangeland surveys conducted over the last 30 years.

For all of the regions surveyed, some 677,800 ha (about 1%) is severely degraded and eroded (Pringle *et al.*, 1994). While some of this information is dated, the situation is unlikely to have changed significantly (see Table 8).

Much of the severely degraded and eroded land in pastoral areas is found on river frontages and deltas. This land has both high pastoral value and high conservation value.

The WA Rangeland Monitoring System (WARMS) is used to monitor changes in the vegetation and soil condition in the rangelands. Recent information from WARMS sites suggests that as many sites are improving as declining but most sites remain stable.

Pressure

The primary pressures leading to erosion are agricultural practices which increase the exposure and vulnerability of soils. These pressures include the removal of protective vegetative cover through grazing, cultivation, compaction and chemical changes to the soil, such as salinisation or acidification. The light, sandy soils of the South Coast and Midwest Coastal Plain regions are particularly vulnerable to pre-frontal winds at the start of winter. Information on the adoption of best management practice for erosion control in agricultural areas is now being collected through the Australian Bureau of Statistics (ABS).

Total grazing pressure is an indicator which considers the grazing impact of domestic, feral and native animals on rangeland vegetation. It is an indicator of pressure on the pastoral lands. While domestic livestock numbers are regularly researched there is limited information on the numbers of other grazing animals.

Current response

There is increased use of best management practices in agriculture including minimum tillage systems for crop establishment which incorporates stubble into the soil rather than burning it. Farmers are also more responsive to adverse seasonal conditions by removing stock from areas susceptible to wind erosion. Research is continuing to determine the best means of managing erosion.

Remote sensing information has been analysed for some parts of the State to monitor the extent and severity of wind erosion. Rangeland surveys have measured the extent of land degradation, particularly erosion, in most pastoral regions. The WARMS monitoring sites provide information on the changing vegetation structure and soil condition at selected sites on pastoral properties throughout the State.

The EPA will continue to investigate the development of environmental protection measures, if required, to underpin and guide ecologically sustainable natural resource management in the rangelands.

Implications

Erosion contributes to environmental problems such as sedimentation and eutrophication. The 1992 *SoE Report* estimated that wind erosion in the agricultural region reduced cereal and pasture productivity at a cost of $21.3 million annually. No recent estimate of the cost of erosion in terms of lost productivity on pastoral and agricultural lands are available.

Table 8 *Extent of erosion as estimated by traverse assessments from rangeland surveys and percentage area of severely degraded and eroded land mapped by rangeland surveys (Source: Pringle et al., 1994).*

Region surveyed (Year commenced) [Year data published]	No. of traverse assessments	Extent of erosion (percentage of traverse assessments)				Total area (km^2) (% severely degraded and eroded)
		Nil	Minor	Moderate	Severe	
Gascoyne (1969) [1972]	2426	Information not available				63,400 (1.9)*
West Kimberley (1972) [1979]	4532	47.1	26.5	16.5	9.9	89,600 (2.2)*
Nullarbor (1974) [1979]	1273	100	0	0	0	47,400 (0)
Ashburton (1976) [1982]	8608	79	13	5	3	93,600 (0.6)
Carnarvon Basin (1980) [1987]	10,952	90	6	2	1	74,000 (0.9)
Murchison (1985) [1994]	13,441	83	11	5	1	88,360 (1.8)
Roebourne Plains (1987) [1994]	1172	75	16	8	1	10,200 (2.3)
NE Goldfields (1988) [1994]	10,470	89.7	6.6	2.3	1.4	100,570 (0.4)
Sandstone-Yalgoo-Paynes Find (1992) [In prep]	9435	94.7	3.6	1.3	0.4	94,710 (0.2)
All areas surveyed	62,309	83	10	5	2	661,840 (1.0)

Erosion can contribute to *Eutrophication* and *Sedimentation* and is related to *Loss of Fringing Vegetation*. See these sections within this report.

See Chapter 5 of the SoE *Reference Group Draft Working Papers* for more information on *Erosion*.

Acidification

Environmental status: ❖ ❖ ❖

Conclusion

Soil acidification can be caused by a range of activities including agriculture, the exposure of natural sulphide bearing rocks and acid deposition from industrial pollutants. This report focuses on acidification as a result of agriculture.

Acidification of agricultural land will reduce agricultural productivity and contribute to environmental problems such as salinity and erosion throughout the agricultural area if not corrected. Soil acidification is increasing as a result of current agricultural practices.

Soil acidification of agricultural land is managed through the application of neutralising substances such as lime sand or limestone which is widely available and provides a solution for most agricultural areas. Lime extraction requires careful management to ensure areas of high conservation value are protected and environmental impacts are managed.

Objectives

- To alleviate the effects of agricultural soil acidification.
- In mining lime, to minimise the impacts of lime extraction and related mining practices on nature conservation and other land-use values.

Suggested response

- Further monitoring of the extent of soil acidification.
- Further research into less acidifying agricultural systems.
- Further education about the costs of managing soil acidification and benefits of applying lime.
- A State Lime Strategy should be developed to secure lime sources and protect areas of high conservation value.

Background

Description

Acidification is a direct result of agricultural production as the increased acidity of soils is caused by the removal of nutrients by plants and animals.

Legume crops and pastures, as well as nitrogen-based fertilisers, have increased soil acidity through the leaching of acid substances directly into the soil (Office of the Commissioner for the Environment, 1991).

Environmental problems can result from soil acidification. For example, if agricultural soils become too acid, vegetation is unable to grow and the soil becomes prone to erosion.

Also, a lack of acid tolerant species inhibits efforts to grow plants to manage other land degradation problems. This has implications for the management of rising groundwater and land salinisation.

Condition

The acidification of agricultural land is gradual, invisible and requires ongoing monitoring.

Since 1992 more accurate estimates of the area affected by acidification are available. These estimates are much higher than those presented in the 1992 *SoE Report* which are now considered conservative. It is also likely that the area affected by acidification will continue to increase without appropriate management. In WA the estimated area affected by soil acidification is 4.7 million ha of highly acidic (pH <4.8) soils and 4.7 million ha of moderately acidic (pH 4.9–5.3) soils (AACM International Pty Ltd, 1995). This occurs throughout the Wheatbelt, South Coast, Midwest Coastal Plain, and South West Forest regions. It is becoming an increasing problem on land used for viticulture in the Naturaliste region.

Pressure

Agricultural production results in a net acid gain to soil. The main pressures causing agricultural soil acidification are legume crop and pasture species and the application of nitrogen-based fertilisers; both critical to maintaining agricultural productivity. The total area planted to legumes has increased between 1993 and 1995. It is likely that this trend will continue. No estimates are available for the amount of nitrogen-based fertilisers applied in WA.

Current response

The number of farmers applying lime to manage soil

acidification has rapidly increased. However, the amount applied is not consistent with the scale of the problem.

Agriculture WA has conducted a successful 'Time to Lime' campaign from 1996, accurate prescriptions for managing acidification are available and research into its management is being conducted. In 1994–95 about 160,000 tonnes of lime and/or dolomite were applied across about 160,000 ha in WA.

Implications

In 1992 it was estimated that soil acidification had the potential to reduce production on about 55 % of the State's agricultural area. The estimated cost of lost production from soil acidification is $150/ha with an estimated loss in areas of high pH of about $70 million annually (Landcare Review Committee, 1995).

Soil acidification is managed through the application of neutralising substances, e.g., lime sand or limestone. The economic benefits of liming are generally greater than the costs. However, it is not a viable management option for all areas of the state, or for all farming systems (AACM International Pty Ltd, 1995).

No other neutralising substance is available in sufficient quantities to manage acidification. While there is sufficient lime to manage acidification for several hundred years, lime sources will come under increasing pressure from many industries, including agriculture.

Lime substances are a finite natural resource often occurring in vegetated areas of high conservation value and their use is not ecologically sustainable in the very long-term. Areas of high conservation and landscape amenity value must be protected and the impacts of lime extraction carefully managed.

See Chapter 5 of the SoE *Reference Group Draft Working Papers* for more information on *Acidification*.

Waterlogging

Environmental status: ❖ ❖

Conclusion

Waterlogging on agricultural land impacts on the environment as well as reducing agricultural productivity.

Waterlogging increases runoff, erosion, recharge and soil structure decline. Waterlogging and runoff from waterlogged areas can damage remnant vegetation, leading to losses in biodiversity.

The extent of waterlogging in WA is generally unknown except for some areas where it has been studied in detail.

Objective

To reduce the extent of waterlogging and inundation (surface ponding) on agricultural land and their associated impacts.

Suggested Response

- Implement the *WA Salinity Action Plan* including surface water control measures.
- Develop and evaluate new enterprises requiring water harvesting and use, e.g., aquaculture.
- Use appropriate technology, e.g., satellite imagery, to monitor waterlogged and saline areas to assist in providing information for improved practices.

Background

Description

Waterlogging is excess water in the root zone of soils and results in damage to, or the death of, plant roots. It reduces soil oxygen levels, causes a build-up of gases toxic to plants and alters the concentration of nutrients around the roots (Setter & Belford, 1990; McFarlane & Belford, 1993).

Waterlogging occurs naturally in low-lying areas, e.g., swamps and wetlands. However, on agricultural land it can severely reduce the yield of crops and pastures. Here waterlogging is caused by reduced use of rainfall by plants, poor runoff, poor drainage of water through the soil profile and the accumulation of groundwater within the soil profile leading to a shallow water table.

Agricultural waterlogging also impacts on the natural environment. Excess water from waterlogged agricultural areas can flow into remnant vegetation, carrying nutrients, sediment and salt. This can damage the vegetation, leading to losses in biodiversity.

Waterlogging can also contribute to other forms of land degradation such as land salinisation, soil structure decline and water erosion (Government of Western Australia, 1992) because of its association with reduced total water use by plants.

Waterlogging and rising salinity are closely related and both can be managed by making use of excess water on agricultural lands (the 'use it or move it' approach), through the establishment of perennial vegetation and agroforestry. Environmentally acceptable surface drainage works are often essential to improved crop and pasture establishment and tolerant crops and pasture species may be developed and adopted.

Condition

The extent of waterlogging varies from year to year because it is highly seasonal. Therefore the area of land affected by waterlogging is not readily measurable.

Lack of information on the extent of waterlogging does not allow for an analysis of change in the area affected since 1992. However, the estimate provided in the 1992 *SoE Report* is now considered conservative (Wheaton, B., 1996, pers. comm.). It is likely that the extent of waterlogging will continue to increase. Detailed information on waterlogging is available for the Great Southern ABS Region only.

Several landforms throughout the agricultural area are particularly prone to waterlogging. These include duplex and sodic soils. Some land which was naturally wet, low-lying and poorly drained, such as coastal, estuarine and riverine systems, now experience waterlogging. These areas probably should not have been cleared for agriculture.

Pressure

The pressures which contribute to waterlogging are largely a result of agriculture, inappropriate management practices, the clearing of low-lying areas,

the absence of surface water management and the inadequate water use of agricultural species. This is confounded by a lack of appreciation of its impact. Waterlogging is generally not perceived as a problem by land managers until inundation occurs.

In addition, the current trend away from wool production means more cropping is occurring in susceptible areas. This increases the total area at risk of crop yield reductions from waterlogging.

Soil cultivation, and compaction by vehicles and stock, exacerbates waterlogging. Some forms of drainage need to be carefully prescribed and regulated to ensure they do not contribute to waterlogging or have other offsite impacts.

Current response

Research is occurring on the use of remote sensing technology to monitor waterlogging. The cost of waterlogging on productivity and the benefits of management of waterlogging using drains, tolerant species and agronomy have also been investigated.

Surface water drainage works and planting of tolerant pasture species are increasing.

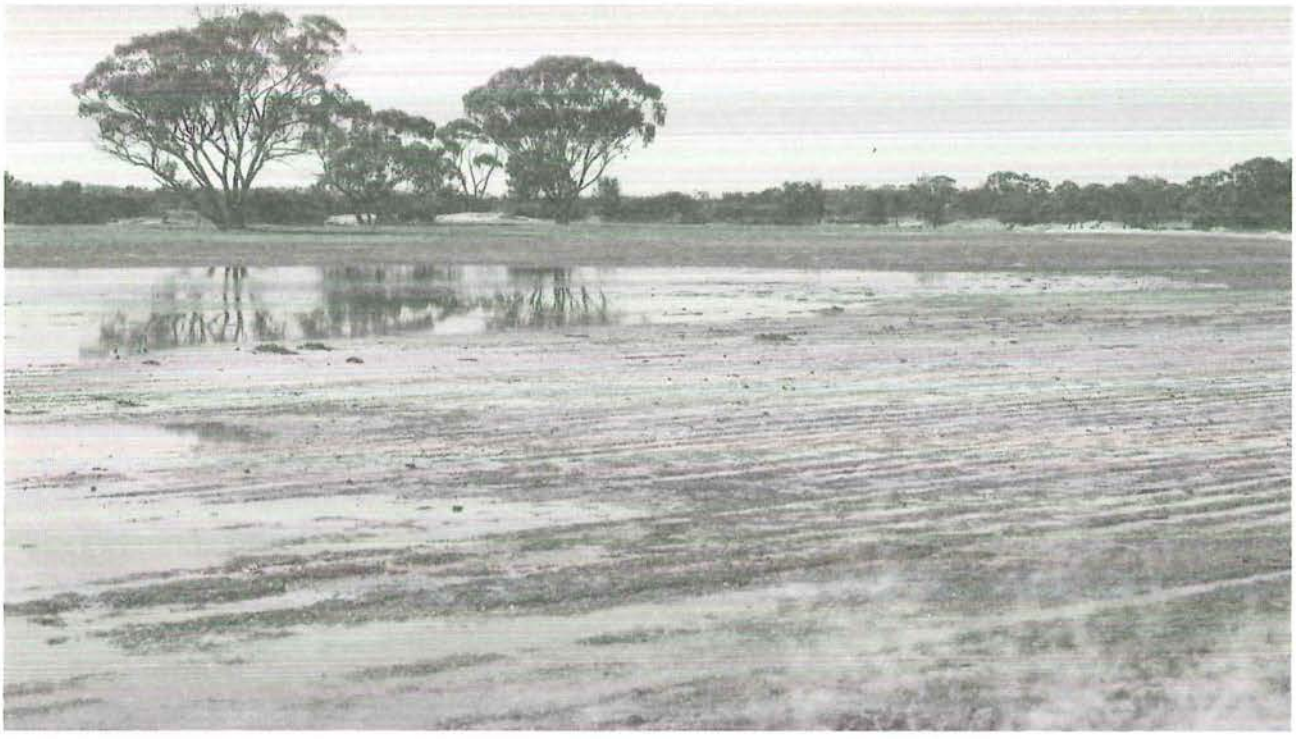
Higher water using perennial and tree crop species are being developed for integration into agricultural systems.

Implications

While waterlogging of agricultural land is a major economic issue, it can have significant environmental implications.

The inundation of remnant vegetation, caused partly by waterlogging and runoff from agricultural land, has been identified as a major contributor to the decline of remnants in agricultural areas. However, no detailed information is available on the direct impacts of waterlogging on remnant vegetation.

Detailed information on the impacts and costs of waterlogging in WA is only available for the Great Southern ABS Region. In this area, lost productivity as a result of waterlogging amounts to millions of dollars each year. In wet years this can amount to over $100 million, with a similar loss expected for pasture production.



Waterlogging can reduce agricultural productivity and contribute to offsite impacts like the inundation of remnant vegetation and salinity. Photograph by Agriculture Western Australia.

See Section 5 of the SoE *Reference Group Draft Working Papers* for more information on *Waterlogging*.

INLAND WATERS

Salinisation of Inland Waters

Environmental status: ❖ ❖ ❖ ❖ ❖

Conclusion

Salinisation has steadily degraded most of the inland waters in the south west of WA since clearing began. Salinisation severely alters aquatic ecosystems and reduces biodiversity and the supply of potable water.

Most rivers in the south west have had lower salinity levels since 1990, compared to the preceding five years, largely due to higher rainfall. Major exceptions are the Avon, Kent and Brockman rivers that have markedly higher salinities. Significant reductions have occurred in groundwater levels and in the amount of salt transported by streamflow from experimental catchments where reforestation has taken place. Discernible reductions have been observed in the salt input to Wellington Reservoir following the reforestation of about 10 % of the total cleared land in the catchment (7000 ha in the highest salt yielding portion of the catchment). As stream flow has also declined with reforestation, reductions in stream salinity are not yet clear and more data are required to show statistically significant trends.

Increases in stream salinity are preventable. However, long-term, concerted effort, involving the establishment of extensive areas of deep-rooted perennial vegetation, is required to halt and reduce the problem. Complete elimination of the problem is unrealistic.

Objective

Consistent with the *WA Salinity Action Plan* the objectives for remedying the salinisation of inland waters are:

- to protect and restore key water resources to ensure salinity levels are kept at a level that permits safe, potable water supplies in perpetuity;
- to protect and restore high value wetlands and maintain natural (biological and physical) diversity within the agricultural areas of WA; and
- to restore additional inland water systems consistent with community driven priorities;

This will be best achieved by establishing a stable water regime within catchments that protects the condition of inland waters.

Suggested Response

Implement the *WA Salinity Action Plan* by:

- expanding programs to recover and protect catchments which have high wetland, biodiversity, and potable water supply values and to protect important infrastructure under threat from salinity; and
- supporting community and farmer groups in the development and implementation of catchment management plans to achieve their defined salinity targets.

Background

Description

Salinisation of inland waters occurs when salts mobilised by rising groundwater enter a river or wetland. As land salinity increases, water which drains the landscape also becomes more saline.

Condition

Before native vegetation was cleared throughout the south west of WA it is believed that nearly all streams were usually fresh or marginally saline. Some streams would have been marginal or brackish during low flow periods.

A series of naturally saline waterbodies occur in the eastern wheatbelt and other inland areas. Such areas were seasonally inundated and before clearing would have caused relatively minor increases in river salinity on rare occasions.

The average salinity of streams which drain cleared areas where rainfall is less than 900 mm/year invariably have become brackish or saline (over 1000mg/L TSS). The average salinity of streams which drain the high rainfall areas of the Darling Range (greater than 1100 mm/year) usually remain fresh following clearing (less than 500 mg/L TSS) although some increases in salinity occur, particularly at low flows. The larger river systems that flow from the inland agricultural areas are

either saline, brackish or of marginal salinity.

In all waterbodies that become saline, the diversity of life that can live in them decreases. Fringing vegetation dies leading to weed invasion and bank erosion or is replaced with salt-tolerant species.

Table 9 shows salinity levels of representative rivers for each affected region. Information on salinity of wetlands is limited.

Pressure

Any activity that disturbs water balance can increase the salinity of inland waters. Clearing native vegetation for agriculture has been the most long-term and severe pressure. Forestry and mining operations cause temporary disturbances to the water balance and can lead to minor and temporary increases in salinity in some areas. The processes causing salinisation of land are the pressures causing salinisation of inland waters because of the relationship between a catchment and its river or wetland. The pressure on inland waters is quantified in *Land Salinisation* and Section 5 of the *SoE Reference Group Draft Working Papers*.

Current Response

All major current responses are focussed on reducing salinisation of land and are outlined in *Land Salinisation*. The Water and Rivers Commission (WRC) is working with the Water Corporation to reduce salinity in some priority water resource catchments through clearing controls and revegetation. Active reforestation has been carried out on two existing water supply catchments, and private investment in commercial tree farming encouraged on other catchments. Programs of research and development to improve the commercial viability of reforestation have been carried out and actively promoted. These activities are being adopted by some landowners, although this is currently focussed on the higher rainfall areas.

Improved protection of streams from the temporary impact of logging has been developed and long-term research and monitoring programs are in place to ensure careful management of bauxite mining and subsequent rehabilitation.

Implications

In addition to the ecological effect of groundwater rise and salinity, the economic and other social costs of salinity are enormous and include the following:

- death of riparian vegetation and salt intolerant aquatic fauna leading to loss of biodiversity;
- loss of potable water and decline in the quality of farm water supplies, that is, dams and soaks. It is estimated that only 48 % of divertible riverine water resources remain fresh in the south west of WA;
- loss of biological productivity of rivers and streams;
- creation of new dams as existing ones become saline;
- significant water treatment costs; and
- infrastructure damage and repair.

Table 9 *Salinity in representative rivers for affected areas of the State (Source: Water and Rivers Commission).*

Rivers	Proportion of Catchment Cleared (% in 1986)	Current Salinity (mg/l TSS)	Rate of salinity increase since 1965 (mg/l/y)
Frankland River	56	2760	74
Kent River	40	2087	58
Swan–Avon River	75	5835	*
Greenough River	50	4908	*
Blackwood River	85	1760	58
Collie River	24	790	24
Murray River	75	2260	93
* Insufficient data to form trend			

The *Salinisation of Inland Waters* is directly related to *Land Salinisation*. See *Land Salinisation* in this report.

See Section 6 of the *SoE Reference Group Draft Working Papers* for more information on *Salinisation of Inland Waters*.

Loss of Fringing Vegetation

Environmental status: ❖ ❖ ❖ ❖

Conclusion

One of the most damaging changes we have inflicted upon inland waters is the widespread loss of native fringing vegetation. All prevailing signs indicate that the fringing vegetation of rivers, wetlands and estuaries has continued to decline since the 1992 *SoE Report*.

Remnant fringing vegetation is not being managed sustainably[1]. If inland waters are to be sustained ecologically they require healthy vegetation along their foreshore. In addition, to buffer against changes in the groundwater regime which may also affect rivers, a significant proportion of the surrounding catchment must have intact vegetation. Revegetation should be strategically located and indigenous vegetation established for conservation purposes.

Objective

To achieve ecologically sustainable management of fringing vegetation zones to meet required environmental values, including water quality objectives (see *Salinisation of Inland Waters*, *Eutrophication* and *Contamination of Inland Waters*), by the year 2020.

Suggested Response

- Large scale restoration of fringing vegetation is necessary to achieve the State's environmental objective (above). Establish vegetated waterway protection corridors on at least 50 % of substantial streamlines[2] by 2010. Corridors should be of adequate width to meet ecological functions. Guidelines should be flexible to meet the needs of the river environment and local community.
- Research into fringing vegetation zone restoration technologies is needed.
- Waterways restoration programs, as part of strategic environmental plans for environmental regions, including catchment-based revegetation programs, are necessary.

Background

Description

Fringing vegetation is the vegetation immediately adjacent to a waterbody. When fringing vegetation is lost, a number of environmental problems result because native fringing vegetation performs several important ecological functions:

- the reduction of erosion and sedimentation;
- filtering of nutrients and pollutants;
- reducing channel erosion by decreasing the speed of riverflow;
- maintenance of river habitats and aquatic biodiversity;
- provision of habitats for important terrestrial fauna associated with riparian environments; and
- provision of ecological corridors for long-term ecological sustainability.

Condition

Generally, zones of fringing vegetation are not being managed sustainably and will continue to degrade in non-forested areas, except in small areas where the community has taken an active role in their protection and restoration.

Weeds now dominate the zone of fringing vegetation in many rivers and wetlands. Table 10 indicates the condition of riparian vegetation for the main channels of all rivers currently surveyed. Forty-six percent have no or sparse fringing vegetation. Smaller streams, which form most of the river network are generally in much worse condition.

Hill *et al.* (1996) assessed the quality of wetlands based on their surrounding vegetation. They found that, of the 60 % of rivers and creeks surveyed between Gingin and Mandurah, 52 % of rivers and 66 % of creeks had lost half of their native fringing vegetation. Only 7.5 % of wetlands in the same area were found to have healthy fringing vegetation. This provides a 1991 baseline for performance evaluation on the northern Swan Coastal Plain.

A recent study of the samphire marshes of the Peel–Harvey estuarine system has found that samphire

[1] A working definition of ecologically sustainable management for riparian zones is included in the Working Papers.

[2] A substantial stream is defined as any stream shown on a 1:50,000 topographical map.

marshes are declining both in quality and quantity and have done so since 1965. Between 1965 and 1994, 37 % of samphire has been lost (McComb *et al.*, 1995).

In a community survey of attitudes toward the health of the Blackwood River's fringing vegetation, more than 80 % of the people who live near the Blackwood River were concerned about its condition and believed that river health would further decline if no action was taken (Butterworth & Carr, 1996).

Pressure

The primary pressure on fringing vegetation is a lack of management and protection to maintain the environmental benefits that it provides. Currently, the proportion of substantial streamlines not managed sustainably is not known.

Fringing vegetation is prone to degradation from overgrazing and trampling by livestock, weed invasion, frequent burning and recreation. Recreation and development is a significant pressure on fringing vegetation of estuaries.

Salinity levels have increased in waterways and this is degrading fringing vegetation (see *Salinisation of Inland Waters*). Drainage can have a significant impact if it carries saline water into fringing vegetation. Groundwater rise, and increases in the volume of runoff, are causing inundation of fringing vegetation which can result in its decline, especially around lakes.

Dieback can be particularly severe in fringing vegetation because the fungus moves rapidly in wet soils.

Weed seeds carried in urban and rural drains can establish large infestations when they discharge into rivers and wetlands. Weeds can also degrade fringing vegetation.

Current Response

A statewide waterways (rivers and estuaries) management strategy is under development. The State government is also funding the assessment of fringing vegetation, education programs and river restoration. Management authorities have been established for some catchments in the south west of WA. Catchment groups in these areas are managing zones of fringing vegetation where possible.

The proportion of substantial streamlines adopted and actively managed needs to be accurately determined, but is probably less than 5 % (Pen L. 1996, pers. comm.).

The Land and Water Resources Research and Development Corporation's National Riparian Zone Program aims to clarify how fringing vegetation, sedimentation and eutrophication interrelate, and how the health of downstream waterways is affected by the health of fringing vegetation.

Implications

There are important implications of loss of fringing vegetation on landscape amenity, biodiversity and the ecological functions of inland waters, e.g., fish nurseries and water bird habitats. There has been no analysis of the social and economic implications of fringing vegetation decline in the State.

Table 10 *Assessment of the condition of fringing vegetation in the South Coast State of Environment region and in the South West other than the South Coast State of Environment region.*

Condition category*	South Coast State of Environment Region† (Proportion in each category %)	South West other than South Coast SoE Region‡ (Proportion in each category %)
Near pristine	17 %	34 %
Relatively natural	21 %	8 %
Corridor river	21 %	3 %
Habitat river	22 %	7 %
Agricultural drain	19 %	48 %

*The condition of fringing vegetation and the main channel is classified using the following categories :
Near pristine — river section and upstream catchment contained within natural bush.
Relatively Natural — river section in natural bush but some portion of upstream catchment cleared for agriculture or some other landuse.
Corridor river — river section in a substantial corridor of vegetation
Habitat river — river section retains significant fringing vegetation.
Agricultural drain — river section with nil or only sparse fringing vegetation.
† (Agriculture Western Australia, in press)
‡ (Source: Water and Rivers Commission)

The *Loss of Fringing Vegetation* is caused in part by the *Salinisation of Inland Waters* and *Land Salinisation* and relates to *Maintaining Biodiversity*. See these sections in this report.

See Section 6 of the SoE *Reference Group Draft Working Papers* for more information on the *Loss of Fringing Vegetation*.

Eutrophication

Environmental status: ❖ ❖ ❖ ❖

Conclusion

Many estuaries and wetlands in the south west of WA are nutrient enriched, that is, eutrophic. The effects of eutrophication have increased since the early 1970s, including:

- the fouling of beaches with macroalgae;
- the loss of important habitat;
- algal blooms in river and wetland systems and a decline in water quality; and
- significant losses of wild life, including large fish kills, mortality of entire ecosystem components and loss of some ecosystem functions.

Eutrophication is the result of complex processes that are not completely understood. While it is necessary to continue investigations to better understand these processes, there is a need for immediate management action to reduce the nutrient loads entering waterbodies, rather than expensive technological solutions to the problems once they have occurred. This management action will require co-operation by landholders and management agencies in the catchments. The perceived negative economic implications of some actions have been the main reason for lack of such action in the past.

Objective

- To protect and enhance the condition of inland waters to meet specified environmental value requirements.
- To reduce soil and nutrient export from industry, farmland and urban sources to waterbodies to sustainable levels by the year 2020.[1]

Suggested Response

- Develop a framework for determining environmental values and solutions to eutrophication in WA, based on the National Water Quality Management Strategy by 1998. Determine environmental values by 2000.
- Develop restoration programs for all affected environmental regions as part of strategic environmental plans and incorporation into integrated catchment management initiatives.
- Best land management practices should be implemented by 50 % of land-users by 2010 and 100 % by 2020.

Background

Description

Eutrophication refers to the ecological changes that result from the overloading of waterbodies with nutrients. Eutrophication of waterbodies is a slow natural process that is greatly accelerated by human activities. Nitrogen and phosphorus are the most important of the nutrients causing eutrophication.

Algal blooms need phosphorus and nitrogen to occur. Phosphorus is the main nutrient causing algal blooms in most inland waters in the south west of WA. Phosphorus can be present either attached to soil particles or dissolved in water. Nitrogen is usually already available in sufficient quantities to support algal blooms and the outflow of nitrogen-rich water from estuaries into coastal waters can cause eutrophication of the marine environment (see *Contamination of the Marine Environment*).

Generally, sandy soils do not hold nutrients and allow direct leaching of dissolved nutrients. Western Australia has low fertile soils which support plants that are adapted to low nutrient levels. In the other areas where soils are heavier and nutrients are bound to soil particles, soil erosion plays a leading role in eutrophication. The release of stored nutrients from sediments into the water column continues to fuel algal blooms. In all regions the decay of organic matter in wetlands, streams, river pools and estuaries can reduce oxygen levels in the water column and thereby trigger release of nutrients from sediments and exacerbate eutrophication.

The changes that result from eutrophication can cause widespread death of aquatic animal and plant life, can decrease diversity, and cause algal blooms which are

[1] Some activities such as logging, road and bridge construction and mining cause short-term soil exports that may be sustainable in the long-term, but require tight controls to prevent long-term degradation.

unsightly, smell and are sometimes toxic.

Condition

The Select Committee into Land Conservation (Legislative Assembly, 1991a) reported that in the south west of WA only seven estuaries out of 22 had low nutrient levels. This situation has not improved. The estuaries that are not eutrophic occur within forested catchments.

Information on nutrient trends over the last few years indicates that except for the Peel–Harvey coastal catchment, phosphorus levels are not being reduced, although most nutrient data have not been rigorously analysed.

Pressure

The most important sources of nutrients are: fertilisers from broad-acre applications; fertilisers leached from horticultural practices; nutrient-rich runoff from intensive rural industries; urban development; and waste water from industrial sources. Western Australia is by far the largest phosphate fertiliser user in Australia (Australian Bureau of Statistics, 1996a).

There is a tendency to over-fertilise private gardens in the false belief more fertiliser results in a greener garden. Excess fertiliser is leached from soil into groundwater or carried as runoff into wetlands, rivers and estuaries.

Various human uses reduce river flow including public and private dams and river diversion. Decreases in river flow often increase the likelihood of eutrophication. This is because there is less flushing for nutrients to be diluted, because the river will move more slowly, and nutrients can accumulate in sediment.

Hirschberg and Appleyard (n.d.) found that agriculture is increasing the nutrient concentration of groundwater, particularly on the Swan and Scott Coastal Plains. Expansion of horticulture on coastal plains is a significant and growing pressure.

Point sources of pollution that contribute to eutrophication include some waste disposal and industrial sites, sewage and waste water discharges.

Figure 7 presents the severity of nutrient loads to various waterbodies in the State.

Current response

Environmental Protection Policies and Statement of Planning Policies have been used to reduce nutrient pressure on some inland waters.

Many government agencies and community groups are acting to reduce nutrient inputs to waterbodies through, for example, revegetation, bank stabilisation and alternative farming practices. Co-ordination and strategic planning of these activities is successfully occurring through integrated catchment management groups in several urban and rural catchments. Integrated catchment management plans have been prepared for the Leschenault, Peel-Harvey, Swan-Avon, Blackwood, Frankland-Gordon, Wilson Inlet, Kent and Albany Harbour's river systems. Other groups are in the process of developing similar plans for addressing eutrophication in some other rivers or smaller catchments.

Research is continuing into the process of eutrophication and remediation options, especially in the Swan-Canning Estuary and in other affected waterways in the south west.

Water sensitive urban design guidelines provide a framework and comprehensive set of best management practices for reducing nutrient inputs to waterbodies from urban areas.

Implications

The impact of eutrophication on recreation has been significant, especially on the Swan Coastal Plain. The total economic cost would be very large and include the cost of lost biological resources, lost nutrient resources and required remedial measures. In addition there are significant implications for local losses in biodiversity.

Eutrophication leads to excessive growth of macroalgae. Here a tractor removes unsightly and pungent algae from an estuary foreshore. Photograph by Ernest Hodgkin.

See Section 6 of the SoE *Reference Group Draft Working Papers* for more information on Eutrophication.

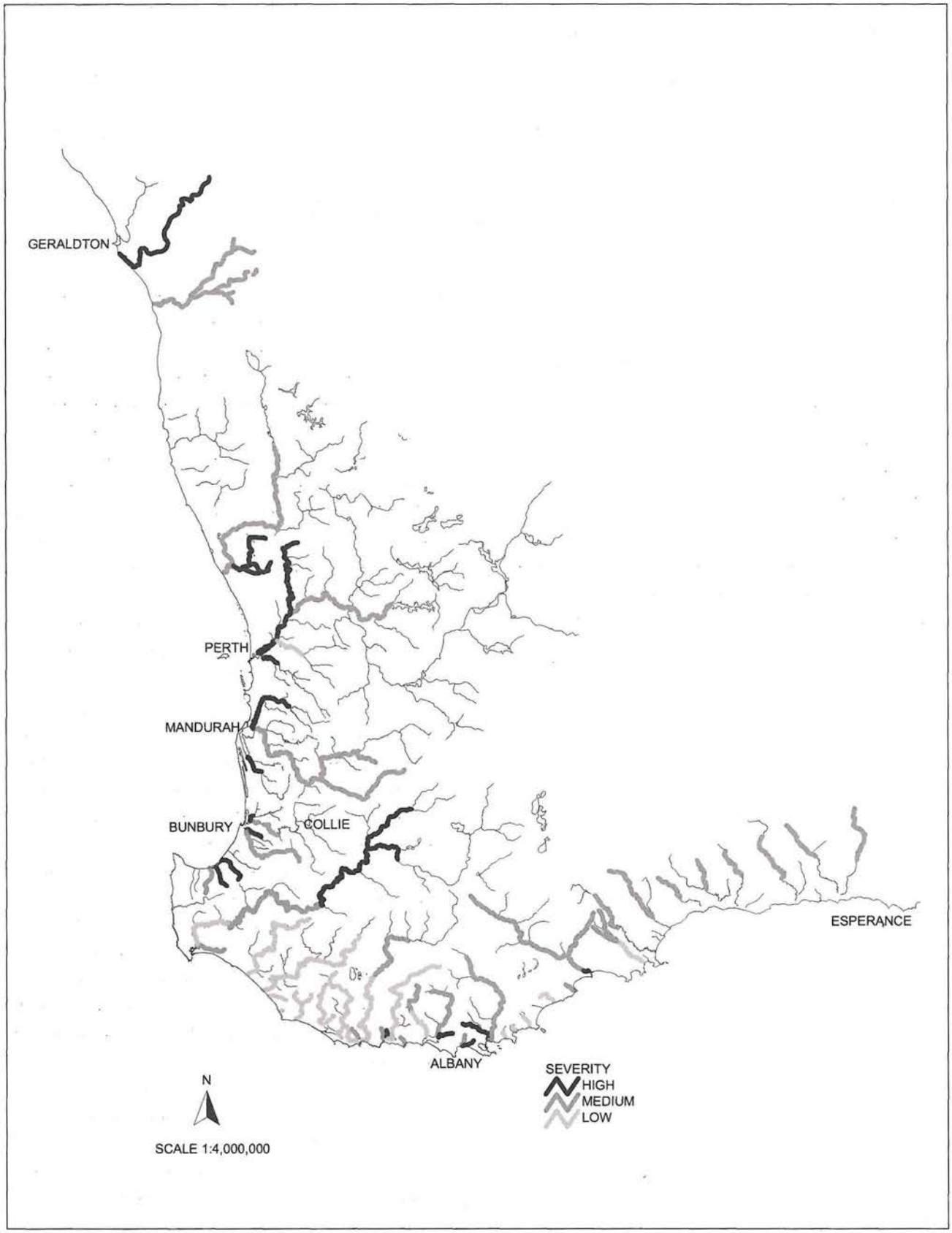


Figure 7 *Severity of nutrient loads to various waterbodies in the State (after Legislative Assembly, 1991a).*

Sedimentation

Environmental status: ❖ ❖ ❖

Conclusion

The extent and severity of river, estuary and wetland sedimentation has not been quantified and no significant information can be added to that provided in the 1992 *SoE Report*.

However, sedimentation is a serious environmental issue that reduces water quality and biodiversity, and increases the likelihood of flooding.

Sediment load from erosion in the surrounding catchment is a major source of nutrients causing eutrophication in the south west.

Objective

To return the sedimentation in waterways and wetlands to ecologically sustainable levels and restore a significant proportion of river channels, pools and wetlands by 2020.

Suggested Response

There is an urgent need to establish realistic long-term targets to achieve the objective for sedimentation of waterways. The targets should be based on research findings and an agreed approach to sediment monitoring by the end of 1998. Responses should include action toward:

- establishing vegetated waterway protection corridors (see *Loss of Fringing Vegetation*);
- minimising the discharge of sediment from rural and urban drains so as to be at ecologically sustainable levels by 2020; and
- ensuring best land management practices are adopted by 50 % of land users by 2000. One hundred percent of land users should have adopted best management practices by 2020.

Responses apply to rural and urban areas and should be developed as a component of the State's integrated catchment management policy.

Background

Description

Sedimentation of waterways and wetlands occurs when soil becomes unstable and erodes from urban and agricultural catchments and the banks and beds of streams.

In the south west of the State, catchment runoff has increased where native vegetation has been cleared. The high peak flow rates that result erode the exposed soil, creating gullies and damaging stream channels. Wind can also disturb exposed soil and carry it into waterbodies. In the north of the state sedimentation rates are naturally high, but pastoral and some mining activities have accelerated the rate of erosion.

Where water flow decreases, sediment falls from suspension, covering vegetation and severely degrading the ecology of aquatic systems. Eventually sediment can completely fill deep river pools. A similar process occurs in wetlands.

Organic material, e.g., animal manure, can cause other problems as it decays, such as decreasing the amount of oxygen available to sustain aquatic life.

Condition

Currently it is not possible to document accurately and consistently the number of river pools, wetlands and estuaries affected by sedimentation. However, it has been estimated that over half of the former pools on the Avon River have been filled with sediment. In all rivers where sedimentation is occurring ecologically important pools are being lost.

Figure 8 shows the rivers currently known to be most affected by sedimentation. Sedimentation and erosion can be severe in the Kimberley, almost all of it resulting directly from past practices of the pastoral industry such as overgrazing and the introduction of feral animals.

The 1992 *SoE Report* estimated that:

- 3–4 m of sediment scours the Fitzroy main channel during peak flows;
- a single summer flood brought 100,000 m^3 of soil to Beaufort Inlet and reduced its depth by 25 mm;
- the depth of Stokes Inlet has been reduced by 20–25 cm in 30 years;
- sediment almost filled the Irwin Inlet in a flood event; and

- many other south west estuaries have become shallower since clearing for agriculture began.

Pressure

Sedimentation affects all rivers where agriculture, pastoral activities and degraded fringing vegetation zones occur (Legislative Assembly, 1991c).

Healthy fringing vegetation protects rivers from soil erosion in the catchment and prevents bank erosion. Information on fringing vegetation zones is reported in *Loss of Fringing Vegetation*.

Human activities in the catchment of a river, estuary or wetland can increase the natural rate of erosion. Erosion from agricultural areas is a major pressure on inland waters and is discussed in *Soil Erosion*.

In the north of the state, pastoral activities have been particularly damaging to flood plains surrounding rivers and wetlands because their grasslands are favoured by stock. While the numbers of animals grazing along river frontages has been significantly reduced in recent years, gully erosion has accelerated in these areas and the total rate of sedimentation has not declined.

In severe cases the natural rate of erosion increases more than 1000 fold and waterbodies rapidly fill with sediment (CSIRO, 1992). Large scale soil disturbance and exposure is the main cause of sedimentation and this was rare before Aborigines were disposessed of their land and land clearing began (Olsen & Skitmore, 1991).

Fire can cause large scale soil disturbance and leads to sedimentation. It seems likely that the vast majority of fires in the Kimberley region are deliberately lit. Natural fires are less frequent and can be caused by lightning strikes. Fire frequency and extent appears to have increased dramatically in recent years. Although data are sparse in WA, it seems likely that fires and fire frequency is causing an accelerating and perhaps irreversible impact upon the natural vegetation of the region and therefore upon soil erosion and sedimentation levels.

Artificial drainage systems built throughout the State also contribute considerable quantities of sediment to surface waterbodies, because many of these structures are poorly maintained and are degraded and eroding.

Current response

The National Riparian Zone Program involves research to quantify the value of riparian vegetation in protecting rivers from sedimentation.

Activities conducted by community groups and supported by government have resulted in fencing and rehabilitation of some waterways, for example, the Kalgan, Hay, and Blackwood Rivers.

Mining activities in places may cause sedimentation. However, when undertaking ground disturbing activities, miners and explorers must submit under the *Mining Act 1978 (WA)* an application for ground disturbance or a Notice of Intent. These detail both the management commitments to avoid environmental impacts, and the rehabilitation procedures to be employed. Ongoing activities are monitored through the annual environmental reporting process.

Significant stretches of the Fitzroy River frontage has been fenced to prevent stock access. Agriculture WA and the Pastoral Board are entering into management agreements with pastoralists to control grazing on river frontages. However, vegetation degradation and increasing levels of soil erosion currently occurring on other rivers in the north west will cause future problems and diminish their potential and economic worth as possible development sites and sources of water supply.

Integrated catchment management provides the framework for co-ordinating custodial management in rural and urban areas.

Implications

Soil is a valuable resource that is being lost at rates that are economically and ecologically unsustainable. The economic and social costs of sedimentation are unknown. However, loss of river pools has significantly reduced recreational opportunities for some agricultural communities and also directly reduces biodiversity.

Bulong pool on the Avon River was once about 10 m deep. It acted as a summer refuge for aquatic fauna. Now the pool is completely filled with sediment from the surrounding catchment. Photograph, Water and Rivers Commission.

Sedimentation is directly related to the *Loss of Fringing Vegetation* and *Soil Erosion*. See these sections in this report.

See Section 6 of the SoE *Reference Group Draft Working Papers* for more information on *Sedimentation*.

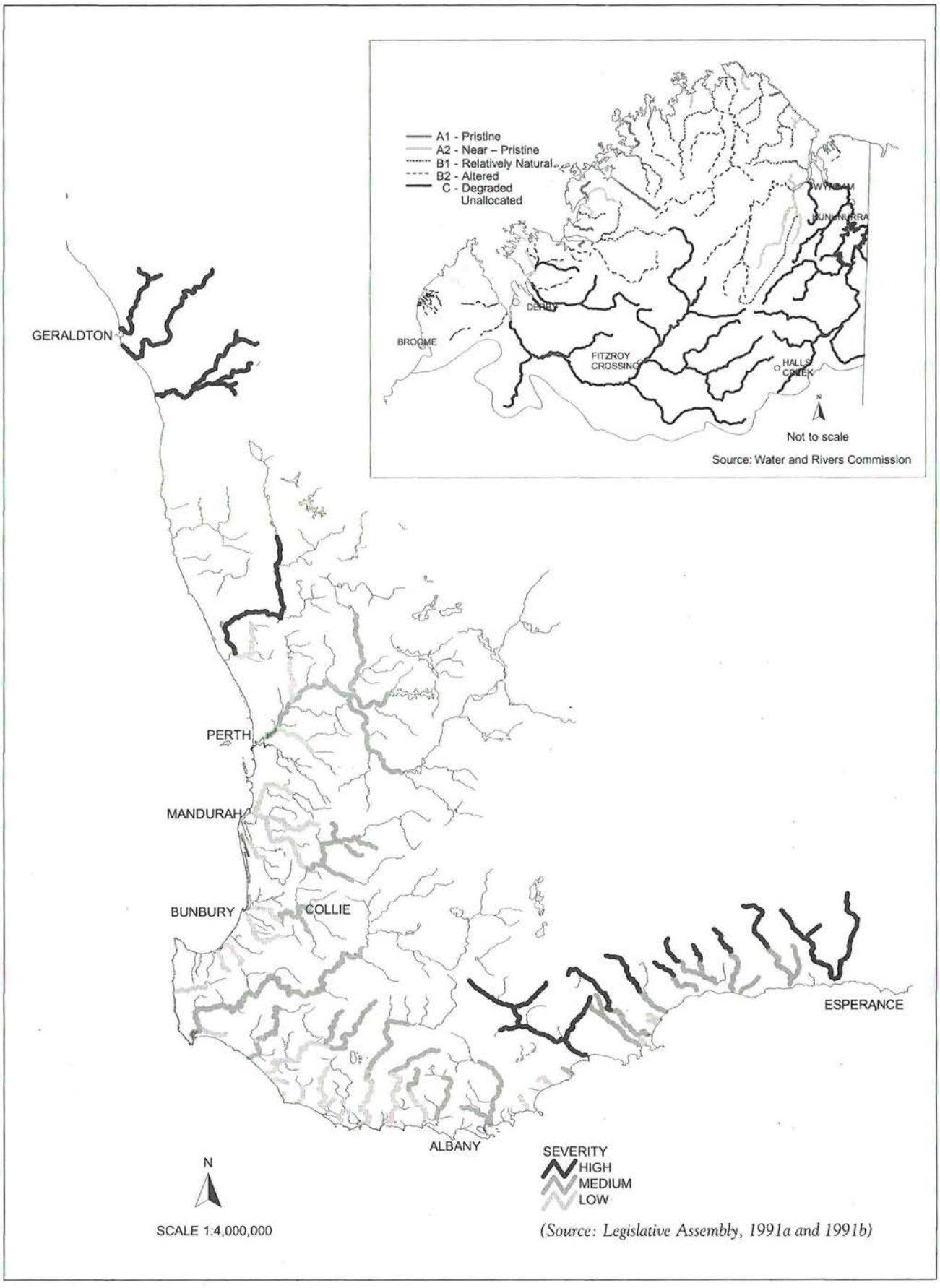


Figure 8 *Severity of sedimentation in rivers of the State currently known to be most affected by sedimentation based on available information.*

Contamination of Inland Waters

Environmental status: ❖ ❖ ❖

Conclusion

In several SoE regions, waterbodies are affected by contaminants at levels that exceed EPA guidelines for the protection of aquatic ecosystems (Environmental Protection Authority, 1993). The effects of contamination are often not immediately visible, and the problem may go unnoticed for a long time. Contamination events are often undetected and monitoring programs rarely detect peak concentrations.

There have been very few measurements of water contamination in WA to assess the extent of the problem at the regional and statewide scale. There is no coherent strategy for addressing contamination by diffuse and unregulated land-uses.

Objective

To identify and contain contamination of inland waters induced by humans at levels below EPA guidelines or environmental value criteria by 2001, while preventing contamination from singular or cumulative sources in future development.

Suggested Response

- The effectiveness of responses to ban or restrict some pesticides has not been assessed and could be linked to the National Land and Water Audit. The audit should also determine the current status of contamination.
- Environmental guidelines are not available for acceptable levels of contaminants in stream and wetland sediment. The EPA should review the guidelines for soil contamination (Australian and New Zealand Environment and Conservation Council & National Health and Medical Research Council, 1992) and develop a suitable set of guidelines for assessing contamination in sediments.
- All significant point sources of contaminants should be identified by 1998 and be fully regulated by the year 2000 as part of a statewide contamination strategy.
- A strategic system of monitoring contaminant loads into major waterbodies subject to significant human pressure to be in place by the year 2000.

Background

Description

For the purposes of this section, contaminants include chemical pollutants (see Environmental Protection Authority, 1993) other than nutrients, salts and sediment which are addressed as separate issues because of their significance (see *Eutrophication*, *Salinisation of Inland Waters* and *Sedimentation*).

Severe contamination can restrict human use of waterbodies and cause health problems. It can also cause many ecological impacts. Above certain levels pollutants can cause mutation in organisms, a decline in the health and diversity of vegetation and at extreme concentrations, the death of plants and animals.

In some cases the effects of pesticides on native fauna are greater than on the target species (Department of Environmental Protection, 1995b).

Condition

The extent and severity of contamination depends on the source of the contaminant, the land-uses and industries in the catchment area and the effectiveness of pollution controls, if any exist.

Pesticide concentrations monitored in the 1970s and 1980s indicated that in many cases EPA guidelines were exceeded, but generally contamination was limited in extent. Many pesticides that have been monitored are now banned from use. Recent monitoring has only been conducted for the Preston River (1985–86) to confirm the effectiveness of these bans at reducing pesticide concentrations (Klemm, 1989). This study confirmed that the number of samples of dichlorodiphenyltrichloroethane (DDT) and dieldrin exceeding EPA guidelines had decreased, but another substance, chlordane, had appeared at levels exceeding the EPA's guidelines in 12 % of samples.

The concentration of many heavy metals (copper, mercury, lead, zinc and chromium) has exceeded EPA guidelines at points in the Swan River Estuary. Recent monitoring of the Peel-Harvey Estuary found the heavy metals chromium, lead, mercury, selenium and zinc well in excess of EPA guidelines (Agriculture Western Australia, 1996).

No consistent method has been developed to report on water pollutants. Information on pollutants other than heavy metals and pesticides is limited and reporting on the condition of the environment at the regional scale is currently not possible.

Pressure

Diffuse source contamination can result from urban, agricultural and forestry use of pesticides and fertilisers. Monoculture crops usually require rigorous pest-management programs.

Soil containing excess fertiliser and pesticides can erode, carrying chemicals into waterways. Poorly timed application of fertiliser and pesticides can also contribute to this problem. Pollutants can leach through sandy soil, contaminate groundwater and often move into waterbodies.

Herbicides are used for maintaining fire breaks and for weed control. In timber plantations perennial and annual weeds are often controlled with herbicide.

Herbicides used to control weed infestation near waterbodies are used in sufficient quantities to cause short-term contamination. Therefore, protecting fringing vegetation from human disturbance is important to prevent weed invasion and contamination from herbicides.

Unsafe disposal or use of chemicals may cause contamination. This problem is often exacerbated by poor industrial and commercial by-product treatment and management. Useful by-products may be wasted because it is often cheaper and easier to discharge them into waterbodies.

Heavy metals and other chemicals enter waterbodies through drains that carry water from industrial and commercial areas. Urban stormwater drains also transport a lot of chemical residue from roads and surrounding land-uses. Dumping of toxic substances such as motor oil and chemical waste into drains is the result of poor disposal practices and lack of economic incentives.

The main contaminants from industrial effluent likely to pollute inland waters are metals, acids, alkalis, surfactants, organic chemicals such as phthalates, phenols and cresols, waste oils, aromatics, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, halogenated aliphatics, pesticides and metabolites, radionuclides and biological contaminants. The amount of these contaminants emitted to waterbodies is unknown.

Current response

The use and disposal of chemicals has been progressively regulated. For example, organochlorine chemicals that have been widely used as pesticides, e.g. DDT, dieldrin and heptachlor, have been banned after many years of use after identification of their adverse environmental impacts. In the past, a rigorous precautionary approach has not been applied when accepting new chemicals for use in the environment. In June 1987, organochlorine pesticides were deregistered for all agricultural uses and in June 1995, the remaining urban uses of organochlorine pesticides were deregistered. The regulation of pesticides in WA is managed jointly by the Health Department of WA and Agriculture WA, through various pieces of legislation. Both agencies actively promote responsible pesticide use in both urban and agricultural environments.

The DEP, Swan River Trust and WRC, along with local community-based environment groups, participate in pollution awareness and education campaigns. The voluntary work of environment groups such as the Conservation Council of WA, Greenpeace and the Australian Conservation Foundation has often set the pace in education and awareness programs.

Many groups have taken up the challenge of reducing pesticide use through research into integrated pest-management, permaculture and organic farming practices.

Environmental Protection Policies (EPP) and a State Planning Policy are being developed to help prevent contamination in some of Perth's valuable groundwater resources. A statewide EPP will be developed in the near future to provide a strategic framework for groundwater protection.

A Select Committee into Metropolitan Development and Groundwater Supplies reported on matters relating to groundwater contamination in 1994 for Perth's public drinking water source areas (Legislative Assembly, 1994). This has led to changes to the boundaries of water pollution control areas and proposed amendments to the Metropolitan Region Scheme.

Implications

Besides the ecological impacts that contamination can cause, human health can also be impaired. Many water pollutants in high doses are known to cause cancer and a range of other illnesses. Information to quantify these effects is not available.

The *Contamination of Inland Waters* is closely related to *Land Contamination*. See this section in this Report.

See Section 6 of the *SoE Reference Group Draft Working Papers* for more information on *Contamination of Inland Waters*.

MARINE

Degradation of Marine Habitats

Environmental status: ❖ ❖ ❖

Conclusion

Based on available information, important marine habitats are generally considered to be in good condition. There are some locations where habitat has been damaged.

Detailed knowledge of most habitats is poor and this needs to be redressed. Lack of information does not allow reporting on the degradation of marine habitats at the regional or State scale.

Objective

- To ensure there is no further significant human induced loss or degradation of marine habitats.
- To protect and enhance all environmental values of marine habitats.
- To document and monitor the condition of WA's marine habitats.

Suggested response

- Establish a representative system of marine reserves in line with the *New Horizons in Marine Management* Policy.
- Improve our knowledge of important marine habitats and resources through a co-ordinated research and monitoring program. Identify, map, and establish baseline conditions of habitats.
- Establish regional strategies for sustainable resource use for areas under greatest pressure (such as Pilbara and Perth metropolitan marine regions).
- Develop a public information program to ensure users of the marine environment act responsibly and do not damage important habitat.

Background

Description

There is large diversity of marine habitats in WA. The main types of marine habitats of concern in WA are mangroves, algal dominated reefs, seagrass meadows, coral reefs and soft sediment sea floor (benthic) communities.

The emphasis in this section is upon degradation of marine habitats which have been identified as significant from community and scientific opinion. This issue should be read in conjunction with the section on *Biodiversity*.

Condition

The coastline of WA supports about 20,000 km^2 of some of the most diverse assemblages of seagrasses in the world. Seagrasses are in good condition except for Albany harbours, Cockburn Sound and parts of Geographe Bay.

The remoteness of many of WA's coral reefs has protected them from degradation. Most reefs are considered to be in pristine condition.

Mangrove forests extend 2500 km around the coast from the Northern Territory border. Most of the mangrove forests are in good condition. In some places, e.g., the Pilbara, the mangrove forests have both local and global significance and some areas have been lost as a result of port and road work, and salt farms.

There are limited data on WA soft sediment sea-floor communities other than in Cockburn and Warnbro Sounds and on the North West Shelf. Data indicate that the North West Shelf is an area of high biodiversity (Ward & Rainer, 1988).

The benthic fauna of southern Cockburn Sound shows signs of pollution effects. (Department of Environmental Protection, 1996).

Pressure

The dominant pressures affecting these habitats are:

- direct physical damage caused by port and industrial development, pipelines, communication cables, mining and dredging, mostly in the Pilbara and Perth Metropolitan marine regions;
- excessive loads of nutrients from industrial, domestic and agricultural sources, mostly in the Lower West Coast, Perth Metropolitan and South West Coast marine regions (see suggested responses in *Contamination of the Marine Environment*);
- land-based activity associated with ports, industry, aquaculture and farming, mostly in the Pilbara, Central West Coast, Lower West Coast, Perth Metropolitan and South West Coast marine regions;
- direct physical damage caused by recreational and

commercial boating activities including anchor and trawling damage, mostly in the Kimberley, Pilbara, Shark Bay, Perth metropolitan coast and Geographe Bay areas.

Current response

Surveys and monitoring studies have steadily increased our knowledge of marine habitats and biodiversity. Petroleum companies, Department of Conservation and Land Management (CALM), Department of Environmental Protection, Murdoch University, the University of WA, CSIRO, WA Museum, the Australian Institute of Marine Science, the Fisheries Department of WA and other organisations have collaborated on various projects to map marine habitats, monitor water quality and undertake research into dugongs, seabirds, turtles, vegetation, fish, crustaceans and molluscs.

Targets for nutrients and monitoring of nutrient levels have been implemented successfully for Princess Royal Harbour and Oyster Harbour at Albany and for the Perth metropolitan coastal waters.

A statewide system of marine reserves is being established by CALM.

There are several other current responses to degradation of marine habitats. For example, the Shark Bay Marine Park protects some of the most important seagrass meadows in WA. The Fisheries Department is presently carrying out seabed surveys to delimit areas for trawling in Shark Bay.

Implications

As the State develops its industrial and resource sectors increased pressures will be placed on marine habitats. Our knowledge of these habitats is scant and any loss of biodiversity could significantly affect existing resources such as fish stocks.

See also *Maintaining Biodiversity* and *Fisheries* in this report.

See Section 7 of the SoE *Reference Group Draft Working Papers* for more information on *Degradation of Marine Habitats*.

Contamination of the Marine Environment

Environmental status: ❖ ❖ ❖

Conclusion

Contamination of the marine environment is most pronounced in the Perth metropolitan coastal waters. Past actions are beginning to deliver reductions in pollutants but as Perth's population increases there will need to be further steps taken to reduce the discharge of contaminants.

Objective

To protect and enhance marine waters to meet environmental value requirements.

Suggested response

- A statewide inventory of contaminant sources should be developed and maintained by Department of Environmental Protection (DEP) as part of the National Pollutant Inventory.
- Environmental surveys should be undertaken in areas of known contamination to quantify any effects and to provide a baseline for the future.
- The Environmental Protection Authority should formally designate environmental values for Perth metropolitan coastal waters by the end of 1997. Designation of environmental values of the remainder of the State should occur by 2000.
- A contaminant management strategy should be developed for Cockburn Sound and Sepia Depression by 1998.
- The WA Government should seek a review of the Australian and New Zealand Environment and Conservation Council recommendations on antifouling paints for vessels over 25 m, with a view to reducing tributyltin levels. Health implications of current tributyltrin levels in shellfish need to be quantified.
- The WA Government should establish a formal framework to co-ordinate environmental management within Perth's metropolitan coastal waters and between these waters and their land catchments.

Background

Description

Contamination of the marine environment is caused by a variety of substances discharged through wastewater in outfalls and drains and from contaminated groundwater, rivers and estuaries. The major contaminants are sewage, agricultural runoff, industrial discharges, and tributyltin which is an ingredient of anti-fouling paint applied to ships and coastal vessels above 25 m in length.

Condition

The Perth metropolitan coastal waters are subject to a number of contaminants. Nutrient-rich waters discharged from the Peel-Harvey and the Swan-Canning estuaries in winter affect the area from Dawesville to Yanchep. Trends in water quality since the 1970s are shown in Table 10.

Organic pollutants such as pesticides and hydrocarbons are low and within the range typical of uncontaminated areas.

Heavy metals are low except in harbours, marinas and within 1 km of the Cape Peron outfall. Heavy metal concentrations in mussels are well within public health standards.

Based on projections made in June 1994, loadings of contaminants from domestic waste water treatment outfalls have increased since the 1992 *SoE Report* and, assuming current levels of treatment and disposal practices, will continue into the future.

Tributyltin contamination is widespread throughout Perth metropolitan waters and has increased since the 1992 *SoE Report* in areas frequented by vessels longer than 25 m. It is highest near marinas and ports. Tributyltin contamination is present in all major ports in WA.

Outside the metropolitan area sewage discharges to the ocean have mostly ceased. There are local cases of sewage contamination. For example, in Coral Bay contaminated groundwater from sewage leach drains is moving into the bay. Nutrient discharge from rivers and estuaries is restricted to the south west. The effects of

these discharges on the marine environment are unknown. Similarly, the effects of discharge of sediment from rivers in the Pilbara and Kimberley following cyclones is unknown.

Pressure

Sources of nutrient to the metropolitan marine environment are predominantly from domestic waste water via outfalls at Cape Peron, Ocean Reef and Swanbourne and to a lesser degree, contaminated groundwater and river and estuary discharges. This waste load is expected to grow significantly as Perth's population increases. Elsewhere in WA, outfalls have been removed. Spills and systems failure remain as potential pressures.

Heavy metal inputs are likely to increase by a factor of two or three over the next 20 years in metropolitan waters.

Further industrial development in the Pilbara and expansion of ports will increase the sources of these contaminants.

Current response

The *Southern Metropolitan Coastal Waters Study* conducted by the DEP and the *Perth Coastal Waters Study* (see Water Authority of Western Australia, 1995) conducted by the Water Corporation are major advances in our understanding of the marine environment. The Water Corporation is investigating treatment options on the Cape Peron outfall which will reduce suspended solids, nutrient and metal loads.

The use of tributyltin in antifouling paint has been banned since 1991 on vessels less than 25 m.

International action on discharge from ships has been adopted by Australia. Emergency plans for shipping accidents and oil spills are in place.

Industry is continuing to reduce its discharges to the marine environment. Moreover, through the Australian and New Zealand strategy to protect the marine environment significant steps are being taken nationally to minimise the incidence of debris from ships and impacts from ships' ballast waters. Also, areas likely to be adversely affected by shipping operations are to be identified.

In Coral Bay an infrastructure plan has been developed to reduce nutrient pressure on the Bay.

Implications

The issue of contaminants to the marine environment involves a wide cross-section of society. The current level of co-ordination and integration is insufficient to ensure that the management of the various uses of the marine waters is socially equitable and ecologically sustainable. There is a need for a formal framework in which this can be achieved.

Fundamental research to improve our knowledge base is needed to ensure that existing contaminant levels are not causing undetected problems.

Table 10 *Trends in nutrient related water quality in Perth's marine waters since the 1970s (Source: Department of Environmental Protection).*

Location	Trend
Cockburn Sound	Initial improvement, subsequent deterioration
Owen Anchorage	Significant improvement
Warnbro Sound	No change
Northern beaches	No change
Cape Peron/Sepia Depression	Slight deterioration

See Section 7 of the SoE *Working Group Draft Reference Papers* for more information on *Contamination of the Marine Environment*.

Introduction of Exotic Marine Species

Environmental status: ❖ ❖ ❖

Conclusion

Exotic marine organisms have been introduced to WA via ballast water and hull fouling from shipping.

Knowledge of species introduced and their distribution has recently been updated.

The risk of damage to marine biodiversity is largely unknown.

Objective

To ensure that there are no further introductions of exotic species.

Suggested response

- Complete baseline studies especially in areas of greatest pressure.
- Adopt the recommendations regarding ballast water in *Maritime Accidents and Pollution: Impacts on the marine environment from shipping operations* (Australian and New Zealand Environment and Conservation Council, 1996).
- Implement the *Draft Australian Ballast Water Management Strategy*, and assist in reviewing and updating that strategy.

Background

Description

Exotic species can be introduced into coastal waters from the hulls of ships or as a consequence of ships discharging ballast water. The issue of controlling international shipping is best dealt with in the international arena. Currently, controls are only voluntary.

Introduced marine species may threaten native marine flora and fauna and human uses of marine resources such as fishing and aquaculture.

Condition

It has been estimated that over 27 exotic species have been introduced to WA (Furlani, 1996) and 21 of these are known to have been introduced into Perth metropolitan waters, the most highly visible being a large polychaete worm. This worm occupied up to 20 ha of the sea-floor and most of the man-made structures in Cockburn Sound, but its incidence may be declining. Limited information is available on the distribution of these species or the effects on the local environment.

Pressure

Ships discharge ballast water to take up their cargo. This water usually has its origin outside WA. The risk of introduction of exotic species is related to the origin and destination of discharged ballast water and the amount of ballast water discharged. The tonnage of shipping is a surrogate indicator of this pressure.

Most ballast water discharged in WA originates in the Asia-Pacific region with 58 % coming from Japan. The Pilbara receives about 50 % of ships to WA. It is estimated that 100 million tonnes is discharged into this region's marine waters each year.

The most significantly affected ports are Dampier, Port Hedland, Fremantle, Cape Lambert and oil terminals off Onslow. Due to the nature of the receiving waters, Esperance is also a high risk port.

Current response

Surveys by CSIRO and the Australian Quarantine Inspection Service are currently underway to establish the number of introduced species and their distribution in WA.

An Australian Ballast Water Advisory Council was established in 1995.

International guidelines have been adopted on a voluntary basis to reduce the risk of transporting marine organisms. In WA a memorandum of understanding has been developed between the Fisheries Department and the Department of Environmental Protection on the translocation of live aquatic non-endemic species into or within WA.

Implications

The risk is that an introduced species will establish and cause significant damage to local biodiversity. It may also pose a threat to existing and or future uses of the marine resources of an area. None of these aspects has been quantified for WA. The cost of removing an introduced species once it is established would be much greater than the cost of preventative measures.

See also *Biodiversity* in this report.

See Chapter 7 of the SoE *Reference Group Draft Working Papers* for more information on the *Introduction of Exotic Species to the Marine Environment.*

Fish Stocks

Environmental status: ❖ ❖ ❖

Conclusion

Each year the Fisheries Department prepares a *State of the Fisheries Report* which describes the status of the exploited fish stocks. In 1995–96 18 of 21 of the major commercial fisheries had breeding stock levels that were adequate to maintain present stocks.

The knowledge base regarding recreational fishing is limited. Improving this is critical for long-term management and is being actively addressed.

Objective

To ensure all fish stocks are managed on a sustainable basis.

Suggested response

- Maintain appropriate management to ensure the sustainability of all commercial and recreational fish stocks.
- Conduct research to improve knowledge of key recreational species.

Background

Description

Fishing, whether commercial or recreational, has the potential to deplete the numbers of target and non-target species. Understanding the relationship between fishing pressure and stocks of target species is fundamental to meeting the objective of sustainability.

The sustainability of individual fish stocks is described by measuring the quantity caught each year, the effort applied to catch that quantity and the size of the breeding stock.

Condition

Most commercial fish species are regarded as being fully exploited. Trends in breeding stock vary, with some increasing, e.g., Shark Bay snapper, western rock lobster and Shark Bay tiger prawns. Most fisheries have adequate stocks, e.g., Australian salmon, catfish and abalone. Limited data have restricted full assessment of some fisheries although their catch histories indicate stable stocks, e.g., Onslow and Nickol Bay prawns. Three fisheries are rated as having decreasing breeding stock levels; two shark fisheries and the herring trap fishery.

Since 1991, the number of commercial fisheries considered over exploited has decreased from 12 % to 8 %.

The status of recreational fisheries is not as sound as that of commercial fisheries. This is especially so for targeted species in the metropolitan area such as herring and dhufish. The trend in stock numbers and distribution for these species is uncertain.

Pressure

The pressures on fish stocks relate to the fishing effort and intensity of that effort. Clearly fishing effort is variable between fisheries and locations around WA. Generally the greatest recreational fishing effort is around coastal population centres such as Perth. The number of recreational fishers is increasing and it is anticipated that marine tourism including fishing will increase, placing added pressure on recreational fish stocks.

Increased pressure on commercial fish stocks arises from improved fishing skills and improved technology such as global positioning systems.

Current response

All commercial fish stocks are protected by appropriate means of regulation. This varies between fisheries and can include limiting the number of boats, the fishing gear, the season and the amount of fish caught. A buy back scheme funded by commercial fishers is reducing the number of commercial fishing licences.

There is not the same level of control on recreational fisheries. A licence is required for some fisheries and there are limits on the size and number of fish caught. Abalone fishing in the metropolitan area represents the extreme case where fishing is presently restricted to 7.5 hours a year. There is also a licence fee and a numbers limit for this recreational fishery.

Implications

Continued vigilance is needed to ensure that the harvested fish stocks of WA are managed sustainably. The commercial species are well understood and managed. Recreational fish species require increased attention.

See Section 7 of the SoE *Reference Group Draft Working Papers* for more information on *Fish Stocks*.

BIODIVERSITY

Maintaining Biodiversity

Environmental status: ❖ ❖ ❖ ❖ ❖

Conclusion

Biodiversity, the variety of genes, species and ecosystems, is essential to human well-being in many ways. It underpins the economy and ecological processes that are vital to human health and survival. Its value to society and the State's economy is immeasurable. It is also valued highly by many people for cultural, ethical and aesthetic reasons.

Biodiversity is potentially affected by all human activities. Measures of impact need to be included in assessments of human activities and in economic indicators.

Our knowledge of the biodiversity of WA is limited, with many species not being scientifically described or named, and the conservation status of many species being unknown. There is no comprehensive catalogue of ecosystems or ecological communities or of their conservation status. Knowledge of the genetic diversity of species is almost non-existent.

Monitoring and management of ecosystems and species is essential if the State's natural heritage is to be maintained. Conservation of biodiversity can be achieved by expanding the conservation reserve system, improving conservation outside the reserve system, ameliorating threatening processes, conserving threatened ecosystems and species, and promoting ecologically sustainable development. Many of these activities are already underway, but their continuing success will require a commitment from all Western Australians and improved methods of monitoring and management.

Objective

- To document and monitor WA's flora, fauna, and ecosystems.
- To ensure there is no further loss by human impact on known native species and habitat diversity.
- To recover populations of threatened native species and ecological communities and to maintain them at sustainable levels.
- To ensure that, by the year 2010, all ecosystems within WA are adequately and comprehensively represented in the conservation reserve system and appropriately managed to ensure their viability.
- To ensure that the principles of biodiversity conservation are integrated into land and marine management practice outside the conservation reserve system.

Suggested response

- Inadequacies in the land and marine conservation reserve system need to be addressed, along with better management of conservation and biodiversity both inside and outside reserves.
- Important vegetation communities and animal habitats (land, marine and freshwater) need to be identified and protective measures put in place.
- Government should consider introducing amendments to the *Wildlife Conservation Act 1950 (WA)* to protect key habitat areas as well as species, by 2000.
- Development and planning should minimise the clearing of native vegetation and encourage the development of corridors of vegetation. By the year 2000, all proposals to clear native vegetation should be subject to a review and approval process that specifically considers biodiversity impacts.
- Local conservation strategies need to be developed and should be based on the *National Strategy for Conservation of Australia's Biological Diversity* (Commonwealth of Australia, 1996).
- Build on existing partnerships between Aborigines and other land-users in biodiversity conservation.
- Develop a package of measures to encourage and facilitate conservation on private lands to complement the conservation reserve system and remove disincentives to conserving biodiversity.

Background

Description

Biodiversity means the variety of all life forms, that is, all plants, animals and micro-organisms in the environment, the genes they contain and the

ecosystems on which they are a part.

The health of ecosystems and the life forms associated with them is crucial to human health and prosperity. Biodiversity is central to the:

- species we harvest;
- genetic resources for crops, medicines and biotechnology;
- health of surrounding agricultural systems;
- protection of water quality; and
- quality of life in urban areas.

Maintaining biodiversity includes all activities that will assist in meeting the objectives for biodiversity as listed.

Condition

Western Australia is one of the most biologically diverse places in the world. This is because of the large expanse of the State, the variety of soil types, climate and the long period of isolation from other lands. There is also a high level of endemism in the biota of the south west.

Knowledge of Western Australia's Biodiversity

Western Australia has about 50 % of Australia's known flowering plants, ferns and cycads. There are over 800 distinctive plant communities. The south west of the State has the greatest variety of these plants. Knowledge of other plants such as mosses, liverworts, algae, fungi and lichen is very poor.

There are over 2700 vertebrate species in WA (Table 11). Of this group of animals, land mammals, birds and reptiles are best known.

There are also many tens of thousands of invertebrate animals, knowledge of which is poor or absent. It is estimated that there are 15,000–20,000 species of insects alone.

The marine environment of WA is extensive and highly diverse. Knowledge of the marine flora and invertebrate fauna is very limited. Fish are better known and about 1500 species have been identified so far.

With the exception of vertebrates, the flora and fauna of inland waters is poorly known. There are about 60 freshwater fish and 77 species of frogs known at present.

Lost and threatened biodiversity

There are 29 plant species presumed extinct and 321 plants threatened. Of the 149 species of terrestrial mammals, 10 are extinct and 36 are threatened. The greatest number of extinctions has occurred in the Wheatbelt region.

Ecosystems have also been lost or are threatened. This is especially so in the Wheatbelt and Swan Coastal Plain regions, for vegetation communities, wetlands and riverine ecosystems.

Pressure

Most of the activities of our society such as providing food, shelter, water, energy, transport, recreation and goods and services, affect biodiversity. The Swan Coastal Plain, Wheatbelt, South Coast, Naturaliste, Pilbara and Great Sandy Desert are regions which experience greatest pressure on biodiversity (adapted from Thackway & Cresswell, 1995).

The most significant pressure is the ongoing modification of habitat. This can be by the clearing and grazing of native vegetation, filling and draining of wetlands, damming rivers, recreation, contamination and introducing feral animals, weeds and diseases. Consequently, activities such as agriculture, aquaculture, forestry, fishing, tourism, mining and urban and industrial development need to be carefully managed to avoid detrimental impacts on biodiversity.

Many of the key environmental issues identified in this report such as land salinisation, loss of fringing vegetation, greenhouse effect, sedimentation, salinisation and eutrophication place pressures on maintenance of biodiversity.

Current response

The *Wildlife Conservation Act 1950 (WA)*, *Conservation and Land Management Act 1984 (WA)* and *Fish Resources Management Act 1994 (WA)*, provide the legislative basis for the State's management of biodiversity. The State is a signatory to the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia, 1996).

Undertaking scientific research and surveys are major activities to redress our lack of knowledge of biodiversity. From this information priority setting for conservation of threatened ecological communities, flora and fauna is reviewed annually.

Recovery programs are in place or being prepared for threatened species and ecological communities (Table 12).

Management and control of introduced animals, plants and diseases is an area of growing importance. Foxes, cats, rabbits, goats and dieback are high profile examples of these. Fox baiting programs have been

successful with native mammals showing a strong increase in numbers.

The *Urban Bushland Strategy* established the Urban Bushland Advisory Group which provides advice to the WA Planning Commission on bushland areas. It has also contributed to reviewing and updating the conservation status of urban bushland by identifying regionally significant bushland for protection. Review of conservation reserve recommendations in the System 6 area, including the Swan Coastal Plain, is also underway.

The conservation reserve system represents 6.2 % of the land area of WA. Marine conservation areas are limited and a program to add to the existing reserve system is underway.

Implications

Our knowledge about biodiversity at the ecosystem and species level is limited and at the genetic level, virtually
zero. There is an urgent need to identify and protect habitats and vegetation assemblages across the state.

Conservation outside the reserve system will need to increase substantially if many species and plant communities are to survive.

Understanding the relationship between human activity and biodiversity needs to be raised in the community, because much of what we take for granted in the environment is deteriorating. Without proactive management by all sections of society, biodiversity will continue to decline. Ultimately this will affect our own well being.

Table 11 *Composition of Western Australia's fauna.*

Group	Total number species described so far[a]	Estimates of known species[b]	Number of species presumed extinct in last 200 years	Number of species/ taxa extant but threatened
Mammals	149	185	10	31 terrestrial 5 marine
Birds	510	516	2	18 species and 13 subspecies
Reptiles	440	484	0	8 species and 3 subspecies
Amphibians	77	83	0	3
Fish	1600	1900	0	2
Vascular plants	~8,000	~12,000	27	293
Non vascular plants	~1,500	~100,000+ to ~200,000	0	1

Data Sources: a unpublished data from the Department of Conservation and Land Management, WA Museum
b Hopper *et al.*, (1996)

Table 12 *Recovery plans and management programs for threatened flora, fauna and ecological communities in Western Australia (data supplied by the Department of Conservation and Land Management).*

Grouping	Approved Recovery Plans and Management Programs	Draft Recovery Plans and Management Programs
Plants	Rose Mallee Wongan Triggerplant Region and District Threatened Flora Management Programs for the: • Northern Forest Region • Metropolitan Area • Merredin District • Albany District	Corrigin Grevillea Matchstick Banksia Wongan Cactus Wyalkatchem Foxglove Region and District Threatened Flora Management Programs for the: • Esperance District • Moora District • Narrogin District • Geraldton District • Katanning District Draft interim recovery plans for 32 other plant species
Mammals	Woylie Chuditch	Numbat Dibbler Shark Bay Mouse Gilbert's Potoroo Antina (Central Rock-rat)
Reptiles	Western Swamp Tortoise	Lancelin Island Skink
Amphibia	Orange-bellied and White-bellied frogs	
Birds	Noisy Scrub-bird	Night Parrot Draft interim recovery plan for the Western Ground Parrot
Ecological Communities		Toolibin Lake

Sheep grazing in unprotected remnant vegetation has led to complete removal of the understorey. Practices such as this continue to threaten biodiversity. Photograph by Agriculture Western Australia.

See Section 8 of the SoE *Reference Group Draft Working Papers* for more information on *Biodiversity*.

TRACKING PROGRESS TO ECOLOGICALLY SUSTAINABLE DEVELOPMENT IN THE USE OF NATURAL RESOURCES

Agriculture

Conclusion

Agriculture currently contributes about 20 % of WA's total exports. Much of the wealth of the State is the result of the development and use of arable and grazing lands over the last 100 years or so. This wealth has come at the great cost of widespread land degradation associated with unsustainable farming and grazing systems. There has been significant progress in developing and adopting more sustainable farming and grazing systems. While there has been progress in catchment scale approaches to sustainable farming systems, many of the existing practices are still degrading the land and waterways.

Objective

- To improve or maintain the condition of the State's natural resources.
- To ensure the use of best management practices which minimise environmental impact while improving profitability.
- To facilitate land-use changes within agriculture.
- To contribute to desirable ecological outcomes and long term profitability.

Next Steps

In the past, agricultural research has looked to increase crop yields, animal weight gains and short term profit margins. The research did not put as much emphasis on the long term effects on the land or the waterways. New ways of farming are required which consider these onsite and offsite effects and let farmers make a living.

No single approach will work. In agricultural areas improvements in sustainability will come from combinations of best management practices, e.g., minimum tillage, and land-use changes, e.g., integrated farm forestry. Implementation of the WA *Salinity Action Plan* coupled with research and development by Agriculture WA, evolution of farming systems and provisions of technical and catchment support services will be vital.

In the rangelands of WA flexible and innovative approaches to land-use options are required which tap the wilderness, conservation and heritage values of these lands.

Background

Description

The wheatbelt of WA supports broad-acre, rain-fed, farming across a wide range of soil types. Farmers grow wheat, other cereals, lupins, wool, meat, oil seeds and pulse crops. Most properties are in a strong financial position.

Farmers in the high rainfall traditional Woolbelt zone, who relied on wool for the major source of income, are now turning to cropping for economic survival. Areas which have not been previously cropped are being sown for the first time.

Farmers within the State's highest rainfall areas have traditionally produced beef cattle and prime lamb. There are many alternative and competing land-uses including horticulture, viticulture, dairying and hobby farms. Over 25,000 ha/year is being planted to commercial trees, particularly Western bluegum and pine.

The pastoral (cattle and sheep) industry of WA occupies about 38 % of the state or about 950,000 km^2.

The intensive agricultural industries, which include horticulture, dairying, piggeries and feedlots are found from Kununurra in the north to Albany in the south.

Environmental impacts

In agricultural areas, clearing over the last 100 years has caused groundwater tables to rise, bringing saline groundwater closer to the surface. This has resulted in about 9 % of the productive land becoming salty. Rivers also become salty. The rising salty water even damages buildings in the towns. Regulations to control clearing have been in place for several years but are not enough. The effects of earlier clearing will be seen for many years to come.

Soils are becoming more acid, as a result of farming practice. This means applied fertiliser is less effective and crop yields are lower. More herbicides are required to kill weeds. Soil structure decline, subsoil compaction

and water repellent soils are widespread affecting up to 34 % of agricultural land. Loss of topsoil through unwise cultural and grazing practices is easy to see but affects only a small area. The number of native plant and animal species has been greatly reduced through land clearing and other agricultural practices.

In pastoral areas, management practices are ecologically unsustainable. There has been widespread soil erosion and loss of perennial grasses and shrubs. Uncontrolled access of cattle has caused damage to critical wildlife habitats and siltation of rivers. There are, however, indications that the land is now being managed in a more sustainable way. Few of the properties in the sheep areas are providing enough money to cover reasonable living expenses. Aging fences are falling down and water points are deteriorating.

Intensive agricultural industries all have highly localised impacts on the environment. Smells, dust and chemical use affect people living nearby. Leaching of nutrients and farm chemicals damages waterways and estuaries. Often these industries are close to expanding towns and cities and compete for scarce farm land.

Challenges to Ecologically Sustainable Development

For agriculture to be assured of a prosperous future, land management practices in agricultural and pastoral lands must change. The Landcare movement has successfully raised awareness of land degradation.

Government assistance programs have adapted to tackle natural resource management, rural adjustment, environmental repair and improved business performance in an integrated way. Governments and the wider community must play a part where a change of management is required that has little benefit to the farmer but makes life better for others. Fixing our damaged waterways is one example. Much remains to be done.

A comprehensive approach is required covering: research and development; improved management practices and land-use changes; better options for economic, natural resource and biodiversity outcomes (including direct financial assistance for the 'public benefit'); and monitoring of outcomes. The best current example of this is the *WA Salinity Action Plan*.

Current response

At the international scale, Australia is committed to a number of conventions that guide ecologically sustainable agriculture.

At a national scale sustainable agriculture is guided by several key strategies reflecting both national and international imperatives.

There has been significant policy response in WA through the natural resource management strategy attached to the National Landcare Program and now regional initiatives for the Swan-Avon and Blackwood Catchments, the South Coast Region and the Gascoyne-Murchison Regional Strategy.

Agriculture WA is the lead agency for implementing these policies and strategies, and has the primary responsibility for achieving sustainable use of the agricultural and pastoral lands, although other agencies also play important roles. Recent changes in Agriculture WA have raised the profile of sustainable land-use and 47 % of its budget is allocated to resource protection and sustainable rural development. Effective monitoring for decision making in use of natural resources is an important component of this program.

Implications

Protection of the resource base is essential to ensure continued viability of agricultural and rural communities. Ecological sustainability provides the basic framework to economic and social well-being. Reclamation to pre-settlement conditions may not be economically feasible particularly on low value per hectare land such as pastoral leases.

Furthermore sustainability of industries is increasingly becoming necessary to access international markets and trade and to get the best prices. Those countries and industries that can show that their products are safe to eat and environmentally friendly 'Clean and Green' are predicted to enjoy an increasing market advantage.

See Section 3 of the SoE *Reference Group Draft Working Papers* for more information on *Agriculture*.

Fisheries

Conclusion

Almost all of WA's major commercial fisheries are being fished at sustainable levels. This is based on an annual assessment of fish stocks, the level of fishing activity and trends in fish catches.

Fishing pressure from recreational fishing however, is expanding and increasing restrictions on this sector will be required in the future.

Objective

To ensure that the State's fisheries resources are harvested sustainably while minimising the effect on the environment.

Next Steps

The Fisheries Department will continue to undertake a combination of directed research and appropriate management to ensure that all fisheries sectors (commercial, recreational and aquaculture) operate at sustainable levels with minimal impact on the aquatic environment. Monitoring the effects of fishing methods will be essential to provide the information required to enable management of fisheries on an ecologically sustainable basis.

The focus in the future will be on controlling recreational catches and developing aquaculture production on a sustainable basis. This will assist in meeting the market demands for seafood without compromising the sustainability of wild stocks or their habitats.

Background

Description

Western Australia's fisheries resources are shared between commercial and recreational fishing and aquaculture. The most valuable commercial fisheries rely on relatively high value, low volume products for their viability. These fisheries, rock lobster, abalone, prawn and scallop combined, are worth approximately $400 million annually. The remaining fisheries produce a large variety of finfish and shellfish in similar volumes but with generally lower prices. It is estimated that the add on value for all commercial fisheries is $1 billion per year.

Recreational fisheries are a major community asset involving about 30 % of the State's population (Reark Research, 1996). Recreational fishing is estimated to contribute more than $400 million a year to the State's economy.

The aquaculture industry competes for space within the marine environment. A diverse range of aquaculture ventures continue to develop throughout the State; however, the culture of pearl oysters in WA is the most successful. Pearl production in WA is worth about $150 million a year.

Environmental Impacts

Most fisheries in WA have limited impact on the general environment. In 1995–96, 18 of the 21 major commercial fisheries had breeding stock levels that were adequate to maintain present stocks. Methods that significantly impact on the environment, e.g., dredging and pelagic drift gill-netting are banned. Other methods that alter the environment, e.g., trawling and purse seining, are restricted but are know to cause environmental impacts. The numbers of these licences will be reduced over time as will the areas in which they are permitted to operate.

Fishing does change the overall abundance of the target species and in some cases the species which are closely related in the food chain.

Challenges to Ecologically Sustainable Development

Population growth and the resulting human-induced environmental changes (pollution, loss of habitat, sedimentation from dredge spoil and agricultural run off) continue to threaten WA fisheries. Improved fishing technology and exploitation of fish in previously remote areas, places unprecedented pressure on many fish stocks at all stages of their life cycle.

Outside of the State's marine waters, but within the EEZ, there is an Indonesian Artisanal fishery which targets a number of species and is difficult to monitor but is subject to an agreement with Indonesia. There is a also Japanese long-line tuna fishery which is the subject of a tri-national agreement between Australia, New Zealand and Japan. This agreement is compromised by fleets from other nations fishing outside the EEZ. A major environmental concern of this fishing is the incidental catch of albatross.

Environmental fluctuations such as the recent extended 'El Nino' condition can also affect fisheries. This climatic condition impacting on ocean currents is thought to have caused the recent decline in the herring trap fishery.

Current Response

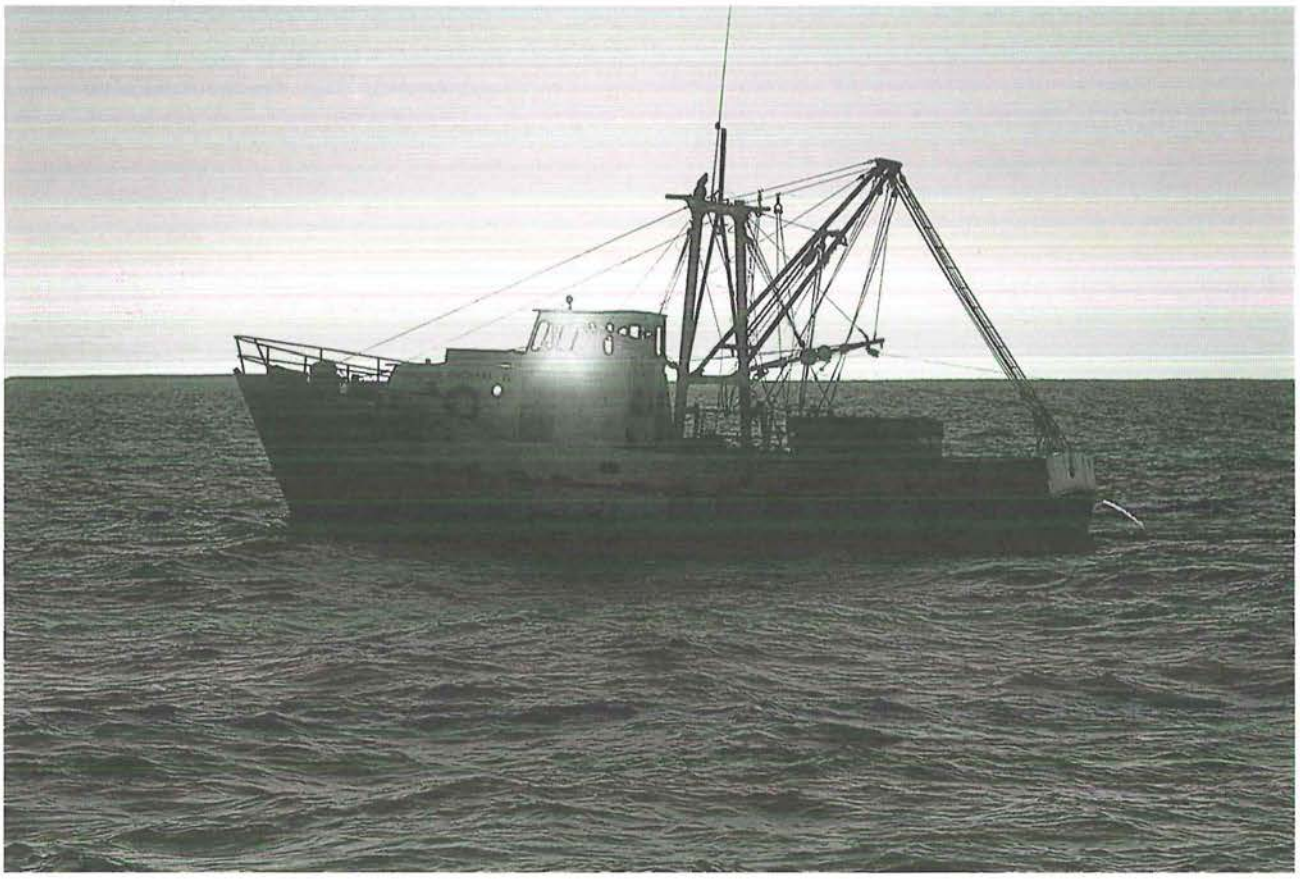
The Fisheries Department uses a range of techniques to manage WA's fisheries. In the commercial fishery, controls are placed on: the number and size of boat; the area of the fishery; and the amount or type of fishing gear; among others. These management arrangements have been successful largely as a result of research, field operations and management co-operation with industry.

Managing the recreational fishery is more difficult because of the increasing number of fishers. Present controls include restrictions on the number and size of fish caught and in some cases the times and areas fished. There is strong community involvement and support for regulation, placing an emphasis on sustaining fish stocks as well as valuing the fishing experience.

The Fish and Fish Habitat Protection Program has recently been established and the Fisheries Department is becoming more involved in habitat and species protection.

Implications

The overall response to management controls for each of the fisheries sectors has been positive. The major risk in the future is from competition between the sectors leading to increases in exploitation of fish stocks. A combination of research and management planning will ensure that all stocks fished are managed sustainably.



Western Australia's commercial fisheries are worth $400m annually. Photograph, Department of Environmental Protection.

See also *Fish Stocks* in this report.

See Section 3 of the SoE *Reference Group Draft Working Papers* for more information on *Fisheries*.

Forestry

Conclusion

Since the proclamation of the *Forests Act 1918 (WA)*, successive governments have managed the State forest for multiple uses, including timber production on a sustained yield basis. State forests are the subject of management plans, continuous research and monitoring that are designed to achieve ecologically sustainable forest uses.

Objective

The Department of Conservation and Land Management's Forest Management Plan 1994–2003 defines the State's objective for forest management: To manage the native forests of the south west of Western Australia, in consultation with the community, so that they provide the values required by society while sustaining indefinitely their biological and social diversity.

Next Steps

Key elements of ecologically sustainable development are already in place in the forestry sector. Action now centres on refinement of the conservation reserve system and forest management systems within the nationally agreed Regional Forest Agreement process and at a State level. Research needs to continue to further define interactions between different pressures on the forest, and their impacts, leading to fine-tuning of management. An increasing demand for timber requires a continued focus on the development of additional plantations on agricultural land, which in turn assists in redressing the water balances in cleared agricultural landscapes.

Background

Description

Approximately 71 % of the jarrah/marri forest and 82 % of the karri/marri forest that existed before European settlement have been retained in WA. Ninety two percent of the existing forest is retained under the control of the Crown and in the tenure of State forest or conservation reserve, e.g., National parks, and the remaining 8 % of native forest is in private ownership and subject to clearing controls under State legislation, e.g., *Soil and Land Conservation Act*. Private landholders are encouraged to manage their forests in a sustainable manner.

Forests are managed for a multitude of diverse industries and conservation values including: conservation and protection of biological diversity; recreation (including tourism); timber production through plantations and native forest on a sustainable yield basis (a wide range of valuable products such as sawn timber, veneers, composite fibreboards and pulp from residues are produced); water catchment protection — a source of drinking water in surface and underground catchments; and mining.

Environmental Impacts

A range of pressures impact on the forest environment. Unmanaged fire, disease, weeds and feral animals can change the forest ecosystem and impact on the beneficial uses and values of forests. Harvesting forest for timber products results in changes to forest structure over the short to medium term (up to 100 years). Other activities, including mining and agriculture, result in even longer term or complete disruption to forest ecosystems. Tourism and recreation development and activities must be carefully managed to minimise impact on the forest environment.

Challenges to Ecologically Sustainable Development

The most significant challenges to ecologically sustainable development of the forestry sector include activities which result in permanent loss of forests, or in plant diseases such as *Phytophthora cinnamomi* which impair the capacity of forest to grow and regenerate. The challenge of meeting increasing demands from our forests is met by increasing plantations for timber, along with value adding of native forest timbers. Changing community values and aspirations concerning forests are accommodated by regularly reviewing forest management plans and making adjustments as required.

Current Response

A range of responses are in place which contribute to sustainable forest management including; legislative procedures, including management planning; intensive research on, and management of, threats to biological processes such as *Phytophthora cinnamomi* on plant communities and feral predators, especially the European Fox, on animal communities; research into tree crops and the establishment of plantations; and management plans for fire. Existing procedures are in place to protect water and conservation values during timber harvesting and regeneration. The Forest Management Plan provides for a balance of age classes and the maintenance of older (mature and senescent) stands throughout the landscape.

Implications

The long history of multiple-use sustainable forest management has already led to many of the major pressures and threats being addressed. Agreement on indicators for reporting on ecologically sustainable forestry is critical to the effective management of forests.

See Section 3 of the SoE *Reference Group Draft Working Papers* for more information on *Forestry*.

Mining and Petroleum Production

Conclusion

The mining and petroleum industries have a good record of environmental performance. In many cases the industry has gone beyond mere compliance to legislative requirements and contributed to the sustainability of our natural resources. To ensure access to resources in the future, these levels of performance will need to be maintained and improved over time.

Objective

The Department of Minerals and Energy is responsible for managing the development of the State's mineral and petroleum resources for the benefit of the community. It aims to ensure sound environmental practice during and after exploration and production operations. The Department of Resources Development is responsible for ensuring the efficient and effective development of the State's natural resources, particularly mineral and petroleum resources, by the private sector for the ongoing benefit of the WA community.

Next steps

Increased scientific knowledge and changing environmental, social and economic conditions lead to the development of new practices and procedures which define and redefine management practices. Annual environmental audits provide additional information on the extent of the pressure on the environment, how industry is responding to these pressures and what further action is required by both industry and government.

Background

Description

Minerals and petroleum are non-renewable resources. However, with adequate environmental safeguards and management, it is possible to discover and develop these in a way that will benefit both present and future generations. Future needs for resources will be met by a combination of changing economics and new technology.

Environmental impacts

If not adequately managed, the following impacts may result from mining and petroleum operations:

Physical

Erosion, soil damage, changes to surface water and groundwater, salinisation, acidification, changes to coastal processes, dust and noise in the terrestrial environment, sedimentation and turbidity in the marine environment.

Biological

Loss of flora and fauna, habitats and food sources, and the introduction of pests and diseases

Social

Impacts on local industry, public works, conservation values, agriculture, heritage and recreation sites and landuse conflict.

Waste and pollution

Soil and water contamination, groundwater contamination, air emissions and localised marine pollution and the possibility of oil spills.

Challenges to Ecologically Sustainable Development

The mining and petroleum industries are a major source of income for WA. However, as the population increases, access to resources will be affected by competing needs. Environmental awareness and social pressure to minimise the impacts of development challenge industry to keep developing new procedures and practices to ensure that mineral and petroleum resources are identified and extracted using techniques consistent with the principles of ecologically sustainable development.

Current response

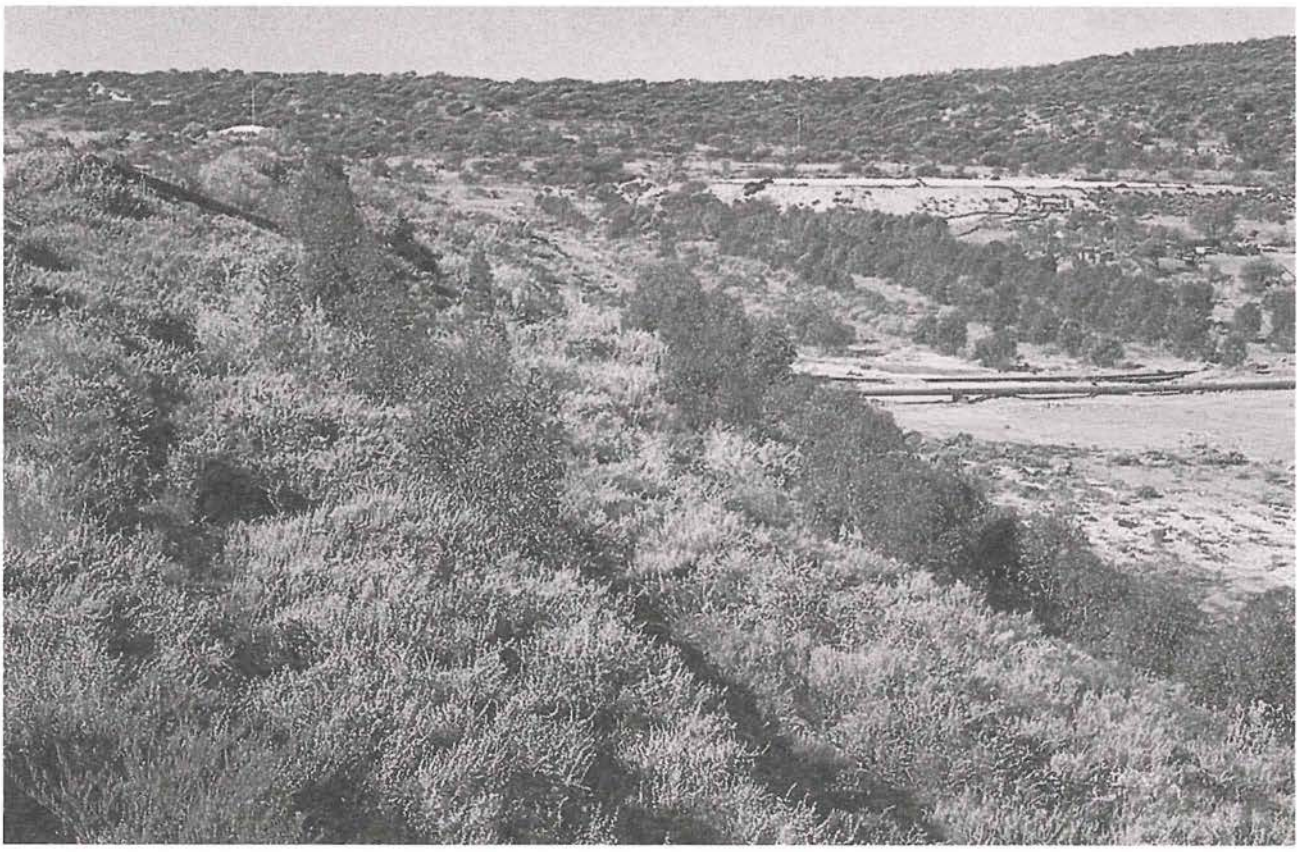
Steps already taken towards sustainabilty include:

- laws and conditions are in place which are continually reviewed to ensure environmental management reflects community values;
- rehabilitation that is compatible with future land use;
- environmental impact assessment of new proposals;
- community consultation;
- environmental reporting, auditing and monitoring of operations (including requirements under State Agreement Acts and the *Mining Act 1978 (WA)*);
- maintenance of a renewable environmental performance bond system to ensure mining companies comply with their environmental obligations;
- petroleum companies must have insurance funds to clean up the environment should the company be

unable to meet its environmental commitments in the event of an environmental accident;
- policy and guidelines are developed to assist mining and petroleum companies to sustainably develop mineral and petroleum resources;
- guidelines for environmental management of mining are prepared to assist industry to meet government and community expectations;
- oil spill contingency planning;
- reviews of industry performance;
- a number of industry associations have developed environmental codes of practice, e.g., the Minerals Council of Australia has a Code of Environmental Management and the Australian Petroleum Production and Exploration Association has a Code of Environmental Practice;
- mining and petroleum companies have contributed to various environmental projects including CALM's Western Shield Project and the Alcoa Landcare Program in the Avon catchment.
- programs to rehabilitate abandoned minesites identified as a public health risk are underway in the Eastern Goldfields, Galena area and at Wittenoom and Ravensthorpe. An inventory of abandoned mines has commenced so that remedial work can be done;
- flora surveys of areas where mining is proposed;
- feral animal control;
- management of pastoral leases through purchase by mining companies; and
- recognition of environmental excellence through a government award system.

Implications

If adequate environmental management and rehabilitation practices are not maintained by companies operating in the mining and petroleum industry, then companies may not be permitted to gain access to resources. The community is unlikely to support mining and petroleum production if such safeguards are not in place, especially in environmentally sensitive areas.



Western Mining Company, Mt Magnet tailings dam wall. Photograph, Department of Minerals and Energy.

See Section 3 of the SoE *Reference Group Draft Working Papers* for more information on *Mining and Petroleum Production.*

Tourism

Conclusion

The current and expected rapid growth of tourism in WA will bring increased pressure on the natural environments used by the tourism industry. To ensure these assets are protected a greater allocation of resources is necessary to measure and understand the potential impacts and to introduce methods to ensure they are controlled.

Objective

To preserve the natural environment while enabling nature-based tourism and other tourism activities.

Next Steps

Government agencies involved in the management and promotion of the natural environments used by the tourism industry must further develop methods of measuring the impact tourism is having on the environment. Existing strategies must be refined and new approaches developed to ensure the areas being utilised by tourists are adequately protected from damage.

Background

Description

The tourism industry consists of many sectors and uses a wide variety of the State's environments in many different ways. This is generally passive use that should not of itself cause a great impact on the environment except in the case of large scale developments or a concentration of developments in one area.

Environmental Impacts

Tourism does have the potential to impact on the environment in the form of accommodation development, coaches, four-wheel-drive and private vehicle travel and possible damage caused by pedestrian traffic. In many cases the level of impact is directly linked to the volume of development taking place and tourist numbers visiting an area or attraction.

Challenges to Ecologically Sustainable Development

The growth of visitor numbers to this State, especially from international markets, will require the introduction of new methods to regulate their potential impact.

The development of methods to identify visitor 'carrying capacities' for our natural assets is a major challenge. If the 'carrying capacity' of areas can be established, the most appropriate form of controls can be put in place to ensure the environment is protected.

It is necessary to change objectives for tourism growth from focussing on visitor numbers to the yield that is achieved from the visitors received, up to the identified carrying capacity. Once the determined carrying capacity is reached the focus will be on gaining optimal visitor expenditure from the visitors received while ensuring the environment is protected.

Current Response

The Department of Conservation and Land Management, as a major manager of lands and waters utilised for tourism, has instituted a range of management practices to ensure the protection of the assets and their sustainable use for tourism.

The WA Tourism Commission and CALM have prepared a draft nature-based tourism strategy to guide the sustainable development of the tourism industry in the future. The strategy will be in place by the end of 1997.

The WA Tourism Commission has in recent times shifted from only measuring increases in visitor numbers to include increases in visitor expenditure.

The WA Tourism Commission is also implementing a quality assurance program for the tourism industry that will encompass environmental guidelines.

Implications

The future of the tourism industry relies on the protection of the State's natural assets and environment. Poor management of these assets has the potential to destroy the very basis of what attracts tourists to WA.

See Section 3 of the SoE *Reference Group Draft Working Papers* for more information on *Tourism*.

Water Supply

Conclusion

Increasing demands for access to water due to population growth and economic activity are being satisfactorily managed although more attention is required for surface water allocation particularly in determining environmental water provisions. Water efficiency responses are being adequately addressed in the priority demand centres of Perth and Kalgoorlie.

Strong actions are required to address land-use pressures on existing and potential water supplies. Salinity threats to the 'marginal' quality south west catchments are an ongoing problem. Urban development pressures on groundwater resources in the Perth region are now being satisfactorily addressed through implementation of the recommendations of the Select Committee on Metropolitan Development and Groundwater Supplies (Legislative Assembly, 1994). Potential climate change effects on water supply system yields in the south west will need to be addressed.

Objectives

- Ensure that consumptive use of water is kept within environmentally sustainable limits.
- Assign access to available water resources in accordance with community priorities.
- Ensure appropriate protection of water resources earmarked for consumptive use.
- Minimise the need for additional water resource development by ensuring efficient use of existing water supplies.

Next Steps

- Continue to manage ongoing pressures for water source development to keep allocations within sustainable limits. Provide additional attention to management of surface water allocation particularly the determination of environmental water provisions.
- In the semi-arid Pilbara and Kimberley regions, identify high value water dependent environmental features, improve the determination of environmental water provisions from existing or proposed sources and increase the management of mine dewatering arrangements.
- Implement the *WA Salinity Action Plan*. Fully implement the recommendations of the Select Committee on Metropolitan Development and Groundwater Supplies.
- Investigate the potential climate change effects on water resources and reach agreement on possible yield reductions of existing and proposed sources for a nominated period. This will need to make provision for environmental water needs.

Background

Description

Water is extracted from rivers, streams, wetlands and groundwater aquifers for domestic, commercial, institutional, industrial, irrigation and rural use. This extraction of water from the natural environment needs to be carefully managed to ensure long term sustainability.

Environmental impacts

The main onsite impacts are:

- cumulative impact on vegetation complexes and associated habitat;
- possible loss of high environmental value river reaches; and
- direct loss of habitat and native fauna, e.g., native fish, at damsites, reservoirs and treatment plants.

The main offsite impacts are:

- reduced water available to maintain downstream water-dependent environments;
- barrier effect on fauna movement upstream; and
- possible saltwater intrusion into fresh groundwater.

Challenges to Ecologically Sustainable Development

Increasing population growth and associated economic and social activity lead to increasing demands for water. At a regional scale the two areas with high levels of utilisation are Perth and the Goldfields.

Areas with comparatively high levels of utilisation need to be carefully managed to prevent over allocation and handle competition for limited available water. About two thirds of the licensed groundwater use is covered by formal groundwater area management plans with highest priority placed on areas with high utilisation levels. About 5 % of groundwater management sub-areas have an over-allocation of water.

There are currently few formal management plans for surface water use. Hence it is more difficult to determine if there is any over-allocation of surface water.

See Section 3 of the SoE *Reference Group Draft Working Papers* for more information on *Water Supply*.

The mining industry in the goldfields makes extensive use of hyper-saline groundwater from paleochannel aquifers to extract minerals from ore. Because the hypersaline water does not support any ecological values, extraction rates well in excess of recharge are allowed and the mining industry accepts the steady depletion of the resource. Surface vegetation does not rely on the saline to hypersaline groundwater in the 20–70 m of the relatively impermeable clays covering the paleochannel aquifers.

Increasing development pressures in the semi-arid Pilbara and Kimberley regions will require careful management of water resources. Water-dependent environmental features have high ecological and social value in these regions and it will be important to identify and prevent loss through inappropriate development. Determining environmental water provisions from surface and groundwater sources in a semi-arid climate is difficult and will require greater attention. Mine dewatering can have significant effects on local groundwater and discharge streamlines.

Past land clearing for agriculture has resulted in rising salinity levels and extensive loss of potential water resources. Ongoing deterioration of unfenced remnant vegetation by grazing is contributing to this problem.

The shallow groundwater sources in the Perth region have come under pressure from potentially polluting land-use activity.

In the south west, average annual rainfalls over the last few decades have been significantly lower than the long term average. Hence water supply systems may not have enough capacity to meet demand without ongoing restrictions on use.

Current responses

National concern about widespread water resource degradation led to the 1994 Council of Australian Governments agreement on water resources policy. The State Government has begun work on this strategic framework for a range of water policy issues.

The process for setting sustainable limits on groundwater use is well established from the extensive work done on the Gnangara and Jandakot mound resources. In contrast to groundwater, the determination of environmental water requirements for surface water is in its infancy.

The WRC requires water users to be efficient in their water use. A water efficiency program, developed as part of the 'Perth's water future strategy' is currently being implemented by the Water Corporation. Likewise a water efficiency program for Kalgoorlie has been highly successful in seeking to achieve a 'waterwise city'.

The WRC gives priority to areas with relatively high levels of utilisation. This involves more detailed assessment of the sustainable yield limit, increased monitoring of indicators (water levels and environmental indicators), more stringent licensing and an emphasis on efficient water use by existing users.

In response to concerns about the rising salinity levels of south west rivers the Government initiated clearing control and land alienation bans on selected catchments in the south west during the late 1970s.

In addition, the WRC has replanted about 8000 ha in a scheme of partial reforestation of the Wellington Dam catchment.

Pressures for urban development over metropolitan groundwater resources were the subject of a recent parliamentary inquiry (Legislative Assembly, 1994). The Select Committee recommended to Government that protection of the shallow groundwater reserves of the Perth area should have precedence over development and that there should be a strengthening of the legislation to achieve this, combined with improved coordination of Government agency processes.

With respect to climatic variability concerns, the previous Water Authority 'derated' the system yields of surface water sources serving the Metropolitan Water Supply system in the mid-1980s.

Implications

There are significant risks to the community and the environment if pressures on the sustainable use of water are not managed well. Inefficient use will lead to excessive development of limited water resources. Overallocation and failure to address climate change will damage water-dependant ecosystems and cause water supply shortages. The water quality of public supplies will deteriorate if land-use pressures are not well controlled.

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Dodson Nick
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Donnes Geoff
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Hardy Justin
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Heywood Andrew
Higgins Brendan
Higham Andrew
Hill Peter
Hill Susan
Hipkins Max
Hoar Peter
Holland McNair Lisa
Holm Alec
Hollyock Ben
Holyoake Kelly
Hudson Peter
Hyder-Griffiths Bridget
James Frank
Jenkins Bryan
Jennings Helga
Johnstone Harvey
Kay Rob
Kealley Ian
Keighery Bronwen
Keighery Greg
Kerr Mike
Kerruish Ron
Kirkman Hugh
Kite Jeff
Klemm Verity
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Laidler Terry
Lambeck Rod
Landsburg Joule
Lane Jim
Laughlin Linda
Lavery Paul
Leaman Greg
Leclercq Sabine
Lewis Fay
Liddelow Shelley
Little Kathy
Loh Ian
Long Vicki
Loughton Eric
Lowe Godfrey
Lukatelich Rod
Macklin Kathy
Majer Karen
Malborough Steven
Mandyczewsky Roman
Marris Julie
Marsack Peter
Martin Kevin
Masini Ray
Maslin Richard
Masters Bernie
Masterson Susan
Mawson Peter
May Andrew
McAlpine Kevin
McCann Tony
McCarthy Mick
McCrae Ian
McCumstie Peter
McFarlane Don
McKellar Richard
McKenzie Norm
McLeod Pauline
McNally Peter
McNamara Keiran
McVeigh Terry
Middle Garry
Miller Darryl
Miragliotta John
Mitchell Andrew
Mitchell Tom
Mondy Terry
Mueller Greg
Muller Chris
Murray Colin
Murray Frank
Narvaez Sally
Nabbin Theo
Neal Roy
Newman Letisha
Nguyen Xuan
Nicholson Charlie
Noonan John
Novelly Paul
Nulsen Bob
Nunn David
Olney George
O'Byrne Margo
O'Rielly Ken
Osborne Sue
Ottaway John
Park Dale
Parker Michael
Paulin Bob
Payne Allan
Pearson David
Peck Adrian
Pen Luke
Pendoley Kelly
Pitt David
Pobar Greg
Porter Bill
Porter Shane
Preston Bill
Pringle Hugh
Quartermaine Rod
Ramshaw Wendy
Rayner Ken
Reid Viv
Reid David
Richardson Tony
Ripepi Joe
Rivers Mark
Rob Malcolm
Roberts Phil
Robertson Gordon
Robins Noel
Robinson Alex
Rose Tom
Rose David
Rose Wendy
Rowe Michael
Rutherford Peter
Ryan Greg
Ryan Peter
Rye Peter
Sanders Colin
Saunders Dennis
Scally Gavin
Scleuter Laurie
Seow Jimmy
Serventy Lynne
Shadforth Ray
Sharma Munna
Sharp Peter
Sharp Jim
Shaw Jenny
Shaw Laurinda
Sheltema Martine
Shepherd Ron
Silcock John
Simms Virginia
Simpson Chris
Sippe Rob
Skitmore Peter
Skitmore Ester
Smith Rochelle
Smith Peter
Smurthwaite Tony
Speed Russell
Star Sue
Stejskal Iva
Stephens Graeme
Stone Roy
Summers Rob
Sutton John
Switzer Carolyn
Taylor Martin
Tiederman Klaus
Thompson Steve
Thomson Peter
Tingey Wayne
Tomilinson Tony
Tucker Jim
Tupman Peter
Turpin Margaret
Underwood Roger
Van der Wiele Henk
Van Vreeswyk Sandra
Vear Kevin
Vellacott Steve
Ventriss Harry
Vlok Adrian
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Waite Mike
Walker Ken
Wallace Ken
Wallace Jeremy
Wallis Ray
Ward Trevor
Warren Jon
Warren Louis
Warrilow Peter
Watson Giz
Watson Ian
Watson John
Watt Leon
Watt Paul
Weaver David
Webb Jean
Wheater Richard
Wheaton Buddy
Whiteman Tim
Whisson Gary
Wignal Don
Wilcox David
Wilke Steve
Williams Adrian
Willing Tim
Wong Jookie
Wright Eric
Wyre Gordon
Young Geoff

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