State of the Environment REPORT

Environment 1998 Western Australia

The production of this report was co-ordinated by the State of the Environment Reference Group with the assistance of Regional Focus Groups, government agencies and scientific experts.

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Environment Western Australia 1998: State of the Environment Report

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Back cover: Jarrah bushland; Pygmy Possum. (Photographer: Lochman Transparencies)

1998 is International Year of the Ocean, in recognition of the importance of the ocean, the marine environment and its resources for life on earth.

This report is printed on recycled paper.

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. A major challenge in undertaking a report of this kind 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 Western Australia, 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 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 1998. These include the following.

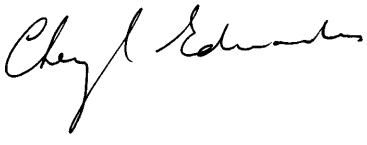
- Specific environmental issues are described concisely and given a priority in terms of environmental status.
- The condition of the environment, pressures acting on it and responses to these are presented.
- This State of the Environment Report is designed as a guide to future policy.
- Important natural 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 report.
- A draft report was released in July 1997 for public comment and reviewed to form the basis of this report.

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

As part of this approach the Government will undertake to indicate its response to the issues and suggestions contained in this report. In particular I envisage that a framework for co-ordinated environmental monitoring and reporting will be established across Government so that progress towards environmental objectives established in this report can be measured in the future.

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 this report.

I commend this report to you and encourage you to act on it.



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

PREFACE

Environment Western Australia 1998: State of the Environment Report provides an overview of the key environmental issues facing Western Australia. The approach taken to produce this report is different from that used to produce the 1992 *State of the Environment Report*. This report 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 State of the Environment Reference Group was established by the Minister for the Environment. Its members include:

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

The Reference Group has made a conscious effort to ensure that the report is easy to read and understand. As a consequence, there is 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 regional information is provided for each of the 22 environmental issues in the *State of the Environment Reference Group Draft Working Papers* (Government of Western Australia, 1997a).

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

Ms Denise Allen; Mr Andrew Higham; Mr Michael Rowe; Dr Ray Wallis and Mr Tim Whiteman.

DR BRYAN JENKINS
CHIEF EXECUTIVE OFFICER
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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STATE OF THE ENVIRONMENT REPORTING IN WESTERN AUSTRALIA

Process

Western Australia's first *State of the Environment Report* (Government of Western Australia, 1992) 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 report based on the Organisation for Economic Co-operation and Development's (OECD) pressure–state–response model (Figure 1).

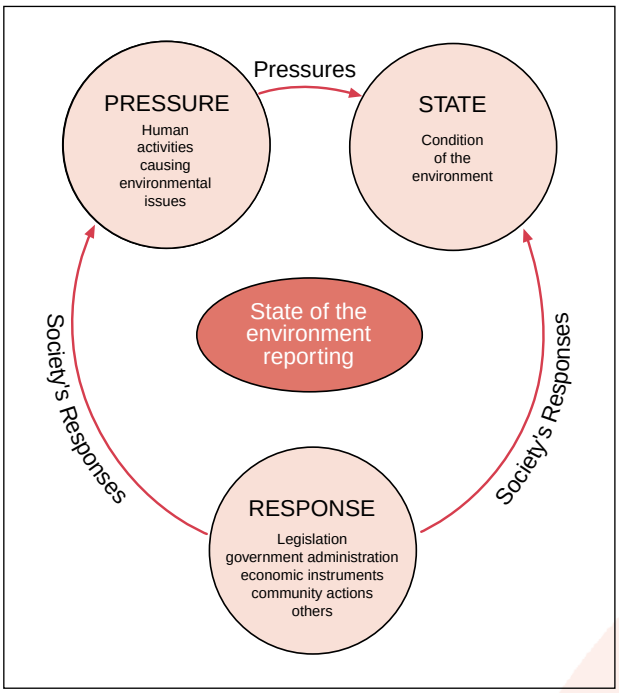


Figure 1. *The pressure–state–response model used in State of the Environment reporting.*

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

This report and the process to develop it differ 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 State of the Environment (SoE) Reference Group to steer the SoE reporting process (see Preface). 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 environment. Rather it focuses on key environmental issues identified by the SoE Regional Focus Groups and the Reference Group and from public comments on the draft report.

Regional Focus Groups were established based on environmental regions across the State. These regions were chosen to reflect the unique diversity of Western Australia's environment and are broadly based on the Interim Biogeographic Regionalisation for Australia (IBRA). 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, for example, 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 *State of the Environment Reference Group Draft Working Papers* (Government of Western Australia, 1997a).

The Minister for Environment released a draft SoE report (*Environment Western Australia 1997*) in July 1997 for a 3-month public comment period. The Reference Group then considered the public input in preparation of this report.

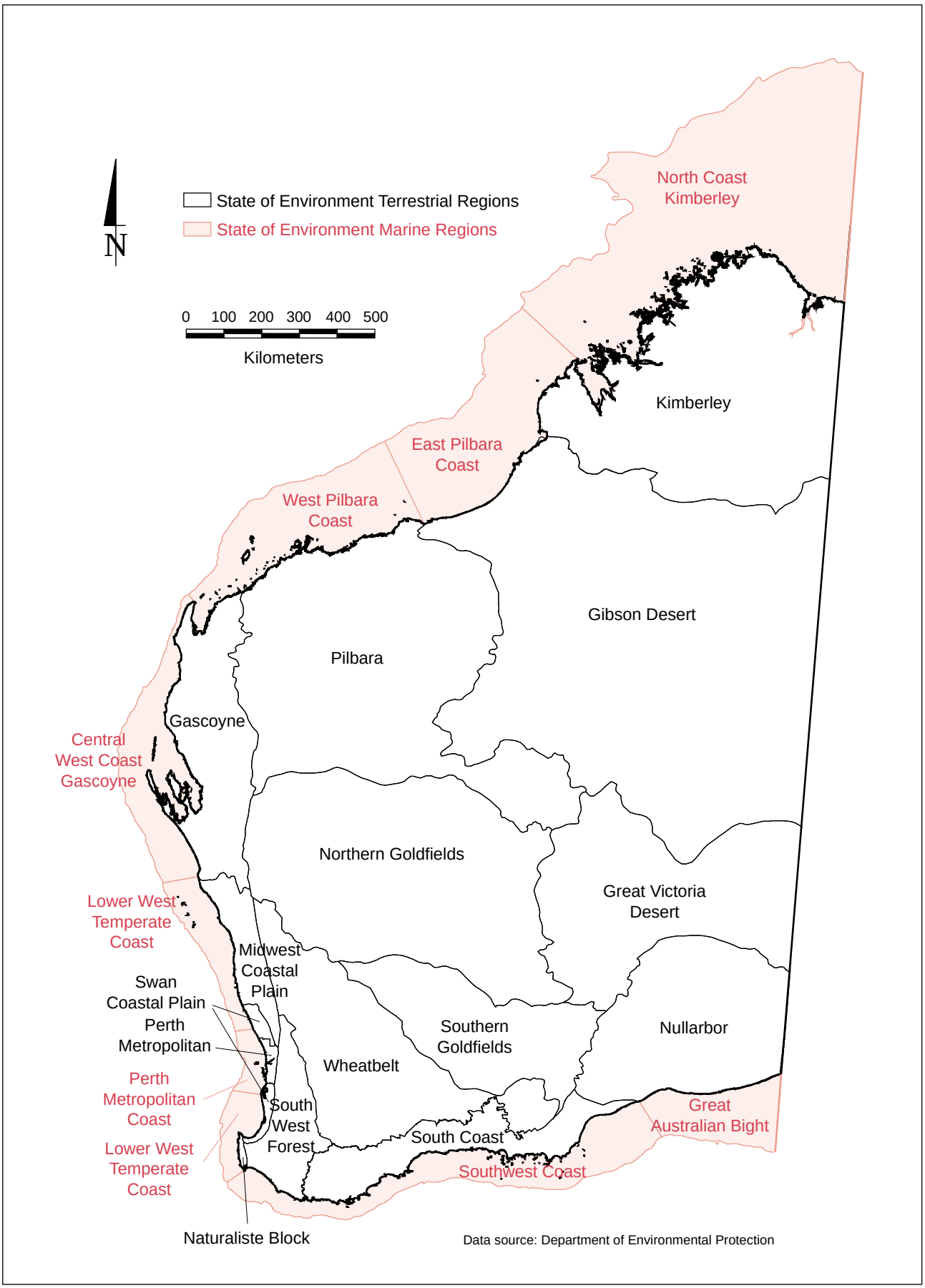


Figure 2. *State of the Environment reporting regions for Western Australia.*

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

- agriculture (Agriculture Western Australia);
- energy (Office of Energy);
- fisheries (Fisheries Western Australia);
- forestry (Department of Conservation and Land Management);
- mining and petroleum production (Department of Minerals and Energy);
- tourism (Western Australian Tourism Commission); and
- water supply (Water and Rivers Commission).

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 report where possible. The full set of first generation indicators is included in the *State of the Environment 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 Report

This report can be divided into three main sections. It provides information on two fundamental pressures which impact on most components of the environment, Population and the Environment and Consumption and the Environment. The report then discusses 22 priority environmental issues facing Western Australia. The format for this section is described below. The sustainability of the main natural resource sectors (agriculture, energy, fisheries, forestry, mining and petroleum production, tourism and water supply) is also described.

The 22 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 maintenance of biodiversity;
- the atmosphere;
- land;
- inland water (groundwater, rivers, wetlands and estuaries); and
- the marine environment.

To some extent this is an artificial grouping as many of the environmental issues are inter-connected and affect different parts of the environment, for example, rangeland degradation includes aspects of erosion, sedimentation and biodiversity. Some of the key inter-relationships between environmental issues are covered in the introductory sections to these main categories. 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 on the bottom of each page.

The format for discussion of each environmental issue is shown in the box.

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 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

A broad environmental objective for the issue.

Indicators

A measure of the severity and extent of the issue (condition indicator); a measure of the cause(s) of the issue (pressure indicator); and a measure of society's response to the issue (response indicator). These are numbered sequentially throughout the report.

Suggested Responses

Makes recommendations on actions required for each issue. The Regional Focus Groups, the community through public submissions and the SoE 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. Where possible, a comparison is made with the 1992 *State of the Environment Report*.

Pressure

Identifies key causes for each issue.

Current Responses

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

Implications

Identifies social, environmental and economic implications of the issue.

Cross-referencing

A reference to the *State of the Environment Report 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 report.

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

The framework for ongoing SoE reporting in Western Australia combines the following principles:

- provide for all relevant government agencies, community-based organisations and the private sector to be part of the process (policy development, monitoring, reporting and so on);
- ensure co-ordination and integration in monitoring, analysis and reporting and avoid omission, duplication and repetition;
- enable reporting to Government on priority environmental issues and associated indicators including recommendations for priority action and funding;
- be compatible with, and actively provide links to, the various tiers of reporting processes that have developed, that is, local, catchment, regional, state and national;
- deliver annual outcomes in line with audit requirements and incorporate appropriate indicators into existing annual reporting mechanisms where appropriate;
- provide opportunities for a number of reports to be produced according to various attributes (for example, by 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 for progress to be reported to the community; and
- be continuously updated and accessible to all members of the community.

The Department of Environmental Protection will be responsible for ongoing SoE reporting based on this framework. The Government will need to ensure that appropriate resources and mechanisms are in place. The collective effectiveness of our actions will be measured by the degree to which they bring about a positive change in all environmental indicators. By linking objectives, indicators and responses in this manner, and having a framework for monitoring and reporting, the community can be confident that actions taken to manage environmental issues will be better targeted, more efficient and 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. It will assist in ensuring that the environmental performance of government agencies is open and accountable.

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

WESTERN AUSTRALIA'S ENVIRONMENT

Physical Features

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

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, for example, the 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-western coastal plains are formed from more recent sand deposits, for example, the 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 are a number of distinct climatic regions. These range from the moist tropical climate of summer monsoons in the north west Kimberley to the hot dry climate with summer cyclones of the Pilbara and Gascoyne, the hot dry arid interior of the Gibson and Great Victoria Deserts and the temperate climate of winter rain and dry summers in the south west of the State. Figure 3 shows the rainfall distribution in Western Australia.

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 Western Australia 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. However, Aboriginals in Western Australia were able to develop complex and diverse communities that were sustainable in the long term.

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

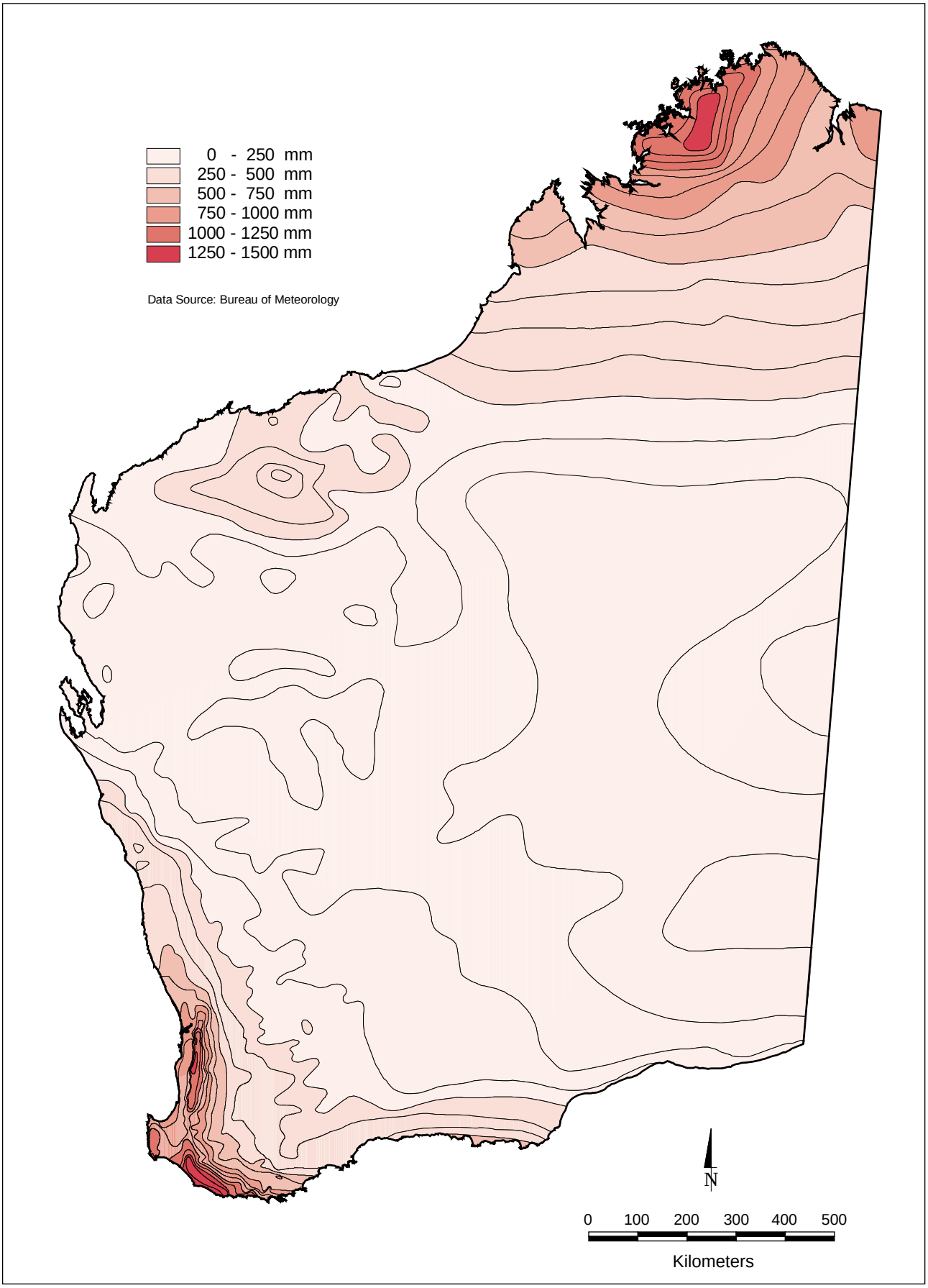


Figure 3. *Average annual rainfall distribution for Western Australia (Data since 1940).*

CONCLUSION AND STATEWIDE PRIORITIES

Conclusion

Since the 1992 SoE Report there is now more information on the environment. This 1998 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.

For each environmental issue facing the State and for each natural resource sector an Objective(s) is given. When taken collectively, these amount to setting the vision for Western Australia's environment by providing clear direction for future management.

The report emphasises the importance of establishing agreed indicators and monitoring mechanisms for the future so that progress can be assessed. A collective response is required by all levels of government and all sections of the community to ensure that monitoring and management mechanisms are put in place.

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, for example, reduced levels of atmospheric lead and sulphur dioxide, declining chlorine levels in the stratospheric ozone layer and the recovery of some threatened mammal species.

Community education is required to improve awareness about how we impact on the environment, and to improve our knowledge of how to adjust our behaviour to reduce our environmental impacts.

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 available to be discussed in this report.

A substantial effort is being applied by the community, government and industry to ensure that social and economic development is ecologically sustainable. At present there are agreed measures for sustainable resource use, for example, fisheries and forestry, but there are few agreed measures of ecological sustainability for these resources. Consequently 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 22 environmental issues considered in this report are important. The SoE Reference Group has assigned priority by rating each issue in terms of its environmental status. The fundamental pressures of population and consumption were not ranked as they are of great importance to any single issue. 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 SoE Reference Group based on core principles of ecologically sustainable development (ESD):

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

The SoE 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 SoE Reference Group has provided an environmental status rating of one to five for each issue on a statewide basis. These are listed below. Within each ranking the order cited has no significance. Five markers indicates the highest priority for government and community action based on the above criteria.

✪✪✪✪✪ (Highest priority environmental status)
- Land Salinisation
- Maintaining Biodiversity
- Salinisation of Inland Waters

✪✪✪✪
- Enhanced Greenhouse Effect
- Erosion
- Eutrophication
- Land Contamination
- Loss of Fringing Vegetation
- Stratospheric Ozone Depletion

✪✪✪
- Contamination of Inland Waters
- Contamination of the Marine Environment
- Degradation of Marine Habitats
- Haze from Particulates
- Introduction of Exotic Marine Species
- Photochemical Smog
- Sedimentation
- Soil Acidification

✪✪
- Carbon Monoxide
- Sulphur Dioxide
- Waterlogging

✪
- Dust
- Lead

Regional Overview

The 22 statewide priority issues ranked above vary in their geographic extent from one environmental region to another within the State. The variation between regions is shown in Figure 4.

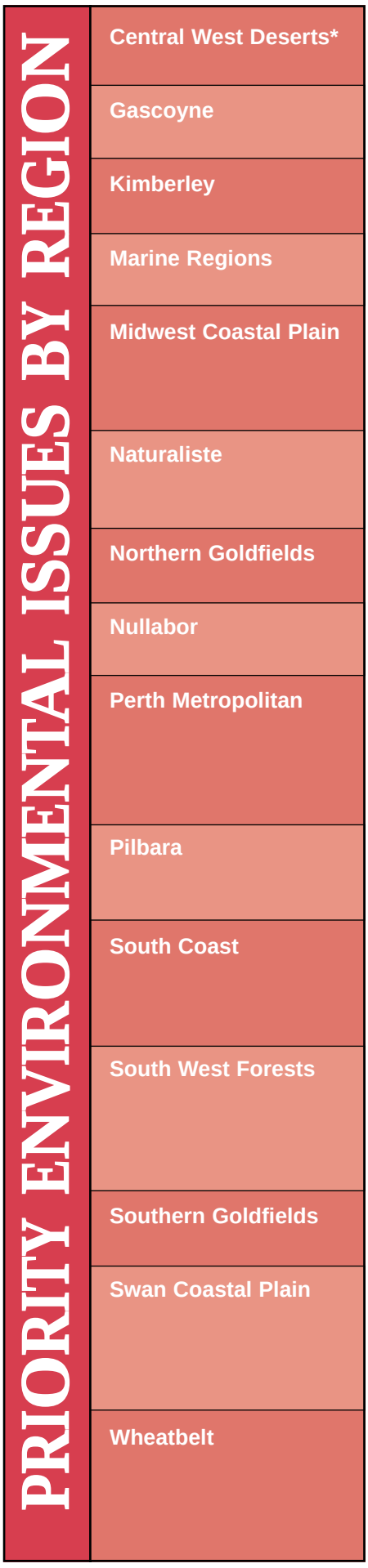


Figure 4. *Priority environmental issues by region.*

• Enhanced Greenhouse Effect • Sedimentation	• Erosion • Stratospheric Ozone Depletion	• Maintaining Biodiversity
• Enhanced Greenhouse Effect • Sedimentation	• Erosion • Stratospheric Ozone Depletion	• Maintaining Biodiversity
• Enhanced Greenhouse Effect • Maintaining Biodiversity	• Erosion • Sedimenation	• Loss of Fringing Vegetation • Stratospheric Ozone Depletion
• Contamination of the Marine Environment • Maintaining Biodiversity	• Degradation of Marine Habitats	• Introduction of Exotic Marine Species
• Acidification • Eutrophication • Maintaining Biodiversity • Stratospheric Ozone Depletion	• Enhanced Greenhouse Effect • Land Salinisation • Salinisation of Inland Waters	• Erosion • Loss of Fringing Vegetation • Sedimentation
• Acidification • Eutrophication • Maintaining Biodiversity	• Enhanced Greenhouse Effect • Land Salinisation • Stratospheric Ozone Depletion	• Erosion • Loss of Fringing Vegetation
• Enhanced Greenhouse Effect • Stratospheric Ozone Depletion	• Erosion	• Maintaining Biodiversity
• Enhanced Greenhouse Effect • Stratospheric Ozone Depletion	• Erosion	• Maintaining Biodiversity
• Carbon Monoxide • Enhanced Greenhouse Effect • Land Contamination • Maintaining Biodiversity • Sulphur Dioxide	• Contamination of Inland Waters • Eutrophication • Lead • Photochemical Smog	• Dust • Haze from Particulates • Loss of Fringing Vegetation • Stratospheric Ozone Depletion
• Dust • Loss of Fringing Vegetation • Stratospheric Ozone Depletion	• Enhanced Greenhouse Effect • Maintaining Biodiversity	• Erosion • Sedimentation
• Acidification • Eutrophication • Maintaining Biodiversity • Stratospheric Ozone Depletion	• Enhanced Greenhouse Effect • Land Salinisation • Salinisation of Inland Waters • Waterlogging	• Erosion • Loss of Fringing Vegetation • Sedimentation
• Acidification • Erosion • Land Salinisation • Salinisation of Inland Waters • Waterlogging	• Contamination of Inland Waters • Eutrophication • Loss of Fringing Vegetation • Sedimentation	• Enhanced Greenhouse Effect • Land Contamination • Maintaining Biodiversity • Stratospheric Ozone Depletion
• Dust • Maintaining Biodiversity	• Enhanced Greenhouse Effect • Stratospheric Ozone Depletion	• Erosion • Sulphur Dioxide
• Acidification • Erosion • Land Salinisation • Salinisation of Inland Waters • Sulphur Dioxide	• Contamination of Inland Waters • Eutrophication • Loss of Fringing Vegetation • Sedimentation • Waterlogging	• Enhanced Greenhouse Effect • Land Contamination • Maintaining Biodiversity • Stratospheric Ozone Depletion
• Acidification • Erosion • Land Salinisation • Salinisation of Inland Waters • Waterlogging	• Contamination of Inland Waters • Eutrophication • Loss of Fringing Vegetation • Sedimentation	• Enhanced Greenhouse Effect • Land Contamination • Maintaining Biodiversity • Stratospheric Ozone Depletion

FUNDAMENTAL PRESSURES

The two fundamental pressures that are discussed in this report are Population and the Environment, and Consumption and the Environment. These pressures are usually the basis for the environmental issues that follow in this report.

For each of these pressures Objectives are established and Indicators are given that endeavour to reflect the severity and extent of the issue (condition indicator), the cause(s) of the issue (pressure indicator) and society's response to managing the issue by reducing the pressures or improving the condition (response indicator).

Population and the Environment

Objectives

These should be developed through the proposed Population and Consumption Strategy for Western Australia (see below).

Indicators

Indicators should be further developed through the Population and Consumption Strategy for Western Australia.

Indicator 1.1

Ecological footprint of the Western Australian population

Discussed in Population and Resource Consumption section below.

Indicator 1.2

Population growth rate

See Current Responses section below.

Suggested Responses

- The Western Australian Government should develop an ecologically sustainable Population and Consumption Strategy for Western Australia. This should outline plans for incorporating environmental and social costs into decision-making, and eventually into pricing mechanisms.
- At present, housing continues to be constructed in a manner that encourages high resource use patterns. A set of building standards should be implemented progressively to meet world best environmental practice in housing design and construction.
- An analysis of the environmental and social costs of development options should be incorporated into decision-making to ensure that economic development maximises the benefits to Western Australians.

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 where population is predicted to increase most rapidly. Most of us live in low density, mainly coastal settlements and we 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 high costs in providing clean air, land and water for our population. Present planning processes cater for continued economic and population growth in Western Australia. Strategies to stabilise growth have not been developed.

Population and consumption 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 Western Australia's population grows, 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 and the rate of migration into and out of Western Australia. In 1996 Western Australia's population was 1.75 million, with 1.28 million (73 per cent) of those people living in Perth. Perth stretches approximately 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 per cent of wetlands in this area have been lost or irreversibly degraded (Government of Western Australia, 1992).

Migration Trends

Interstate and overseas migration continues to be an important factor in Western Australia'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, 1996).

Settlement Patterns

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

Planning Processes

Land-use planning in Western Australia 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.

Planning from the mid-1950s has directed Perth's growth predominantly along corridors. This growth has fed strategic regional centres mostly to the north (Joondalup and Midland) and south (Rockingham and Armadale) of the city centre. Private motor vehicles have been the favoured mode of transport between regional and city centres to date and previous corridor planning has provided for the ease of private car usage over and above the supply and usage of public transportation (especially to the south of the city). This, in turn, has increased air pollution, noise, energy consumption and urban congestion problems (see section on Carbon Monoxide).

The corridor plan and earlier planning frameworks have had unintentional benefits by preventing urban development on Perth's valuable groundwater supply areas and allocating these areas to forestry reserves.

Currently, long-term planning builds on earlier corridor principles in addition to encouraging population growth in regional centres (Western Australian Planning Commission, 1997). Recent changes to planning laws now allow for statutory planning schemes to be prepared in regional Western Australia, and 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 resources we need to live, for example, air, food, water, shelter and warmth. We also use the environment to satisfy our wants such as clothing, furniture, cosmetics and toys. The environment is 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 over-used.

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 more wealthy 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; that is, 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 of outside 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, that is, the average Australian consumes 10 times that of an average person from India (Australian Bureau of Statistics, 1996b) (Indicator 1.1).

Environmental degradation is a sign that we are exceeding the environment's 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 and the area of productive land is decreasing due to urban encroachment and land degradation.

Current Responses

There is currently no mechanism to examine fundamental questions about the sustainability of our population and consumption patterns. However, the current State Planning Strategy (Western Australian Planning Commission, 1997) provides a framework for managing growth. In providing this framework, the State Planning Strategy accepts that population will increase at 1.3 per cent per year for the next few decades (Indicator 1.2).

Similarly, the Department of Commerce and Trade's examination of Western Australia's future to 2029 (Dawkins, Lang & Thorpe, 1996) only considers two scenarios: current and 'quantum' growth levels; quantum growth being an even higher rate of growth than at present.

Thus, some difficult questions need to be debated in developing a Population and Consumption Strategy for Western Australia:

- Are there limits to growth in Western Australia?
- Is there an optimum population size for the State?
- Should we be planning to limit the size of our cities?
- Are we better off managing population growth, consumption levels or both?
- How will society incorporate full environmental costings and population options into its development decisions?

Given the strong growth ethos in Western Australia these are difficult issues for some individuals even to contemplate. However, 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 be established to investigate the relationships between economic growth, population and environment and to formulate a policy position. Other mechanisms that involve the community should also be established in the preparation for the development of a Population and Consumption Strategy for Western Australia.

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

Recycling is now common in most urban areas of Perth and in some regional centres. Photograph Courtesy of Department of Environmental Protection.

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

Consumption and the Environment

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 move our society's culture of consumption to one based on conservation and the re-use of resources.

Objectives

- Objectives and targets for consumption are not developed. These will be set in the proposed Population and Consumption Strategy for Western Australia and resource conservation strategy for Western Australia. An interim objective is to reduce Western Australia's per capita consumption of resources and to manage all waste in accordance with the waste management hierarchy (avoid, reduce, recycle, recover, treat and dispose in descending 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, public health and social amenity by appropriate waste management practices and promotion of waste avoidance and reduction strategies.

Indicators

Indicator 2.1

Consumption of key resources

This information is currently not reported.

Indicator 2.2

Volume of waste to landfill compared with the 1991 baseline and the 2000 target

See Figure 5.

Suggested Responses

- Local government authorities should develop local Agenda 21s to serve as frameworks for ecologically sustainable development.
- 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 the environmental impacts of necessary consumption. A public education program should be developed to encourage resource conservation.
- Based on the ecological footprint model, develop a procedure that can be used in development planning and decision-making to compare the ecological efficiency of options. This could be used as a precursor to incorporating the environmental costs of consumption into pricing.

Description

Historically, most of Government and community effort in the area of consumption and 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 this State are treated or disposed of in accordance with best practice and in a manner which should have minimal environmental impact. We should also have halved the amount of waste we dispose of to landfill from the 1991 estimated baseline of 1.4 tonnes per capita (see Figure 5).

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 Western Australia 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 Western Australia. Many of these (particularly remote and rural) landfills are unlined and are potentially polluting surface water and groundwaters 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 low hazard materials are being directed to landfill and this may 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 facilities has also increased and this is increasing the amount of pollutants entering the marine environment, groundwater and surface water systems. These pollutants 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 significant polluters 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 and liquid wastes are now being directed to liquid waste treatment plants.

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.

The abundance of certain natural resources in Western Australia, such as coal and natural gas, has fostered high rates of resource and land use by the State's relatively small population for domestic and export markets. The environmental, economic or social costs of extracting the non-renewable natural resources that remain in Western Australia will become unacceptable. We should plan to use the resources we are currently exploiting to meet the needs of current and future generations. This means changing patterns of consumption and reducing the amount we consume, both individually and collectively. It also involves substituting unsustainable consumption of non-renewable resources with ecologically sustainable consumption of renewable resources.

Excessive consumption of resources and increasing production of wastes are resulting in considerable environmental impact. There is an increasing awareness of the need to recycle and reduce waste. However, there is also little evidence of any real ability for the community to reduce the level of consumption without support and direction from government and other large institutions.

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 Western Australia 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 global nature of the economy.

The availability of cheap energy has made possible our level of consumption. For example, since farming began some 450 generations ago, the total energy use of human society has increased 10,000 fold. About 75 per cent of this energy is used by the 25 per cent of the world population that live in the developed countries (Commonwealth of Australia, 1996a).

Energy consumption as well as the consumption of minerals, water and land is increasing in Western Australia. The world environment and Western Australia's environment can not endure human activity of this scale indefinitely (World Commission on Environment and Development, 1987) and in Western Australia we should address this when managing our population and consumption rates.

Current Responses

Successive Governments have implemented 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 ways which prevent 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 within the Department of Environmental Protection, 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. These policies will be funded primarily by the proposed levy on waste to landfill.

Local governments have implemented kerbside recycling programs but their standards vary greatly and at this stage they divert less than 10–20 per cent 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 waste 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.

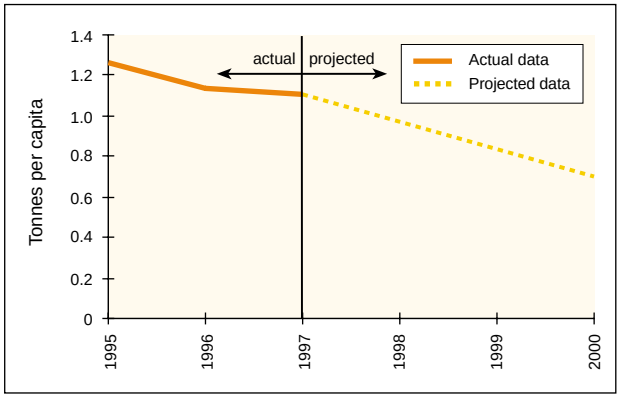


Figure 5. *Volume of waste disposed to landfill (Source: Department of Environmental Protection).*

BIODIVERSITY

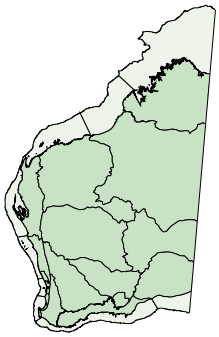
Biodiversity, the variety of genes, species and ecosystems, is essential to human well-being in many ways. It underpins the economy and ecological processes that are vital to human health and survival and the continued evolution of life on Earth. Its value to society and the State's economy is immeasurable. Biodiversity is potentially affected by all human activities. Many of the environmental issues discussed in this report affect biodiversity in some way. This is one of the reasons why biodiversity is given the highest priority environmental rating.

Biodiversity is central to the:

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

It is also valued highly by many people for cultural, ethical, spiritual and aesthetic reasons.

Objectives are established and Indicators are given that endeavour to reflect the severity and extent of the issue (condition indicator), the cause(s) of the issue (pressure indicator) and society's response to managing the issue by reducing the pressures or improving the condition (response indicator). Currently these indicators are in the early stages of development.



Maintaining Biodiversity

Environmental Status: ✪ ✪ ✪ ✪ ✪

Environment 1998 Western Australia

Conclusion

Our knowledge of the biodiversity of Western Australia is limited. Many species have not been scientifically described or named and the conservation status of many species is unknown. There is no comprehensive catalogue of ecosystems or ecological communities or of their conservation status. Knowledge of the genetic diversity within species is almost non-existent.

Monitoring and management of ecosystems and species are 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.

Measures of impact need to be included in assessments of human activities and in economic indicators.

Objectives

- To document and monitor Western Australia'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 Western Australia 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.
- To control the introduction and spread of alien species and genetically modified organisms and manage the deliberate spread of native species outside their historical natural range.

Indicators

Because of its inherent complexity and our incomplete understanding of its components, considerable work remains to be done to develop adequate but practical indicators of the condition of biodiversity, the pressures on it and responses to those pressures. These indicators need to reflect:

- the state of our knowledge of the Western Australian biota;
- trends in the number of taxa and ecological communities that are threatened (classified into the internationally recognised categories of presumed extinct, critically endangered, endangered and vulnerable), and the implementation of recovery plans for them;
- progress towards the establishment, across the full range of ecosystems, of a comprehensive, adequate and representative conservation reserve system that is well managed;
- the implementation of complementary off-reserve conservation measures; and
- the degree to which threatening processes have been identified and are being controlled or managed.

Some of these indicators are readily measurable, for example, the number of threatened taxa formally listed under the *Wildlife Conservation Act 1950* (*WA*), and quite sophisticated measurement is feasible, but often expensive, for individual taxa or communities. However, the challenge is to develop meaningful overall indicators across the full range of taxa, ecosystems and ecological processes.

There is a need to develop a comprehensive set of biodiversity indicators for Western Australia. Although incomplete, the following set of indicators is used for the purposes of this report:

Condition

Indicator 3.1

Composition of Western Australia's flora and fauna

See Table 1.

Indicator 3.2

Current distribution of the twenty-nine most threatened terrestrial animal taxa

See Figure 6.

Indicator 3.3

Former distribution of presumed extinct marsupials and rodents

See Figure 7.

Indicator 3.4

Current distribution of threatened terrestrial mammal species in Western Australia

See Figure 8.

Indicator 3.5

Current distribution of threatened terrestrial bird species in Western Australia

See Figure 9.

Indicator 3.6

Number of presumed extinct and threatened animal and plant taxa

This indicator is discussed in Condition below.

Pressure

Indicator 3.7

Rate of land clearing in Western Australia

Information to support this indicator will become available with the results of the Land Monitor project.

Indicator 3.8

Estimated number of environmental weed species

This indicator is discussed in Pressure below.

Response

Indicator 3.9

Recovery Plans and Management Programs

See Table 2.

Indicator 3.10

Number of vegetation types comprehensively and adequately represented in conservation reserves.

This indicator is discussed in Condition below.

Suggested Responses

- Implement *The National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth of Australia, 1996b) and develop and implement a complementary strategy for Western Australia.
- Inadequacies in the terrestrial 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 habitats (land, marine and freshwater) need to be identified and protective measures put in place.
- The *Wildlife Conservation Act 1950* (*WA*) should be replaced by new legislation incorporating modern biodiversity conservation principles.
- Ensure that land clearing in Western Australia is in line with Australia's commitment to the Kyoto Protocol on greenhouse gas emissions and climate change.
- Development and planning should minimise the clearing of native vegetation and encourage the development of corridors of native vegetation.
- The interagency Memorandum of Understanding on vegetation clearing should be progressively revised so that, by the year 2000, all proposals to clear native vegetation other than those rejected on existing criteria are assessed on biodiversity criteria.
- Local conservation strategies need to be developed and should be based on *The National Strategy for the Conservation of Australia's Biological Diversity* and on the Western Australian strategy when developed.
- 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.
- Implement the *National Weeds Strategy* (Commonwealth of Australia, 1997b) and develop and implement a complementary strategy for Western Australia which targets control of weeds according to their environmental threat.

- Implement the *Wetlands Conservation Policy for Western Australia* (Government of Western Australia, 1997b).
- Expand feral animal control programs including the successful Western Shield program to enable larger coverage of the State with community involvement. Continue to develop and refine assessment of the translocation of live aquatic non-endemic species into or within Western Australia and ensure adherence to the Ministerial Guidance on aquaculture and recreation fish stock enhancement.

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 of which they are a part.

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

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

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 and 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 per cent 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 lichens is very poor.

There are over 2700 vertebrate species in Western Australia (Table 1). Of this group of animals, land mammals, birds and reptiles are best known.

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

The marine environment of Western Australia 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 fauna of inland waters is poorly known. There are about 60 freshwater fish and 77 species of frogs known at present.

No systematic survey of wetlands across the entire State has been conducted in Western Australia. One hundred and ten sites covering several hundred discrete wetlands have been identified to date as being important wetlands (Australian Nature Conservation Agency, 1996). Nine of these have been listed as wetlands of international importance under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention).

Lost and Threatened Biodiversity

There are 25 plant species presumed extinct and 321 plant species threatened. Among the 149 known species of terrestrial mammals, 10 species are extinct and 31 taxa are threatened (Indicator 3.6). 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. Currently 56 per cent of vegetation types identified in Western Australia are not represented in existing conservation reserves. A further 31 per cent are poorly represented in the reserve system (Hopkins *et al.*, 1996). The establishment of vegetation corridors between the many small, isolated remnants of native vegetation in the agricultural region will be necessary to ensure their ecological viability.

Wetlands in the greater metropolitan area of Perth and other urban centres are undergoing ecological changes due to urban development, recreation, frequent fire and eutrophication. Those in agricultural areas are threatened with ground and surface water inputs of salts and nutrients, as well as diseases, feral animals and weeds. Wetlands elsewhere are being modified by grazing. Mining is also occurring in a small number of wetlands.

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).

Table 1. *Estimated composition of Western Australia's fauna and flora.*

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	25	321
Non vascular plants	~1,500	~100,000+ to ~200,000	unknown	unknown

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

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 the introduction and spread of 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, enhanced greenhouse effect, sedimentation, salinisation and eutrophication place pressures on the maintenance of biodiversity.

Introduced Animals

Introduced animals include vertebrates (notably mammals, birds and fish) and invertebrates (notably insects, but most phyla are represented) from Africa, America, Europe, Asia and other parts of Australia. They have colonised every biogeographic region in Western Australia and occur in terrestrial, freshwater and marine habitats. Introduced animals compete with native fauna for food, shelter and water, prey upon native fauna, and graze native vegetation and destroy habitat. (Introduced marine animals are discussed in the Introduction of Exotic Marine Species section.)

The majority of introduced animals offer little economic benefit and some are serious pests. However, many were introduced for economic values and are still managed for economic or social benefit in areas of natural habitat where they affect biodiversity, conservation and other natural values. Their effects are often poorly understood. They include invertebrates (for example, honey bees) and fish (for example, trout) but the most important species are cattle and sheep.

Many mammalian herbivores have escaped from managed populations (not always in Western Australia) to become feral pests (for example, cattle, pigs, goats, camels, donkeys, rabbits and horses). Some commensal species have been able to naturalise (house mice are the most successful). Many invertebrates were introduced unintentionally with imported products. A few species (for example, kookaburra) were introduced for aesthetic reasons.

Two of the most serious pests are predators. European foxes can sustain relatively high numbers by preying on rabbits, carrion or invertebrates while driving indigenous species to extinction. The effect of fox predation has been demonstrated by the recovery of native species where foxes are controlled. Cats occur as self-sustaining wild populations, but in settled areas the distinction between domestic and feral cats is blurred. The effects of feral cats are poorly documented. They consume a wide array of indigenous animals and they have thwarted attempts to re-introduce some mammals to arid areas but the greatest impacts may have occurred before 1900.

Land Clearing

In 1995 the CSIRO conducted an assessment of land cover disturbance for Australia, based on satellite imagery from 1991/92 (Graetz *et al.*, 1995).

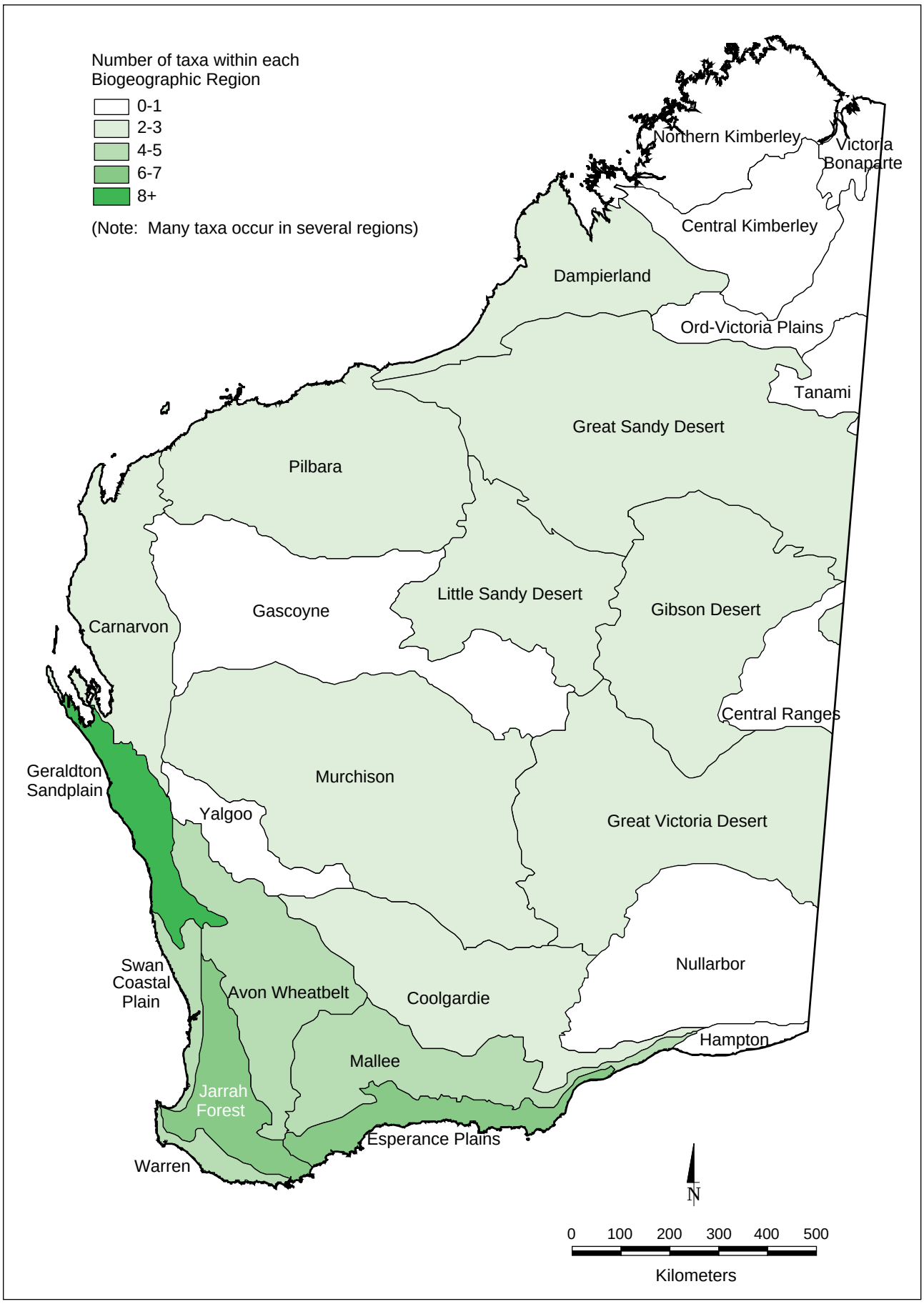


Figure 6. *Distribution of the twenty-nine most threatened terrestrial animal taxa in Western Australia as of July 1997 (Source: Department of Conservation and Land Management and Department of Environmental Protection).*

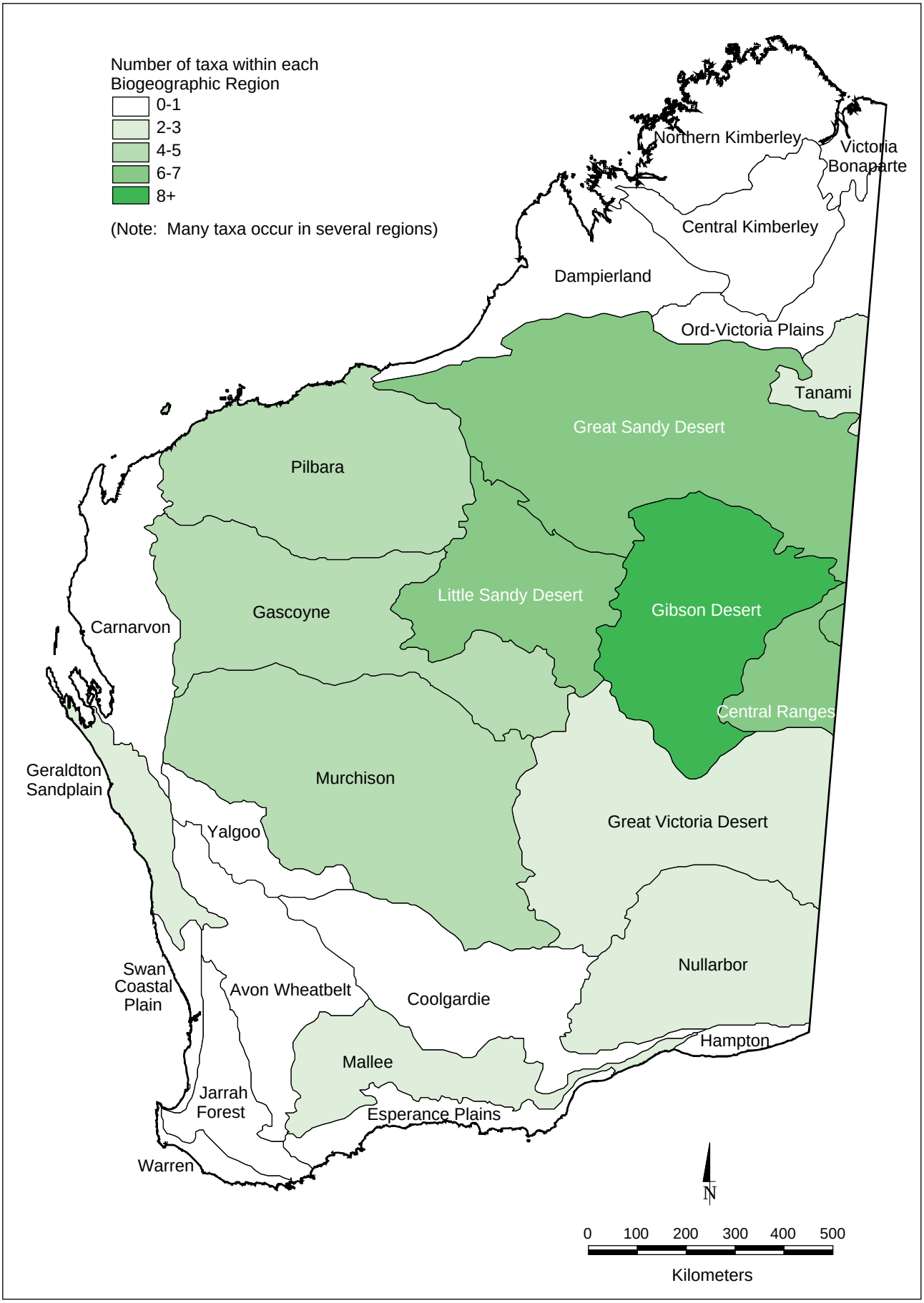


Figure 7. *Distribution of presumed extinctions of marsupials and rodents as of July 1997 (Source: Department of Conservation and Land Management and Department of Environmental Protection).*

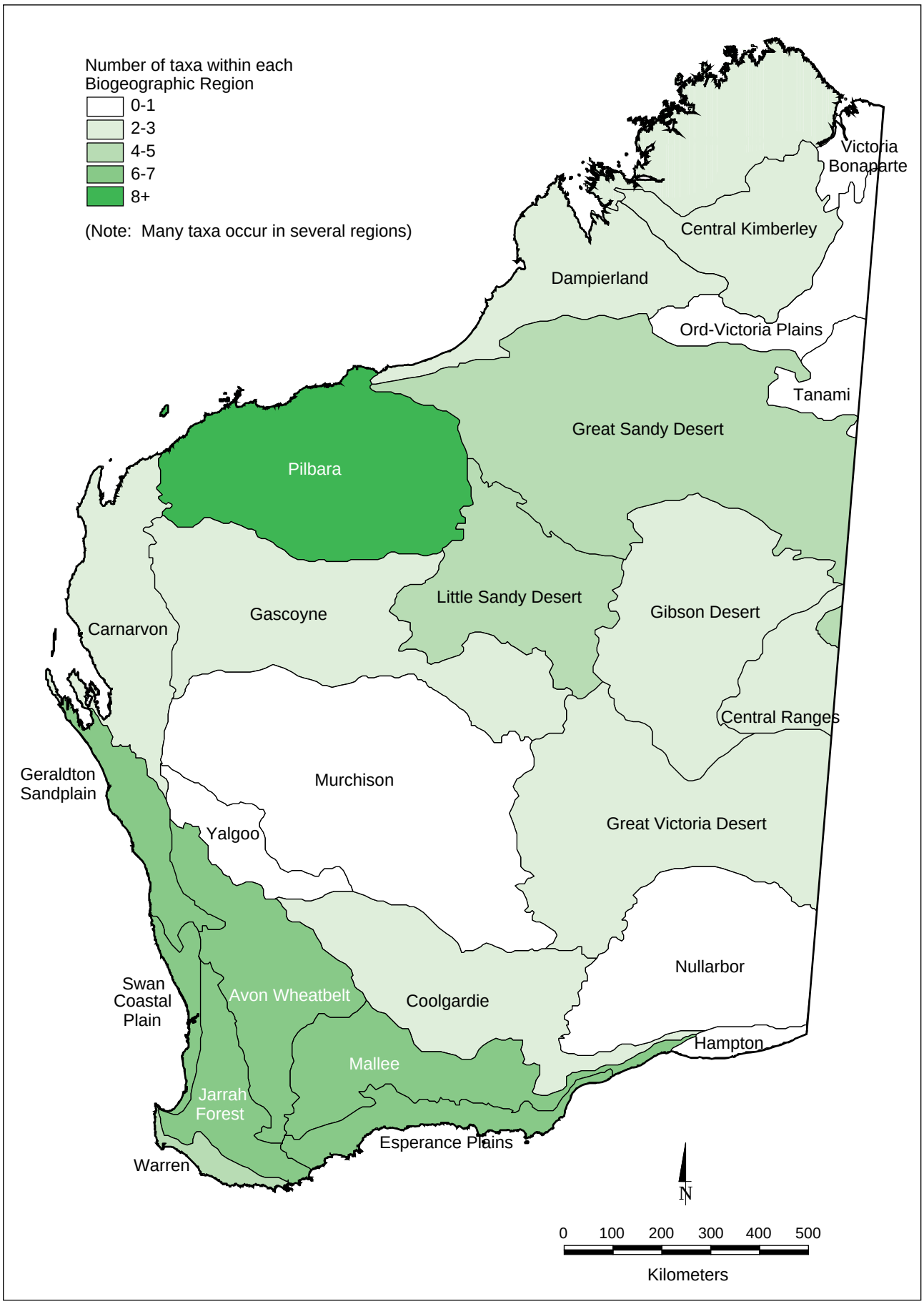


Figure 8. *Distribution of threatened terrestrial mammal species in Western Australia as of July 1997 (Source: Department of Conservation and Land Management and Department of Environmental Protection).*

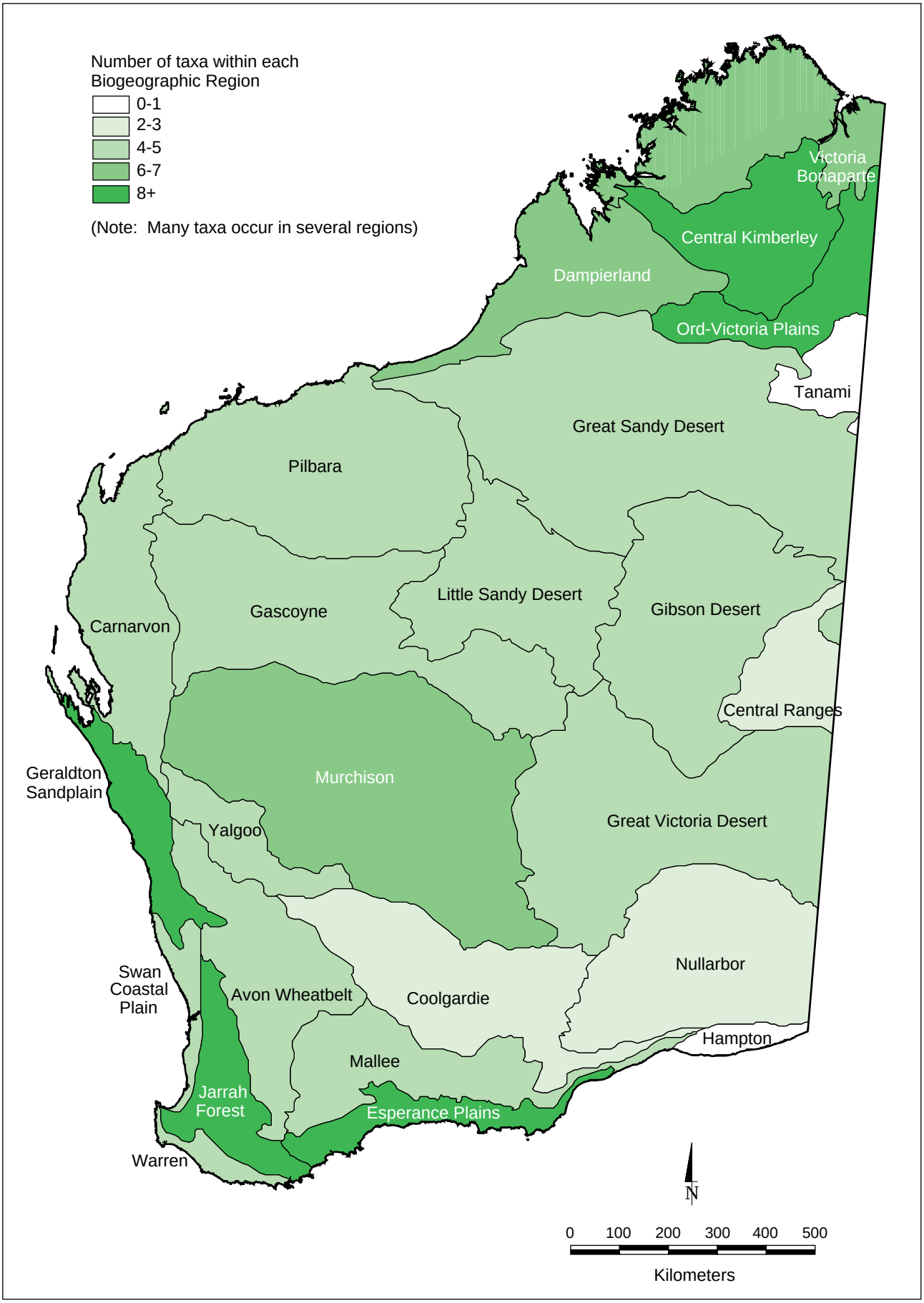


Figure 9. *Distribution of threatened terrestrial bird species in Western Australia as of July 1997 (Source: Department of Conservation and Land Management and Department of Environmental Protection).*

Western Australia was divided into an intensive land use zone (south-western corner) and an extensive land use zone (the rest of the State). This assessment estimated that 33 per cent of the south-western corner remains uncleared of its native vegetation and that 29 per cent of the rest of the State has substantially or significantly modified land cover. It is currently not possible to accurately indicate the rate at which native vegetation is being cleared in Western Australia.

Weeds

The introduction and spread of weeds is a major threat to biodiversity (Humphries, 1995). The most recent estimate suggests that over 1032 vascular plants are weeds in Western Australia, of which 558 are present in bushland and at least 50 are very serious threats to biodiversity (Keighery, 1995) (Indicator 3.8). Weeds constitute a major threat to remnant bushland, threatened flora populations and threatened ecological communities in Western Australia both directly and indirectly by increasing the threat of fire.

Diseases

The slow moving epidemic of destructive root disease in native plants was first observed in Western Australia in 1921. Early European settlers probably introduced the causal agent *Phytophthora cinnamomi* into Western Australia soon after 1828. The arrival and spread of *P. cinnamomi* in Western Australia is now seen to be a biological disaster of global significance given the richness and high degree of endemism of the flora of south-western Western Australia.

A number of plant species face extinction unless recently formulated programs of phosphite treatment and germplasm storage are effectively implemented and sustained, along with hygiene and quarantine measures. Ecological communities significant for their floristic diversity and importance as habitat for native fauna are suffering rapid and massive disruption over much of their range. Within the 400+ mm rainfall isohyet of the South-West Land Division approximately 15 per cent of the forested region is infested, with some national parks having between 60 and 70 per cent of their area infested. Other plant diseases include *Armillaria inteobubalina* and *Cryptodiathrorthe melanocrespida*, both of which are affecting biodiversity in the south west.

Fire

In most Western Australian ecosystems, fire is a natural environmental factor affecting the composition and distribution of organisms. Species and communities have evolved a diverse array of structural, physical and behavioural adaptations to persist under a range of fire regimes. For example, an examination of grasstree stems suggests that prior to European settlement, parts of the south-western forests may have burnt every 2–4 years. In the south-western forests, regular fuel reduction burning has reduced the threat to both property and conservation values posed by large, intense fires. There is strong evidence that, traditionally, Aborigines used fire regularly in other ecosystems including the hummock grasslands of the arid zone. Today large and intense fires regularly occur in remote regions of the State, such as the interior and the Kimberley. This modern regime, compared with a former regime of smaller patchy burns, is likely to be having a negative impact on the biodiversity of these regions.

Current responses

The *Wildlife Conservation Act 1950* (*WA*) and the *Conservation and Land Management Act 1984* (*WA*) provide the primary legislative basis for the State's management of biodiversity. Other relevant legislation includes the *Environmental Protection Act 1986* (*WA*) and the *Fish Resources Management Act 1994 (WA)*. The State is a signatory to the *National Strategy for the Conservation of Australia's Biological Diversity*.

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 with priority given to those classified as critically endangered.

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. Fox baiting programs have been successful, with native mammals showing a strong increase in numbers.

The *Urban Bushland Strategy* established a policy framework for conservation of urban bushland. Perth Bushplan is a coordinated program across the DEP, Ministry for Planning, CALM and the WRC to review conservation on the Swan Coastal Plain.

The conservation reserve system represents 6.2 per cent of the land area of Western Australia. Marine conservation reserves are limited and a program to add to the existing reserve system is underway.

A Wild Rivers Project has been documenting the health of rivers and their catchments in Australia. The remaining wild rivers of Western Australia have been identified and guidelines will be developed for their management and protection (Water Authority of Western Australia, 1995b).

The area of land approved for clearing under the *Soil and Land Conservation Act 1945 (WA)* has decreased significantly since 1990 (Figure 10). An interagency memorandum of understanding has been developed to coordinate the assessment of private land clearing in the agricultural areas of the State. It has also enabled the incorporation of biodiversity principles into the assessment process.

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.

The understanding of 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.

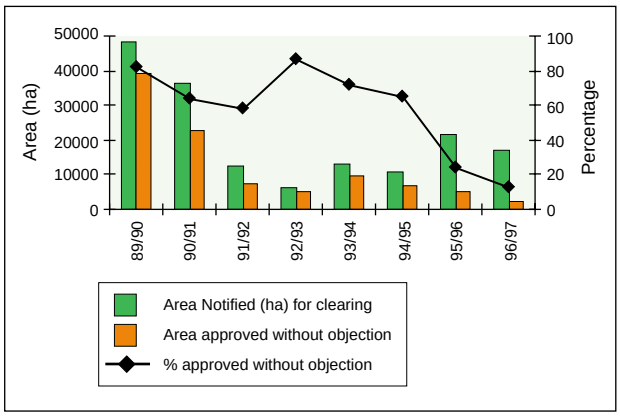


Figure 10. *Trends in land clearing controls in Western Australia (Source: Commissioner for Soil and Land Conservation).*

Table 2. *Recovery plans and management programs for threatened flora, fauna and ecological communities in Western Australia as of July, 1997 (Source: Department of Conservation and Land Management).*

Grouping	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 Western Ground Parrot
Ecological Communities		Toolibin Lake

ATMOSPHERE

For the purpose of this report, 'atmosphere' refers to all air above the ground up to and including the stratosphere. It excludes air inside buildings workplaces and homes (indoor air).

The condition and movement of the atmosphere affects all life on Earth, from the local and regional to the global scale.

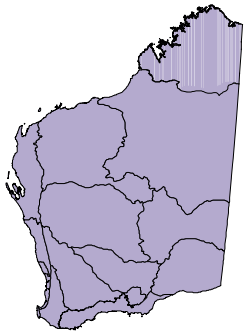
Western Australia is subject to changes in the atmosphere at the global, regional and local scales. At the global scale the key environmental issues are the emission of greenhouse gases which has been linked to long-term climate changes and the depletion of stratospheric ozone. Short-term climate changes such as those characterised by the El Niño Southern Oscillation are not addressed in detail in this report.

A number of regional and local air quality issues face Western Australia. These are primarily the result of industrial and domestic emissions, vehicle use and land-use practices. The key issues are photochemical smog, haze from particulates, sulphur dioxide, carbon monoxide, lead and dust. Emerging issues such as air toxins and the combined effects of air pollutants are not addressed in this report largely due to lack of data relevant to Western Australia.

Climate itself is a major factor in determining the distribution of plants and animals. Long-term climate change has the potential to affect all of Western Australia's environment. For example, changes range from modified river flow and water availability caused by rainfall changes to large scale losses in biodiversity. Other more local climatic changes have been attributed to land-use practices such as extensive clearing. Work at Murdoch University is showing reduced cloud formation as a result of past clearing of vegetation for agriculture. This makes greenhouse gas emissions and land-use practices significant factors in most environmental management issues.

The environmental consequences of the emission of other gases tend to be restricted to local and regional areas, for example, emissions around industrial centres such as Kalgoorlie and Kwinana. Similarly, issues such as haze and photochemical smog have regional impacts.

For each issue Objectives are established and Indicators are given that endeavour to reflect the severity and extent of the issue (condition indicator), the cause(s) of the issue (pressure indicator) and society's response to managing the issue by reducing the pressures or improving the condition (response indicator).



Enhanced Greenhouse Effect

Environmental Status: ✪ ✪ ✪ ✪

Environment 1998 Western Australia

Conclusion

In December 1995 the United Nations Inter-governmental Panel on Climate Change (IPCC) concluded that greenhouse gas concentrations in the atmosphere have continued to increase and that "the balance of evidence suggests a discernible human influence on global climate". The IPCC also "project an increase in global mean surface air temperature relative to 1990 of about 2°C by 2100", which is "approximately one third lower than the 'best estimate' in 1990" (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 Western Australia need to take a precautionary approach and contribute to reducing greenhouse gas emissions.

Many activities emit greenhouse gases, for example, power generation, transport, mining and agriculture. The rate of production of greenhouse gas emissions in Western Australia 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 United Nations 1992 Framework Convention on Climate Change.

Indicators

Condition

Indicator 4.1

Atmospheric greenhouse gas concentrations

This indicator is discussed in the Condition section.

Indicator 4.2

Estimates of changes in frequency and severity of extreme climatic events, for example, extreme temperatures and rainfall events

This indicator is discussed in the Condition section.

Pressure

Indicator 4.3

Greenhouse gas emissions in Western Australia for each sector.

See Table 3 and Figure 11.

Indicator 4.4

Rate of consumption of fossil fuel resources

See Energy section.

Indicator 4.5

Change in vegetation cover

A Commonwealth project is being conducted to provide this information.

Response

Indicator 4.6

Proportion of total energy use from renewable sources

See Figure 22 in Energy section.

Indicator 4.7

Land clearing and revegetation trends

See Indicator 3.7 in Maintaining Biodiversity section and Indicator 12.7 in Land Salinisation section, respectively.

Suggested Responses

- The Western Australian Government should develop a Western Australian Greenhouse Strategy which is based on a National Greenhouse Strategy (when finalised) but takes into account regional differences and imperatives. As such, the Strategy should reflect the measures included in the Prime Minister's Statement, *Safeguarding the Future: Australia's Response to Climate Change* and include agreed outcomes of the Kyoto Protocol.

- The Western Australian Government should also initiate a Western Australian Greenhouse Council to advise on:

  a) achieving the objectives and targets of the National Greenhouse Strategy and Framework Convention on Climate Change.

  b) coordinating Western Australia's contribution to the national greenhouse gas inventory.

  c) providing advice to the Western Australian Government on climate change matters.

  d) developing strategies for monitoring and reporting on the implementation of the National Greenhouse Strategy and the Western Australian Greenhouse Strategy.

  e) climate change policies and programs in other jurisdictions.

  f) methods of informing and raising awareness about climate change and greenhouse response in the community.

- Develop as part of the State Greenhouse Strategy, a Sustainable Energy Policy that specifically addresses the use of natural gas, energy conservation and renewable energy.
- Local government authorities should take energy efficiency issues into account in planning decisions, conduct energy audits of city facilities and educate householders and businesses to reduce greenhouse gas emissions.

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 its lower atmosphere. However, greenhouse gas concentrations in the atmosphere have been increasing as a result of human activity since the industrial revolution.

This increase has resulted in the 'enhanced greenhouse effect'. There is now discernible scientific evidence that the enhanced greenhouse effect is causing the 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 per cent, methane by 145 per cent and nitrous oxide by 15 per cent (Indicator 4.1).

Climate change as a result of the enhanced greenhouse effect is difficult to measure because of natural climatic variability. However, the 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 Western Australia's climate (Hennessy & Whetton, 1994) and the environment more generally (Bouma *et al.*, 1996).

The enhanced greenhouse effect may result in:

- 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 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. The lowest estimate of the frequency of extreme temperatures is not significantly different from the present frequency at any site. However, 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 per cent 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 per cent at Broome, Derby, Donnybrook, Esperance, Geraldton, Kalamunda, Kalgoorlie, Perth, Port Hedland, Wiluna and Wyndham (Hennessy & Whetton, 1994) (Indicator 4.2). Such estimates will be subject to continued revision.

Pressure

Western Australia's source of energy is largely non-renewable fossil fuels (97 per cent) and is thus unsustainable in the long-term. Australia with 0.3 per cent of the world's population contributes 1.4 per cent of global greenhouse gases, of which Western Australia currently contributes about 10 per cent.

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 Australia's emissions for each year from 1988–95 and Western Australia's greenhouse gas emissions for 1988 and 1990. Between 1988 and 1990 Western Australia's greenhouse gas emissions increased by 12 per cent. No more recent estimates are available using this methodology. Under current circumstances it is predicted that Western Australia's emissions of carbon dioxide will double its 1990 levels by 2010.

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 3) 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 Western Australia in 1990, contributing about 50 per cent of the total emissions.

Industrial processes includes by-products of various production processes not including greenhouse gases produced by the combustion of fossil fuels in industrial processes. This category contributed least to Western Australia's emissions, only 1.3 per cent 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 per cent of the total emissions.

Land-use change and forestry primarily covers carbon dioxide emitted and removed from the atmosphere as a result of land management activities. The emissions include clearing and thinning of vegetation which causes carbon stored in the wood and soil to be released as carbon dioxide; burning or decay of waste agricultural and forestry products; and grazing. Carbon dioxide removals from the atmosphere include new forest growth and soil organic matter increase due to pasture improvement. In Australia, forestry is considered a net sink of carbon dioxide because the carbon dioxide used in forest growth exceeds the carbon dioxide emitted as a result of timber harvesting. Up to 40 per cent of carbon dioxide taken up in forest growth remains sequestered in wood used for products such as furniture and roofing. Significantly less carbon dioxide is sequestered if the wood is used in highly processed materials, such as paper and particle board. It should be noted that there is large uncertainty associated with estimating national emissions in the land-use change and forestry sector. In 1990 this sector was estimated to contribute 22.1 per cent of 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 per cent of Western Australia'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 Western Australia. Figure 11 shows projected carbon dioxide emissions as a result of energy use in Western Australia.

Table 3. *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 Responses

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

A range of Government and private programs exist to establish woody vegetation and protect remnant vegetation. The rapid expansion of commercial timber plantations on cleared farmland, up to 25,000 ha per year in recent years, has been particularly beneficial in this regard. Vegetation absorbs carbon dioxide and contributes to reducing greenhouse gases in the atmosphere. Land clearing in the agricultural areas of Western Australia has decreased substantially since 1990.

The DEP will coordinate a greenhouse gas inventory for Western Australia in 1998 to provide essential information for the Western Australian Greenhouse Council and which will assist in developing strategies to reduce greenhouse gas emissions.

The EPA can require proponents to minimise greenhouse gas emissions from new proposals as part of the environmental impact assessment process (Environmental Protection Authority, 1998).

A draft Strategy for the Management of Green and Solid Organic Waste (Government of Western Australia, 1997d) is currently being finalised and landfill sites are required under licence conditions to prevent methane emissions. Several landfill sites are being used to generate power from methane.

Research on the implications of the greenhouse effect on Western Australia'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 including energy efficient residential development promoted by both State and local governments.

Co-operative programs are in place between industry and the Commonwealth Government under Environment Australia's Greenhouse Challenge Program to reduce greenhouse gas emissions. Several leading Western Australian companies are involved, however, many others with the potential to reduce greenhouse gas emissions are yet to become involved in the program.

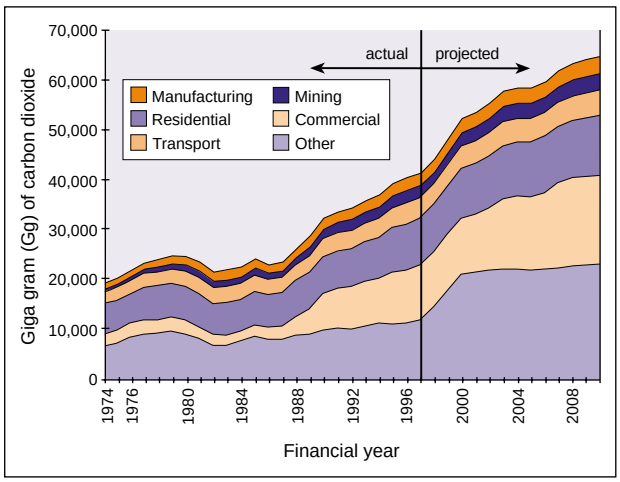


Figure 11. *Carbon dioxide emissions from end-users of energy in Western Australia, 1974–2010 (Source: Office of Energy).*

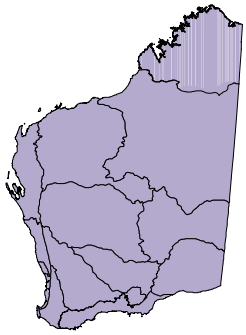
Implications

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 predicted increase in the severity of natural events such as cyclones, bushfires and floods may also have significant implications.

The State Government has embraced energy deregulation and this, combined with the increasing discoveries of natural gas off the north-western coast, will encourage resource processing based on competitively priced energy in Western Australia. This is already evidenced in the construction of BHP's hot briquetted iron plant, five other gas-based iron processing projects under consideration, new nickel laterite projects, expanded alumina refining and great interest in the Pilbara petrochemical proposal. However, these projects are all relatively energy intensive and have significant greenhouse gas emissions. For example, each single direct iron reduction plant could increase Western Australia's greenhouse gas emissions by 5 per cent.

Predictions of the implications of global warming on biodiversity are significant and highlight the need to establish a comprehensive, adequate and representative reserve system in Western Australia that provides for genetic flow across ecosystem types. Without such a system it is predicted that loss of plant and animal species in Australia would occur as vegetation systems shift from more closed to more open environments.

For plants alone the rate of loss is predicted to range from 65 species per hectare in tropical environments in the north to five species per hectare in temperate environments in the south (Specht, R. L. *et al.*, 1995).



Stratospheric Ozone Depletion

Environmental Status: ✪ ✪ ✪ ✪

Environment 1998 Western Australia

Conclusion

As with 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. Depletion of the ozone layer allows more ultraviolet radiation to reach the Earth. This is affecting human health and the environment. Australian Governments, industry and the community must work together to manage this issue.

Objective

To phase out the use and emission of ozone-depleting substances in Western Australia according to the Montreal Protocol which sets out the following schedule:

Chlorofluorocarbons	- Phased out by end of 1995
Halons	- Phased out by end of 1993
Carbon tetrachloride	- Phased out by end of 1995
Methyl chloroform	- Phased out by end of 1995
Hydrobromofluorocarbons	- Phased out by end of 1995
Hydrochlorofluorocarbons	- Freeze from beginning of 1996
	- 35 % reduction by 2004
	- 65 % reduction by 2010
	- 90 % reduction by 2015
	- Totally phased out by 2020
Methyl bromide	- Freeze in 1995 at 1991 base level
	- 25% reduction by 1999
	- 50% reduction by 2001
	- 70% reduction by 2003
	- Totally phased out by 2005

Indicators

Condition

Indicator 5.1

The concentration of stratospheric ozone over Australia

Data collection has begun but is not sufficient to be reported at this stage.

Indicator 5.2

Trends in ultraviolet-A and -B radiation for Western Australia

Data collection has begun but is not sufficient to be reported at this stage.

Pressure

Indicator 5.3

Estimated consumption of ozone-depleting substances in Western Australia

This information is not currently being collected.

Indicator 5.4

Atmospheric levels of ozone-depleting substances

Discussed in Pressure section below.

Response

Indicator 5.5

The extent to which ozone-depleting substances are regulated by legislation as compared with the Montreal Protocol

This information will be available after the review of the Environmental Protection Policy (EPP) for ozone-depleting substances.

Indicator 5.6

Progress on the phasing out of ozone-depleting substances, including levels of sales and purchases, and collection of halons in Western Australia

This information will be available after the review of the EPP for ozone-depleting substances.

Suggested Responses

- Continue to implement the 1994 Australian and New Zealand Environment and Conservation Council national strategy for protection of ozone by reviewing Western Australia's *Environmental Protection (Ozone Protection) Policy 1993*.
- Current education campaigns are focussed on industry. There is a need for the Department of Environmental Protection to expand current education campaigns to target the wider community.

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; carbon tetrachloride; methyl chloroform; hydrochloro-fluorocarbons (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 per cent. 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 to bring ozone levels over Antarctica almost back to normal.

Since 1981, the global ozone layer has decreased by 6 per cent. In Antarctica, this has been much higher, with an estimated loss of 1 per cent 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 square kilometres whereas the aerial extent for 1987 and 1989–92 averaged 18–19 million square kilometres.

Decreased stratospheric ozone allows more ultraviolet radiation (particularly ultraviolet-B) to reach the surface of the Earth. A 1 per cent decrease in stratospheric ozone has been calculated as equivalent to a 1–2 per cent 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 manufacture and import of ozone-depleting substances into Australia (without a licence) was enacted from 1 January 1996, some of these substances are still being used. The amount of these chemicals being released in Western Australia 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 (Indicator 5.4).

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.

Hydrochlorofluorocarbons

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, HCFC–142b and HCFC–22 is growing rapidly.

HCFC–22 levels are growing steadily at 5 per cent per year. Between 1979 and 1996 its concentration has more than trebled from 36 to 116 ppt.

Chlorofluorocarbons and Halons

At the beginning of the decade, concentrations of CFCs were rising at between 4 per cent and 10 per cent 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. CFC–12 continues to accumulate in the atmosphere, but its growth rate has slowed significantly in response to reduced emissions under the Montreal Protocol. 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 Responses

Australia together with some 160 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 *Revised Strategy for Ozone Protection* in Australia (ANZECC, 1994). 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 1993 the use of CFCs in Western Australia has been controlled by the *Environmental Protection* (*Ozone Protection*) *Policy 1993*. The use of halon (portable) fire extinguishers has been banned since January 1996. Some exemptions apply in those areas where there are life threatening situations. Some halon use is still allowed, for example, halons in fixed flood systems for fire control such as those used in computer rooms. It is proposed that the EPP will be amended to prohibit this use.

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 are provided by technical and further education institutions, 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 needed 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, 1996a).

The effort to reduce the release of ozone depleting substances is a good example of global action to address a global environmental problem.

See Section 3 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 number of times that the draft National Environmental Protection Measure (NEPM) standard is exceeded is predicted to increase significantly.

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

Objective

Ambient ozone levels should be kept below the NEPM goal of 100 ppb (1-hour average).

Indicators

Condition

Indicator 6.1

Ambient ozone concentration

See Table 4.

Pressure

Indicator 6.2

Emissions of nitrogen oxides and reactive organic compounds

Discussed in Pressure section below.

Indicator 6.3

Changes in nitrogen oxide emissions with vehicle kilometres travelled in Perth

See Figure 12.

Response

Indicator 6.4

Vehicle kilometres travelled

Indicator 6.5

Change in average motor vehicle emissions over time

Currently not reported.

Indicator 6.6

Trends in public transport patronage

See Figure 13.

Suggested Responses

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.

- Develop and implement an Air Quality Management Plan for Perth.
- Ensure new vehicles have appropriate emission levels, and that these are maintained over the life of the vehicle.
- Ensure the reporting, inspection and repair of defective motor vehicles.
- Better manage car parking in the City of Perth to improve air quality.
- Promote higher car occupancy.
- Promote travel alternatives, including public transport, cycling and walking.
- Ensure industrial emissions are as low as possible, given ongoing technological improvements.
- Ensure urban development patterns and densities promote short trips and public transport, walking and cycling.
- Improve public transport service levels in Perth and regional centres (Indicator 6.6).
- Promote gas conversion of car fleets. Compared with cars running on unleaded petrol, natural gas vehicles produce 80 per cent less hydrocarbons, 50 per cent less nitrogen oxides, 53 per cent less carbon monoxide and 20 per cent less carbon dioxide.
- Adequately fund existing alternative travel and education programs.

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 5-year period from July 1992 to June 1997, there were on average 12 days per year on which the ozone concentration exceeded the WHO goal somewhere in the Perth region. Similarly, the draft NEPM goal is exceeded on about three days per year somewhere in the Perth region (see Table 4).

Table 4. *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
1996–97	12	5	5

Since the 1992 SoE Report, the *Perth Photochemical Smog Study* (Western Power Corporation & Department of Environmental Protection, 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 (for example, service station vapour losses, paints and thinners) and biogenic emissions (vegetation emits reactive organic compounds).

Motor vehicles contribute 51 per cent of the total nitrogen oxides emitted and over 40 per cent of ROC. Industry contributes 44 per cent of nitrogen oxides and 19 per cent of ROC. Area sources contribute 5 per cent and 37 per cent of nitrogen oxides and ROC respectively (Indicator 6.2).

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 and cycling with 'travel demand management'. A comprehensive Perth Bicycle Network is being developed to link existing cycleways and railway lines over the next four years.

Airwatch, a school-based air quality monitoring program, has been implemented in some schools by the DEP. Smogbusters is a community-based education and involvement program coordinated by the Conservation Council of WA.

Australian Design Rule 37/01 which further limits 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 Parliamentary Select Committee on Perth's Air Quality has been examining the issue of air pollution in Perth. The State Government has given a commitment to develop and implement an Air Quality Management Plan for Perth.

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 significantly increase the number of times air quality objectives are exceeded.

A study conducted in Brisbane estimated that the economic cost of air pollution was between $255 million and $462 million per year (Simpson & London, 1995). If 10 per cent of Australian vehicles ran on natural gas, 1.8 million litres of petrol would be saved per year and motorists would save approximately $600 million per year.

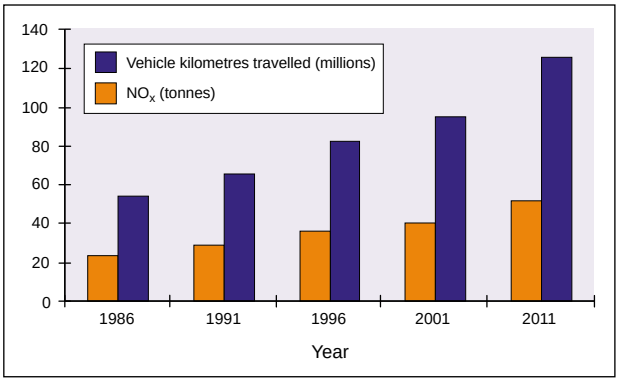


Figure 12. *Changes in nitrogen oxide emissions with vehicle kilometres travelled in Perth (Department of Environmetnal Protection & Western Power Corporation, 1996).*

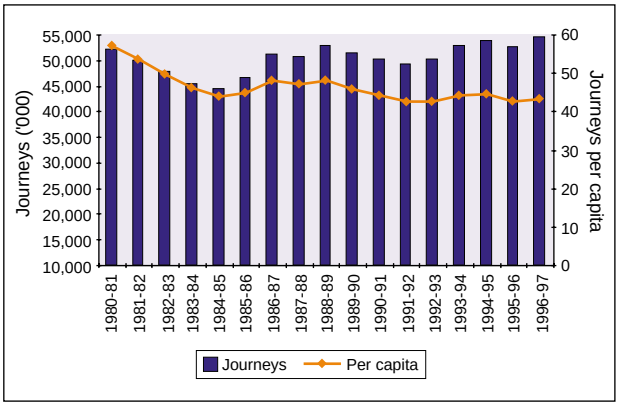


Figure 13. *Trends in public transport patronage (Source: Department of Transport).*

See Section 3 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. Currently, fine particulates pose the greatest air pollution-related health risk to the Perth community.

Objective

To ensure that haze levels do not cause local visual distance (LVD) to fall below 20 km (1-hour average) and are below the draft NEPM PM10 goal for particulate matter concentration.

Indicators

Condition

Indicator 7.1

Ambient levels of haze compared with interim objectives

See Table 5.

Indicator 7.2

Local visual distance

See Table 5.

Pressure

Indicator 7.3

Estimated emissions from a range of sources

This indicator is currently not reported.

Response

Indicator 7.4

Ambient levels of haze compared with interim objectives

See Table 5.

Other indicators to evaluate the effectiveness of responses to reduce haze are to be developed.

Suggested Responses

- Determine appropriate legal standards for particulate haze.
- Implement a comprehensive community awareness campaign based on the findings of the 'Halt the Haze' trial.
- The *Environmental Protection Act 1986* (*WA*) was amended (May 1998) to enable a ban on the sale of appliances, for example, wood stoves and heaters, that do not comply with Australian Standard 4013. The DEP is developing regulations preventing the retail sale of wood with more than 25 per cent moisture content.
- Studies are required to determine the health impacts of current haze levels.
- Develop and implement an Air Quality Management Plan for Perth.

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 µm in diameter (referred to as inhalable particulates) and PM2.5, less than 2.5 µm in diameter (referred to as fine particulates). There is international 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 particulate 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 5).

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 haze in Perth are smoke from domestic wood heaters; particulates emitted from motor vehicles (notably from diesels); 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 has almost tripled in the past 22 years and accounted for 31.4 per cent of total transport energy use in 1995–6. The use of diesel is expected to increase nearly three times that of motor spirit by 2010 (Office of Energy, 1997). Without tighter emission controls on diesel engines and the increased use of low sulphur fuel the predicted increase in the use of diesel vehicles is likely to cause an increase in particulate emissions.

Current Responses

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 upon populated areas from hazard reduction burning.

All licensed wood merchants will be supplied with a meter so that they can test the moisture content of the wood before it is sold. The DEP has produced a free chimney checker, which helps people to determine whether their wood stoves are operating efficiently.

A draft National Environmental Protection Measure for Air Quality has been adopted and a Measure for diesel fuels is beginning to be developed.

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

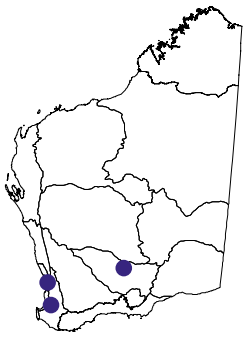
There has been considerable work on setting standards for haze internationally.

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

Year	No. of Days			
	LVD < 20 km (1 hour)	No. of sites	PM10 > 50 µg/m^3 (24 hour) Hivol (every 6th day)	No. of sites
1993–94	63	4	3	3
1994–95	80	5	5	5
1995–96	76	6	2	4
1996–97	57	7	0	4



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 continuing to fall as a result of management programs.

Objective

To maintain sulphur dioxide (SO_2) levels below the following agreed standards (1-hour average):

- for the Goldfields Residential Area (SO_2) Environmental Protection Policy (EPP) levels are not to exceed 700 µg/m^3 more than eight times per year and are never to exceed 1400 µg/m^3;
- for the Kwinana Atmospheric Wastes EPP levels in residential areas are not to exceed 350 µg/m^3 more than eight times per year and are never to exceed 700 µg/m^3;
- elsewhere not to exceed 570 µg/m^3.

In the future the draft NEPM goal should be met.

Indicators

Condition

Indicator 8.1

Trends in the number of exceedances of sulphur dioxide standards and guidelines

See Table 6 and Figure 14.

Pressure

Indicator 8.2

Levels of sulphur dioxide mass emissions

Although this information is available, it is currently not reported.

Response

Indicator 8.3

Progress toward objective

See Figure 14.

Indicator 8.4

Progress toward draft National Environmental Protection Measure standard

Although this information is available, it is currently not reported in this format.

Suggested Responses

- 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.
- There is concern that the Kalgoorlie EPP standard is greater than the NHMRC goal. The Kalgoorlie EPP should be reviewed before its scheduled review in 2000.
- The proposed NEPM and complementary State Air EPP should provide for regional differences in Western Australia.

Description

Sulphur dioxide is a significant air pollutant in Western Australia, 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 sulphur content such as coal, through the removal of sulphur from ores or industrial feed-stocks, and 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 rain common in parts of Europe and America has not been examined in Western Australia.

Condition

Since 1992 the SO_2 levels around Kalgoorlie have improved although they have still occasionally exceeded the EPP criteria (see Figure 14). Kwinana levels have stabilised (see Table 6) 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 have fallen following the recent installation of scrubbing equipment at the largest industrial source.

Kwinana is 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, although this is increasing with the construction of a new coal-fired power station.

Table 6. *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	6
1994–95	89	10	3	6
1995–96	91	10	0	6
1996–97	6	10	0	6

Current Responses

Environmental Protection Policies have been established to control SO_2 for Kwinana and Kalgoorlie. The policies provide standards and limits for sulphur dioxide levels. Standards are defined as being 'desirable not to exceed' and limits are concentrations 'which shall not be exceeded'.

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.

A redetermination of emission limits under the Kwinana Atmospheric Waste EPP (1993) is planned for 1998 which will include the use of statistical discharge limits.

Implications

It is likely that the high SO_2 levels around Kalgoorlie have 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 NEPM), will require more intensive management.

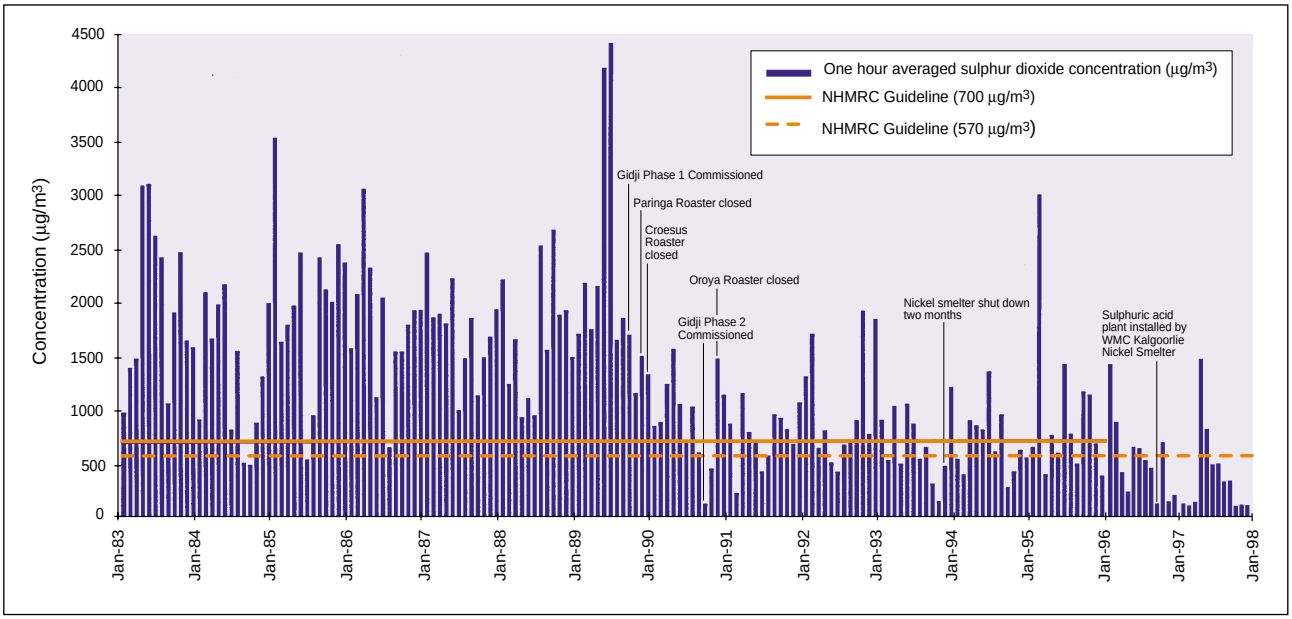


Figure 14. *Maximum average hourly sulphur dioxide levels at Kalgoorlie Hospital with significant events resulting in changes to the ambient sulphur dioxide concentration (Source: Department of Environmental Protection).*

Carbon Monoxide

Environmental Status: ✪ ✪

Conclusion

Carbon monoxide is an urban pollutant caused mostly by vehicle emissions. High levels in suburban areas are also caused by poor combustion in domestic wood fires. 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

To maintain ambient carbon monoxide levels below the draft NEPM goal, NHMRC goal of 9 ppm (8-hour average) and the WHO goal of 25 ppm (1-hour average).

Indicators

Condition

Indicator 9.1

Ambient carbon monoxide levels compared with NHMRC and WHO goals

See Table 7.

Pressure

Indicator 9.2

Changes in carbon monoxide levels with Vehicle kilometres travelled

See Figure 15.

Response

Indicator 9.3

Vehicle emission standards

Discussed in Current Responses section below.

Indicator 9.4

Trend in vehicle kilometres travelled and public transport patronage

See Indicators 6.4 and 6.6 respectively.

Suggested Responses

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. These responses should be developed through the Air Quality Management Plan for Perth and include:

- adequately funding existing alternative travel and education programs;
- promoting higher car occupancy;
- promoting travel alternatives, including public transport, cycling and walking;
- ensuring new vehicles have minimum emission levels, and that these are maintained over the life of the vehicle;
- ensuring urban development patterns and densities which 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.

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 per cent 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 (8-hour average) and the WHO goal of 25 ppm (1-hour average) has not been exceeded (see Table 7). There is insufficient evidence to conclude that carbon monoxide levels are falling. Perhaps because of increased use of motor vehicles, the highest recorded 8-hour levels have remained close to the NHMRC goal.

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 on 1 January 1997) has lowered the new vehicle carbon monoxide emissions standard to from 9.3 g/km to 2.1 g/km (Indicator 9.3).

Implications

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

Table 7. *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	13.0	7.6	3
1995–96	12.1	8.7	3
1996–97	12.3	7.2	3

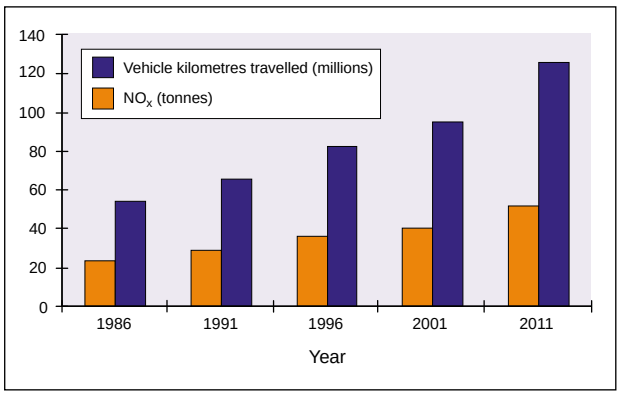


Figure 15. *Changes in carbon monoxide emissions with vehicle kilometres travelled in Perth (Department of Environmetnal Protection & Western Power Corporation, 1996).*

Lead

Environmental Status: ✪

Conclusion

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

Objective

To ensure that ambient lead levels are below the draft National Environmental Protection Measure of 0.5 µg/m^3 (1-year average).

The NHMRC goal is for all Australians to have a blood lead level below 10 micrograms per decilitre.

Indicators

Condition

Indicator 10.1

Ambient atmospheric lead concentration

See Figure 16 and Table 8.

Pressure

Indicator 10.2

Vehicle kilometres travelled

See Indicator 6.4.

Indicator 10.3

The consumption of leaded petrol

This indicator is currently not reported.

Response

Indicator 10.4

Change in vehicle kilometres travelled

See Indicator 6.4.

Indicator 10.5

The consumption of leaded and unleaded petrol

This indicator is currently not reported.

Suggested Response

- Monitoring of ambient atmospheric lead levels should continue.

Description

Lead-based paints were used in many Australian houses before 1970. The risk of exposure is increased if the paint is flaking or chalking and is particularly high when the paint is being removed by sanding, hot air guns, sandblasting or burning.

Lead from motor vehicles is the main source of atmospheric lead.

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

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. Ambient lead levels are within the NHMRC goal (see Table 8). Since the late 1980s, airborne lead levels have declined and are now levelling off.

Table 8. *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. (µg/m^3)	No. of Sites
1991–92	1.44	1
1992–93	1.14	1
1993–94	0.83	1
1994–95	0.59	1
1995–96	0.37	1
1996–97	0.22	1

The 1996 National Survey of Lead in Children (Australian Health and Welfare Council, 1996) found that, Australia-wide, 7.3 per cent of children aged one to four years exceeded the NHMRC goal and that 10.5 per cent exceeded the NHMRC goal in Western Australia.

Pressure

Sources of lead include:

- Lead in petrol — all new Australian vehicles since 1986 have used unleaded petrol; however, in 1995 about 43 per cent of petrol sold still contained lead.
- Lead-based house paint — before 1950 many Australian paints contained as much as 50 per cent lead and high levels persisted even after the replacement of much of the lead by titanium oxide in exterior wall paints. In 1965 the NHMRC uniform paint schedules recommended a maximum lead content of 1 per cent for domestic paint; the maximum allowable concentration in paints today is 0.25 per cent.
- Auto enamel paints, lacquers, driers and anti-corrosive primers.
- Lead industry (smelter and mining activities) — a source of lead exposure for the local community.
- Various hobbies — stained glass and lead-lighting; pottery (lead glazes); casting lead weights for fishing; indoor pistol shooting.
- Cigarette smoke.
- Contaminated dust, soil and water.

Lead particles emanating from industrial processes may accumulate in household dust, soil and water.

Current Responses

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.

All State and Federal environment and health agencies are cooperating to educate the community on the effects of lead and the dangers associated with exposure to sources of lead.

Implications

The concentration of atmospheric lead is not expected to return to levels that would cause health effects. However, non-atmopheric lead exposure can be significant and can impair the intellectual development of children under the age of five.

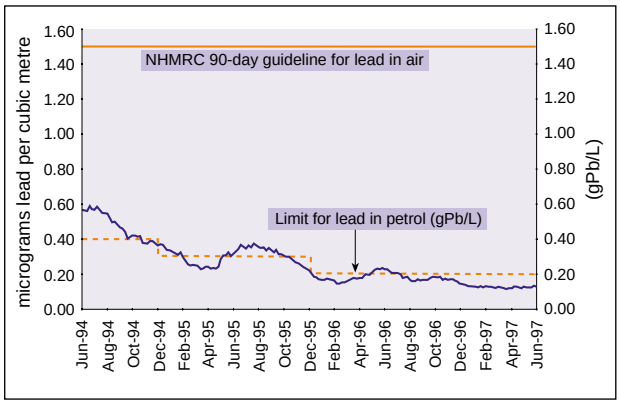
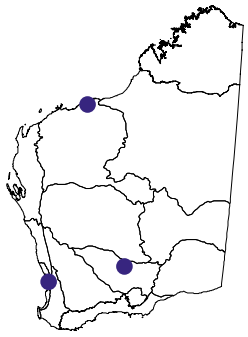


Figure 16. *Lead levels from samples taken at Queens Building, Perth (Source: Department of Environmental Protection).*

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.



Dust

Environmental Status: ✪

Environment 1998 Western Australia

Conclusion

Atmospheric dust resulting from industrial activity and urban land clearing and development can have severe effects on amenity and 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 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.

Indicators

Condition

Indicator 11.1

Annual average dust concentrations in residential areas near ports and facilities prone to dust emissions

See Figure 17.

Response

Indicator 11.2

Proportion of facilities and developments where dust levels are maintained below DEP guidelines

Information is not currently being collected.

Suggested Responses

- Future development should consider dust management as an integral component of environmental management strategies.
- Standards concerning dust levels should be developed and enforced.
- Studies are needed regarding the health effects of ambient dust.

Description

For the purposes of this report, dust includes all airborne particles that are greater than 10 µm in diameter (PM10). Particles less than PM10 are discussed in the section on Haze from Particulates. 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 the Erosion section. However, the clearing of vegetation and other agricultural practices can cause increased dust levels for which there are no available measurements.

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 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 climate of the area. Currently, dust causes minimal ecological damage, and impacts of dust emissions on human health have not been detected. Dust can also be generated by vehicle movement on unsealed roads.

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 and the handling of large volumes of other products such as wheat in agricultural areas and ports.

In 1995, 1.2 million tonnes of iron ore were 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.

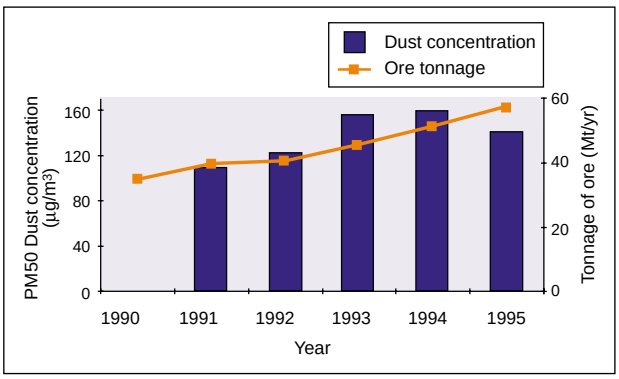


Figure 17. *Tonnage of ore handled through Port Hedland versus annual average townsite dust concentration (Environmental Protection Authority, 1996).*

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 dust pollution.

Current Responses

Land developers and industry are required and, in some cases, are 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 total suspended particulates within set criteria.

Before mining approval is given, industry is required to provide details on management of dust covering the 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, 1996b). 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.

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

LAND

For the purposes of this report and for ease of interpretation, 'land' is taken to mean the soil and subsoil resources that constitute the top of the Earth's surface. The animal and plant life that inhabit the land surface are discussed where they are important to the protection and rehabilitation of land.

Land, like water, is a fundamental resource supporting much of the life on Earth. Vegetation is directly supported by the land and in turn acts as a protective cover of the land resource by: preventing it from being eroded by wind and water; contributing to the development of the soil profile through aeration of the soil and affecting the movement of water; and through contributing organic matter.

In their natural state soils are biologically rich. The ecological relationships between soils, soil biota and natural vegetation ensure healthy soils. Therefore, the primary pressure on the land resource is the removal of vegetation and the decline in soil biota. The amount and rate of this removal is a consequence of our population and the resources we consume.

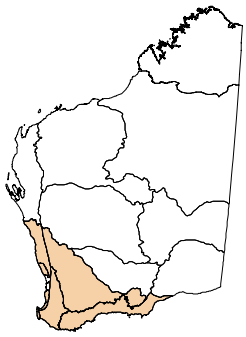
Clearing native vegetation underlies a set of environmental issues that are common across Western Australia. Clearing in the wheatbelt has lead to salinisation of land, erosion, waterlogging, sedimentation of rivers, eutrophication, loss of fringing vegetation, the emission of greenhouse gases, and large losses of biodiversity, as has clearing on the Swan Coastal Plain for urbanisation and other uses. The condition of inland waters is a consequence of the health of their catchments. Many of the State's waterbodies continue to decline as a result of land degradation.

Following the removal of vegetation there can be a range of activities that lead to further degradation of the land resource. These activities include urbanisation, agriculture, disposal of wastes and the introduction of chemicals for a variety of purposes. These activities give rise to a number of environmental issues. In Western Australia the key environmental issues are land salinisation, contamination of land, erosion, acidification and waterlogging.

Use of the land for agriculture has given rise to many of these environmental issues. Changing our agriculture systems is fundamental to achieving a sustainable agricultural industry. These aspects are discussed in the section on Agriculture.

The environmental issues leading to degradation of the land resource also impact on other aspects of the environment. While it is recognised that environmental issues do not occur in isolation or have a single cause or effect, for clarity and to aid understanding, the key issues affecting the land resource are examined separately. These issues are cumulative and often affect the same areas of land. This is important to our understanding of the overall health of land resources.

Objectives are established for each issue and indicators are given that endeavour to reflect the severity and extent of the issue (condition indicator), the causes of the issue (pressure indicator) and society's response to managing the issue by reducing the causes and/or by rehabilitation of the land resource (response indicator).



Land Salinisation

Environmental Status: ✪ ✪ ✪ ✪ ✪

Conclusion

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

It occurs throughout the dryland 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 per cent 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 on private land 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) sets 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
- to protect and maintain natural (biological and physical) diversity within the agricultural areas of Western Australia.

Indicators

Condition

Indicator 12.1

Area of salt-affected land

See Table 9.

Indicator 12.2

Number of threatened taxa and communities at risk from salinity

Information to support this indicator is currently being collected by the Department of Conservation and Land Management.

Pressure

Indicator 12.3

Area of cleared land

See Indicator 3.7 in the section on Maintaining Biodiversity.

Indicator 12.4

Extent of low water-use crops and pastures

Information to support this indicator will be available from the Land Monitor project.

Indicator 12.5

Trend in groundwater levels

Information on trends in groundwater levels is being collected. Methods of presentation are currently being developed. Discussed in Pressure section below.

Response

Indicator 12.6

Proportion of farms and catchments using biophysical water balance information to design farm plans and the proportion of farmers implementing farm plans

Information to support this indicator will be available with the implementation of the SoE reporting framework. Agreed standards should be set for farm plans.

Indicator 12.7

Area of land revegetated

Reported in Current Responses below.

Indicator 12.8

Area of farmland supporting commercial tree crops in the less than 900 mm rainfall zone

Information to support this indicator will be available from the Land Monitor project (Agriculture Western Australia).

Indicator 12.9

Area of farmland supporting perennial shrubs and grasses within appropriate regions.

Information to support this indicator will be available from the Land Monitor project.

Indicator 12.10

Area of remnant vegetation protected from salinity

Discussed in Condition section below.

Suggested Responses

- Re-establish large areas of deep-rooted perennial vegetation and continue to improve high water-use farming systems throughout the agricultural landscape to address the hydrological imbalance.
- Implement the *WA Salinity Action Plan* in consultation with the community.
- Protect existing remnant vegetation on public and private lands, especially where they are at risk of the effects of rising saline groundwater.
- A comprehensive education campaign should be implemented to ensure that people in urban areas are informed of the salinity threat in rural areas and its impact upon them.
- Progressively implement the recommendations of the *Farm Forestry Taskforce* (1995).
- The Western Australian Government should develop economic instruments and tax reform as part of the pending national review of tax arrangements to complement the *WA Salinity Action Plan* and initiatives addressing other environmental issues.
- Fines for illegal land clearing should be significantly increased.
- Incorporate nature conservation and restoration into property management plans.

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 moves off the land as run-off or into the ground to become 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. In addition to those factors that lead to dryland salinity, recharge from excess irrigation and leakage from irrigation channels can cause groundwater to rise, contributing to salinity.

When groundwater comes close to the surface it enters 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 and the salinisation of land, rivers and wetlands are all related to groundwater rise. Importantly, this also changes the water levels and flow regimes in wetland and river environments.

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 per cent of Western Australia's agricultural land is currently affected by salinity (Table 9). 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.

Preliminary results from an Agriculture Western Australia assessment of salinity on the Swan Coastal Plain suggest that up to 20 per cent of agricultural land is affected by salinity and waterlogging. While salinity is currently not a significant issue in the Ord River catchment, this issue may be emerging and will need to be managed in the long-term.

Table 9. *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.

Salinity has markedly decreased biodiversity, particularly at the local and regional scales. Up to 80 per cent of susceptible remnants of native vegetation on farms and 50 per cent on public lands (including nature reserves) could be lost in the agricultural regions of Western Australia within the next century (Indicator 12.10). Losses will continue for many years even if practices to combat salinity are implemented immediately.

Pressure

Past land clearing and replacement of native vegetation with low water-use 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 Western Australia to prevent land degradation. It is still occurring in some areas (see Figure 10 in Maintaining Biodiversity).

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

Groundwaters continue to rise at a rate of between 5 cm and 1 m per year in agricultural areas (Nulsen, 1998) (Indicator 12.5).

Current Responses

A comprehensive *WA Salinity Action Plan* has been adopted by the State Government which includes monitoring and reporting on the extent and severity of salinity. To achieve the aims of the Plan, the Government in partnership with farmers and the community has undertaken to:

- plant another three million hectares of perennials across the agricultural area;
- ensure that other commercially viable water management practices complement these plantings to maximise water-use and economic benefits; and
- protect and manage remnant vegetation in perpetuity.

Research to quantify the nature and extent of salinity has occurred over many years. The Department of Conservation and Land Management is currently carrying out a biological survey in agricultural areas at risk from salinity.

There are many community involvement programs which promote action to slow the rate of land salinisation.

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

Research has been conducted to design more productive and higher water-use farming systems and these are gradually being adopted. Many catchment groups and farmers have focused on salinity management. However, salinity management through widescale revegetation or adoption of other high water-use practices has occurred in few catchments.

Research and development are also being conducted to assist in the broad-scale introduction of commercial tree crops on cleared agricultural land and the integration of these tree crops into farming systems. It is important that a diverse range of commercial tree crops, including local provenance species, are developed. There is also a need to rehabilitate large areas of agricultural land with native vegetation to integrate the responses to salinity and loss of biodiversity.

Clearing controls exist to protect remnant vegetation. In some catchments, there are total clearing bans. Where landholders fail to lodge notifications of intent to clear, they are prosecuted under the *Soil and Land Conservation Act 1945* (*WA*) and a Soil Conservation Notice is served which may require revegetation or other measures to 'make good' on the potential land degradation.

Remnant vegetation has been protected under the Remnant Vegetation Protection Scheme which provides partial funding for fencing and under clearing controls by Agreements to Reserve. The Remnant Vegetation Protection Scheme has funded fencing of 70,000 ha of remnant vegetation.

Under the *Income Tax Assessment Act 1936* (Commonwealth) there is provision for capital expenditure primarily to combat land degradation to be deductable from taxable income. Activities that permit a full tax deduction include tree planting to combat salinity, fencing or remnant vegetation, feral animal and weed control or the cost of preparing a property management plan to prevent land degradation.

In 1995–96 approximately 25,000 ha of land in the south-western agricultural area was revegetated (ABS Agricultural Census Data) (Indicator 12.7).

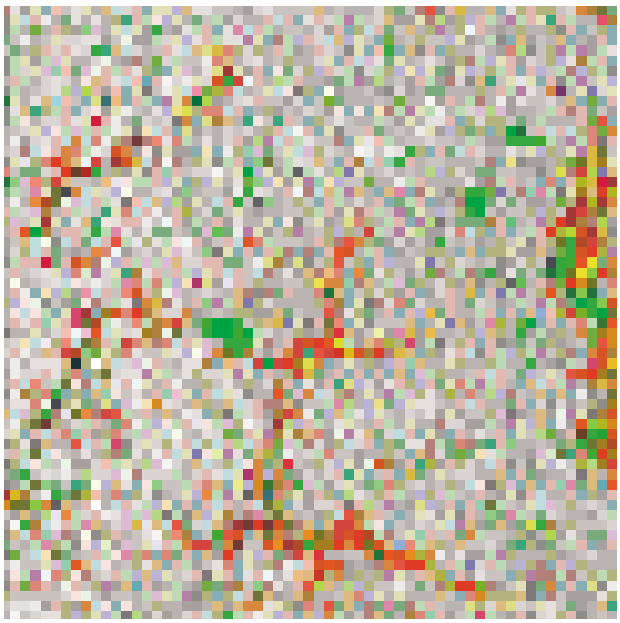
Implications

The implications of land salinisation for Western Australia's environment and society are enormous (Chief Executive Officers *et al.*, 1996). A conservative estimate of the 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 escalate from a minimum of $64 million each year until a new hydrological balance is reached.

In addition, 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 as soils becoming salty. Waterlogging will dramatically increase the magnitude of run-off volumes and peak flood events which has implications for the health of rivers and wetlands.

Forty-six million dollars has already been spent to compensate 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. Many wheatbelt towns are being damaged by encroaching salinity problems. Existing infrastructure, for example, roads, have been located and designed without considering the risks associated with increased salinity and waterlogging. The social and environmental costs of land salinisation have not been fully quantified, but probably exceed the estimated economic costs. Unprecedented effort is required by the entire community to arrest the degradation of agricultural soils and the loss of the remainder of the natural environment in the agricultural areas of Western Australia.



Mapping and monitoring of dryland salinity from Landsat TM and landform data. The area shown is approximately 120 km by 120 km of the Upper Blackwood catchment, WA. Areas mapped as saline using 1989/90 image data are shown in red; yellow shows increases in salt affected land from 1990 to 1994; remnant vegetation and waterbodies are shown in green. Satellite image courtesy of CSIRO, Perth.

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

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

Land Contamination

Environmental Status: ✪ ✪ ✪ ✪

Environment 1998 Western Australia

Conclusion

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

Over 1500 contaminated sites are thought to exist in Western Australia (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 Western Australia.

Objective

To ensure that further land contamination is prevented and that all existing contaminated sites are identified and managed to prevent environmental impacts.

Indicators

Condition

Indicator 13.1

Number, area and distribution of contaminated sites, the nature of contaminant and associated risk

Currently, it is only possible to provide information on the estimated number of potential contaminated sites in Western Australia.

Pressure

Indicator 13.2

Location, number and nature of contaminating activities

Information to support this indicator will be available with the implementation of the National Pollutant Inventory.

Response

Indicator 13.3

Proportion of contaminated sites that are well managed and contained according to the contaminated sites management framework

Information to support this indicator will be available with the implementation of the SoE reporting framework.

Indicator 13.4

Management notices for organochlorine pesticide contamination

Discussed in Condition section below.

Suggested Responses

- Remediation and prevention measures for land contamination should meet best practice management. A land contamination prevention strategy should be developed as part of the integrated contaminated sites management framework.
- Establish an inventory of contaminated sites.

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 section).

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 Western Australia, 1200 of these occur on the Swan Coastal Plain (Indicator 13.2). 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 previously used for industry or agriculture has been turned into residential land. In some cases this land may be contaminated from past activities and practices, for example, 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 the Consumption and the Environment section). 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, for example, some potato growing areas near Manjimup. The 1992 SoE Report indicated that 12,700 ha are subject to management notices under legislation. More recent estimates are in preparation (Indicator 13.4). 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.

Landfill sites in rural areas have caused contamination of groundwater and streams due to relatively poor standards and because they have been located in unsuitable areas.

Dams created to store the waste material from mines are often rehabilitated; however, they remain as contaminated sites. If managed or constructed inappropriately they can also lead to contamination of surrounding land, groundwater, streams or wetlands.

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 a neighbouring land-use, either as vapour, leachate or movement of liquids through the soil;
- the use of agricultural chemicals (Australian and New Zealand Environment and Conservation Council & National Health and Medical Research Council, 1992); and
- mining activities such as tailings dams and some disused mine sites, such as Wittenoom (blue asbestos). The dams of tailings deposits are, in most cases, not built as engineered structures, but by piling up the coarse fraction of the tailings slurries themselves.

There are three broad sources of low radioactive wastes that can be stored at the Mount Walton East Intractable Waste Disposal Facility: industrial, medical and research/education. Generated wastes are disposed of at Mount Walton East by burial in deep trenches. The radioactive waste will be take between 1,000 and 1,000,000 years before it has decayed beyond the point of concern.

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

Current Responses

New environmental legislation is proposed to provide an integrated contaminated sites management framework which will require identification, investigation and remediation of contaminated sites.

The Water and Rivers Commission has released draft guidelines for the location, specifications and operation of underground storage tanks over sensitive areas.

In 1997, the Clean Up Australia Day initiative removed approximately 10,000 tonnes of rubbish from 7,858 sites, involving over 550,000 volunteers nationwide. A significant portion of this waste is toxic and has the potential to contaminate.

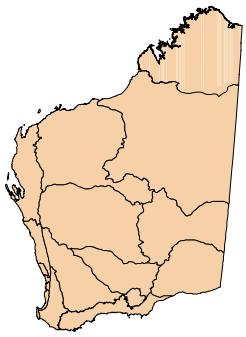
The Australian Dangerous Goods Code (Department of Transport and Communications, 1992) outlines detailed, stringent guidelines for the transport of dangerous goods, most of which are potenital pollutants.

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, for example, contaminated meat arising from pesticide use. Land contamination also has significant effects on water quality. The economic consequences of land contamination are considerable and far outweigh the costs of stringent measures for prevention.

See also Contamination of Inland Waters within this report.



Erosion

Environmental Status: ✪ ✪ ✪ ✪

Conclusion

Soil erosion continues to affect the productivity of agricultural and pastoral lands. It can also lead to environmental effects, such as sedimentation and eutrophication of inland waters and the decline of vegetation.

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

Minimum and no-till farming systems have been developed to reduce wind and water erosion rates in the past 10 years. Although methods to manage erosion are well established more effort is required to promote best management practices for this issue. Improved hazard assessment in the face of unseasonable conditions and better defined management responses are required.

Objectives

To prevent and minimise the extent and severity of soil erosion.

To stabilise and, where possible, rehabilitate eroded lands.

Indicators

Condition

Indicator 14.1

Area of land affected by soil erosion

See Table 10. Additional methodologies need to be developed to support this indicator.

Indicator 14.2

Area of land with adequate vegetative cover

Information to support this indicator will be available either from Agriculture Western Australia's Land Monitor project or the National Landcover project.

Pressure

Indicator 14.3

Total Grazing Pressure (TGP) adjusted for seasonal condition (grazing by stock, ferals and kangaroos combined)

Additional information to support this indicator will be available with the implementation of the SoE reporting framework.

Indicator 14.4

Area of cultivated land

Information to support this indicator will be available from the Land Monitor project.

Response

Indicator 14.5

Area or proportion of regions maintaining adequate protective vegetation cover

As for Indicator 14.2.

Indicator 14.6

Area protected by wind breaks

Discussed under Current Responses below.

Indicator 14.7

Area of sloping cultivated land with effective water management

Information to support this indicator will be available with the implementation of the SoE reporting framework.

Suggested Responses

- Implement the State Government policy *Managing the Rangelands* (see Agriculture).
- Further develop better management practices for erosion and communicate these to land managers. Preventative measures such as revegetation with natural vegetation and farming systems that conserve soil need to be developed and applied widely.
- Integrate the need to rehabilitate eroded lands with current and proposed revegetation strategies.
- Develop more effective indicators of erosion for agricultural lands. There is an urgent need for a quantitative assessment and estimates of current annual sediment transport in key river basins including its current level of deposition along stream courses, in pools, in estuaries and out to sea.
- Develop an 'early warning system' which can trigger land managers to take steps to prevent or ameliorate land degradation events such as wind erosion.

Description

Soil erosion occurs when landform or soils are exposed and disturbed, for example, during mining activities, 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, downwind or downstream.

Erosion causes a loss in agricultural productivity through the loss of fertile topsoil and exposure of infertile 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. Human induced soil exposure and erosion can be exacerbated with natural events such as floods and droughts.

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 Western Australia (Indicator 14.1).

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 five years (affecting tens of thousands of hectares) and some erosion can occur every year (affecting thousands of hectares). However, severe wind erosion events have occurred more frequently along the South Coast and the Midwest Coastal Plain regions in recent years (1987, 1990, 1991, 1994, 1995 and 1996).

As much as 20 mm of topsoil has been lost from parts of some paddocks during a single storm. Damage done in severe events has taken many years to recover.

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 per cent) 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 10).

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 are declining but most sites remain stable.

Pressure

The largest 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 increased water repellence. The light, sandy soils of the South Coast and Midwest

Table 10. *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) [1992]	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) [1998]	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)

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. Since the late 1980s, wind eroded areas in the southern Stirlings and the Midwest Coastal Plain Region have been mapped.

Stubble burning continues in some areas. This practice is unacceptable and should be discouraged.

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

Throughout the State mineral exploration and mining have caused localised erosion through seismic surveys and massive local changes in landform mostly associated with road building and abandoned mines.

Current Responses

There is increasing adoption of best management practices in agriculture including minimum tillage systems for crop establishment which incorporate 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.

There are many Landcare community involvement programs which promote action to prevent soil erosion and rehabilitate eroded lands.

Remote sensing information has been analysed for some parts of the State to monitor the extent and severity of wind erosion. In 1995, 3500 km of windbreaks were planted (Indicator 14.6).

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.

A study of erosion rates since the 1950s in agricultural and pastoral areas of the State will be published by Agriculture Western Australia in 1998.

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 is available.

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

Soil Acidification

Environmental Status: ✪ ✪ ✪

Environment 1998 Western Australia

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 from the exposure of natural sulphide-bearing rocks during mining is discussed in Contamination of Inland Waters.

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 develop approaches to prevent and 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.

Indicators

Condition

Indicator 15.1

The area of land affected by soil acidification

Discussed under Condition section below.

Pressure

Indicator 15.2

The amount of chemical fertiliser applied in agricultural areas

Discussed under Pressure section below.

Indicator 15.3

The area of leguminous crops planted and pastures grown

Discussed under Pressure section below.

Response

Indicator 15.4

The amount of lime applied in agricultural areas and the area over which it is applied

See Table 11.

Suggested Responses

- Further monitoring of the extent of soil acidification.
- Further research into less acidifying agricultural systems (crops, fertilisers and management).
- 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 conservation value.

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. Because plants growing in acidic soils are unable to use fertilisers effectively, eutrophication of inland waters and nearshore marine areas is more likely.

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 Western Australia 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) (Indicator 15.1). 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 of these activities are critical to maintaining agricultural productivity. The total area planted to legumes increased by 44 per cent between 1993 and 1995 (Indicator 15.3). It is likely that this trend will continue.

In 1993–94 the area of land fertilised for agriculture in Western Australia was the largest in Australia at 7.56 million ha, with a total of 866,000 tonnes applied (Australian Bureau of Statistics, 1996a) (Indicator 15.2).

Current Responses

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. In 1996, less than 20 per cent of farmers who should be applying lime did so.

Agriculture Western Australia 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 Western Australia (Table 11) (Indicator 15.4).

Table 11. *Lime and/or dolomite usage for Western Australia 1994–95 (Source: Austalian Bureau of Statistics).*

District	Area (Ha)	Quantity (t)
Perth	1378	3885
South West	24,195	35,772
Lower Great Southern	38,627	37,400
Upper Great Southern	18,439	17,021
Midlands	3544	42,110
South Eastern	1899	2680
Central	18,987	20,279
Kimberley	10	14
Western Australia	138,980	159,165

Implications

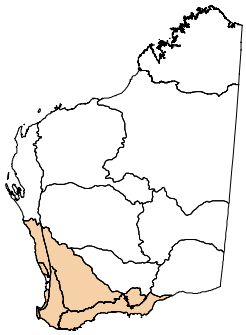
In 1992 it was estimated that soil acidification had the potential to reduce production on about 55 per cent of the State's agricultural area. The estimated cost of lost production from soil acidification is $150 per ha with an estimated loss in areas of high pH of about $70 million annually (Landcare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

Soil acidification is managed through the application of neutralising substances, for example, 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 large but finite natural resource often occurring in vegetated areas of conservation value and their use is not ecologically sustainable in the long-term. Areas of high conservation and landscape amenity value must be protected and the impacts of lime extraction carefully managed.

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



Waterlogging

Environmental Status: ✪ ✪

Environment 1998 Western Australia

Conclusion

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

Waterlogging increases run-off, erosion, recharge and soil structure decline. Waterlogging and run-off from waterlogged areas have damaged remnant vegetation, leading to losses in biodiversity.

The extent of waterlogging in Western Australia 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.

Indicators

Condition

Indicator 16.1

Areas of waterlogging categorised on the basis of temporal extent (that is, occasional, seasonal and permanent)

Additional information to support this indicator will be available with the implementation of the SoE reporting framework.

Pressure

Indicator 16.2

Area of cleared land

See Indicator 3.7 in Maintaining Biodiversity section

Indicator 16.3

Intensity of land use (amount of cultivation, stocking rates, reduction in organic matter in soils)

Information to support this indicator will be available with the implementation of the SoE reporting framework.

Response

Indicator 16.4

Extent to which appropriate management methods are adopted, for example, surface drainage, minimum and zero tillage, gypsum applications, controlled grazing when soils are wet, high water-use crops

Information to support this indicator will be available with the implementation of the SoE reporting framework.

Indicator 16.5

Extent to which low-lying waterlogged areas are managed as naturally wet areas or revegetated

Information to support this indicator will be available with the implementation of the SoE reporting framework.

Suggested Responses

- Implement the *WA Salinity Action Plan* including surface water control measures.
- Develop improved soil and surface water management practices.
- Develop and evaluate new enterprises requiring water harvesting and use, for example, aquaculture. These should be developed within strict environmental guidelines.
- Use appropriate technology, for example, satellite imagery, to monitor waterlogged and saline areas to assist in providing information for improved practices.

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 such as swamps and wetlands. However, on agricultural land it can severely reduce the yield of crops and pastures. Here waterlogging is caused when winter rainfall exceeds evaporation and where soils have a low waterholding capacity.

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 and lead 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, 1996). 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 experiences 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 inadequate water-use by 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 exacerbate 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 Responses

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

Improved soil management practices combined with surface drainage are being developed to prevent waterlogging in crops and to increase the productivity of land prone to waterlogging.

An interagency Memorandum of Understanding on drainage controls is in development and is likely to be finalised in 1998. The development of drainage systems is regulated through the *Soil and Land Conservation Act 1945* (*WA*).

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

Higher water-use perennial and tree crop species are being developed for integration into agricultural systems. Further long-term work is required in this area.

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 run-off 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 Western Australia is available only 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.

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

INLAND WATERS

For the purpose of this report and for ease of interpretation, 'inland waters' is taken to mean groundwater, rivers, wetlands and estuaries. The animal and plant life that inhabit inland waters is discussed where it is important to the protection of inland waters (such as fringing vegetation) or where it is directly affected by changes in the condition of inland waters. The biodiversity of inland waters is discussed in the Maintaining Biodiversity section.

Water is a fundamental resource supporting life on Earth. The quality and availability of water is critical to all living organisms. There are a range of factors that may cause one or both of these aspects to change. The two underlying factors are climate variability (natural) and climate change (human-induced).

In the short-term, changes are arising from human population and activities which place significant pressures on surface and groundwaters in Western Australia. These activities include agriculture, water abstraction, recreation, industry and urbanisation.

In Western Australia the key environmental issues are salinisation of inland waters, loss of fringing vegetation, eutrophication, sedimentation and contamination of inland waters. Inland waters can also be affected when water flows are modified and when water is extracted for human use. These aspects are discussed in the Water Supply section.

Water quality is a function of the health of a catchment and the inputs which flow directly or indirectly from activities in the catchment. Where native vegetation in a catchment is largely intact, water quality is usually good. Water quality and water quantity issues combine to directly affect the biodiversity of inland waters and the humans that use these resources. Erosion can lead to turbidity and sedimentation which in turn can result in habitat loss. Increasing salinity can restrict the movement of aquatic organisms and preclude uses such as drinking or irrigation. Contamination and eutrophication of waterways, especially our rivers and estuaries, can also impact on the ecosystem health of the nearshore marine environment.

While it is recognised that environmental issues do not occur in isolation or have singular causes or effects, for clarity and to aid understanding, the key issues affecting inland waters are examined separately. However, it is crucial to understand that a number of issues are likely to affect inland waters simultaneously. In time, programs such as the Monitoring River Health Initiative will provide a means to assess the cumulative effect of these issues on the health of inland waters. There are significant inter-relationships between the key environmental issues which require integration in the development and implementation of responses.

For each issue an objective is stated and indicators are given that endeavour to reflect the severity and extent of the issue (condition indicator), the cause(s) of the issue (pressure indicator) and society's response to managing the issue by reducing the causes and/or by rehabilitation of inland waters (response indicator).

Salinisation of Inland Waters

Environmental Status: ✪ ✪ ✪ ✪ ✪

Environment 1998 Western Australia

Conclusion

Salinisation has steadily degraded most of the inland waters in the south west of Western Australia 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. Reforestation has led to significant reductions to groundwater levels and in the amount of salt transported by streamflow in experimental catchments (Bell *et al.*, 1987). Discernible reductions have also been observed in the salt input to Wellington Reservoir following the reforestation of about 10 per cent 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.

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.

Objectives

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 Western Australia; 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.

Indicators

Condition

Indicator 17.1

Trend in the proportion of stream length, wetland area and total number of farm water supplies which exceed water quality objectives for salts

Information to support this indicator is currently not being collected.

Indicator 17.2

The duration of time that salinity is above water quality criteria at specific locations on key river systems

Information to support this indicator is being collected but is currently unavailable in this form.

Indicator 17.3

The average annual salinity concentration of key river systems in each region (corrected to reflect a year of average/median flow)

See Table 12.

Indicator 17.4

The trend (mg/L/year total soluble salts) in the salinity of a year of median flow of key river systems in each region

See Table 12.

Pressure

Indicator 17.5

The area of cleared land throughout the agricultural area between the 900 mm isohyet and the catchment boundary of river systems that regularly drains to the coast each year

Information to support this indicator will be available from Agriculture Western Australia's Land Monitor project.

Indicator 17.6

The area of newly established deep-rooted perennial vegetation from the 900 mm isohyet to the catchment boundary of river systems that regularly drains to the coast each year

Information to support this indicator will be available from the Land Monitor project.

Response

Indicator 17.7

For key potable water resource catchments, the effectiveness of the response will be reported as the ratio of current salinity minus target salinity to maximum historic salinity minus target salinity.

As an average there has been 5 per cent progress until 1997 in reaching defined targets on recovery catchments (Loh, 1997).

Indicator 17.8

Indicators for key wetlands and natural diversity recovery catchments are being developed by CALM as part of the Salinity Action Plan.

Indicator 17.9

Proportion of salt-affected catchments with revegetation targets set by 2000

Revegetation targets are currently being developed.

Indicator 17.10

Proportion of designated streams with defined salinity targets.

Information to support this indicator is currently unavailable.

Indicator 17.11

Proportion of designated streams meeting salinity targets, for example, salinity targets defined for the Blackwood River at Bridgetown by the Blackwood Catchment Co-ordinating Group.

Information to support this indicator is currently unavailable.

Suggested Responses

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.

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 Western Australia it is thought 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 are 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 per year invariably have become brackish or saline (over 1000 mg/L TSS). The average salinity of streams which drain the high rainfall areas of the Darling Range (greater than 1100 mm per year) usually remains 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 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 12 shows salinity levels of representative rivers for each affected region. Information on salinity of wetlands is limited.

Table 12. *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)	Trend - 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

Pressure

Any activity that disturbs the water balance where significant salt is stored in the soil 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.

Any change in salinity is likely to have an impact on freshwater ecosystems. 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 the Land Salinisation section of this report, and in Section 5 of the *State of the Environment Reference Group Draft Working Papers*.

Current Responses

The Water and Rivers Commission is working with landowners 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 is 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.

The *Environmental Protection (South West Agricultural Zone Wetlands) Policy*, *Swan Coastal Plain Lakes Environmental Protection Policy* and the *Wetlands Conservation Policy for Western Australia* (Government of Western Australia, 1997b) all provide means by which wetlands with high conservation values can be protected from salinisation.

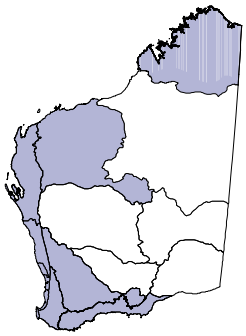
Improved protection of streams from the temporary impact of logging has been developed and long-term research and monitoring programs are in place to ensure careful management of bauxite mining and subsequent rehabilitation.

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 per cent of divertible riverine water resources remain fresh in the south west of Western Australia;
- 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.

Salinisation of Inland Waters is directly related to Land Salinisation and relates to Maintaining Biodiversity. See these sections in this report.



Loss of Fringing Vegetation

Environmental Status: ✪ ✪ ✪ ✪

Conclusion

One of the most damaging changes 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. Because these areas are so biologically rich, degradation is leading to significant losses of biodiversity.

Remnant fringing vegetation is not being managed sustainably. 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 focussed on using indigenous species 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 sections) by the year 2020. Ecologically sustainable management is defined for the purposes of this objective to involve the maintenance of environmental values and the protection of biodiversity as outlined in the objectives in the section Maintaining Biodiversity.

Indicators

Condition

Indicator 18.1

Length of healthy fringing vegetation corridors (of adequate width) as a proportion of total estuary, wetland and substantial streamline[1] length

See Table 13.

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

Pressure

Indicator 18.2

The proportion of substantial streamlines not managed sustainably and therefore susceptible to degradation

Information to support this indicator is being developed.

Response

Indicator 18.3

The proportion of substantial streams adopted by managers and with active management plans

Information to support this indicator is being developed.

Suggested Responses

- Large scale fencing and restoration of fringing vegetation is necessary to achieve the State's environmental objective for fringing vegetation (above). Establish vegetated waterway protection corridors on at least 50 per cent of substantial streamlines 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 the local community. A research program is required to determine specific widths for protection corridors and should refer to buffer functions outlined by Davies and Lane (1995).
- Research into fringing vegetation zone restoration technologies is needed.
- Waterway and wetland restoration programs are necessary, as part of strategic environmental plans for environmental regions, including catchment-based revegetation programs.
- A long-term program based on the initial work of the Wild Rivers Project (Water and Rivers Commission, 1997a) should be developed for mapping and assessing the northern rivers of

Western Australia in a cooperative approach with community groups. This should be designed to complement the Monitoring River Health Initiative.

- Specific clearing controls on fringing vegetation and measures to facilitate restoration should be introduced. Formal planning mechanisms should be used to protect existing areas of fringing vegetation to ensure that development prevents any further losses.

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;
- controlling light, colour and temperature conditions in the water column;
- reducing channel erosion by decreasing the speed of river flow;
- 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 government and 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 13 indicates the condition of riparian vegetation for the main channels of all rivers currently surveyed. Forty-six per cent 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 per cent of rivers and creeks surveyed between Gingin and Mandurah, 52 per cent of rivers and 66 per cent of creeks had lost half of their native fringing vegetation. Only 7.5 per cent of wetlands in the same area were found to have healthy fringing vegetation (Indicator 18.1). 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 marshes are declining both in quality and quantity and have done so since 1965. Between 1965 and 1994, 37 per cent of samphire has been lost (McComb *et al.*, 1995) (Indicator 18.1).

In a community survey of attitudes toward the health of the Blackwood River's fringing vegetation, more than 80 per cent of the people who live near the Blackwood

Table 13. *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, 1997)
‡ (Source: Water and Rivers Commission)

River were concerned about its condition and believed that river health would further decline if no action was taken (Butterworth & Carr, 1996).

In the north of Western Australia where pastoral, mining and tourism activities dominate, fringing vegetation has been degraded by stock, feral animals, weed invasion and erosion. Figure 18 presents the health of vegetation along rivers of the north of Western Australia (Water and Rivers Commission, 1997a).

Pressure

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

Fringing vegetation is prone to degradation from grazing and trampling by livestock, weed invasion, frequent burning and recreation. Recreation and development are significant pressures on fringing vegetation of estuaries. Inappropriate fire regimes can have particularly significant effects on wetlands. Fire is a compounding factor for weed invasion (such as bulrush and ryegrass) and the effects of grazing (Pen, 1998). The burning of peat substrate in wetlands is also an issue; however, there is little scientific information on the effects of peat burning on wetland health (see Horwitz *et al.*, 1997).

Salinity is a major pressure on fringing vegetation. More than 80 per cent (by length) of stream fringing zones are seriously degraded by salinity in the cleared agricultural areas and many wetlands are threatened or already in decline (see Salinisation of Inland Waters section). Drainage can have a significant impact if it carries saline water into fringing vegetation. Groundwater rise and increases in the volume of run-off are causing inundation of fringing vegetation which can result in its decline, especially around wetlands.

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 Responses

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 Western Australia. 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 per cent (Pen, 1996) (Indicator 18.3).

The *WA Salinity Action Plan* is implementing a Key Wetlands and Natural Diversity Recovery Program in three catchments currently and this number will increase.

A Wetlands Conservation Policy for WA (Government of Western Australia, 1997b) has been developed and implementation has begun.

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, for example, fish nurseries and waterbird habitats. There has been no analysis of the social and economic implications of fringing vegetation decline in the State.

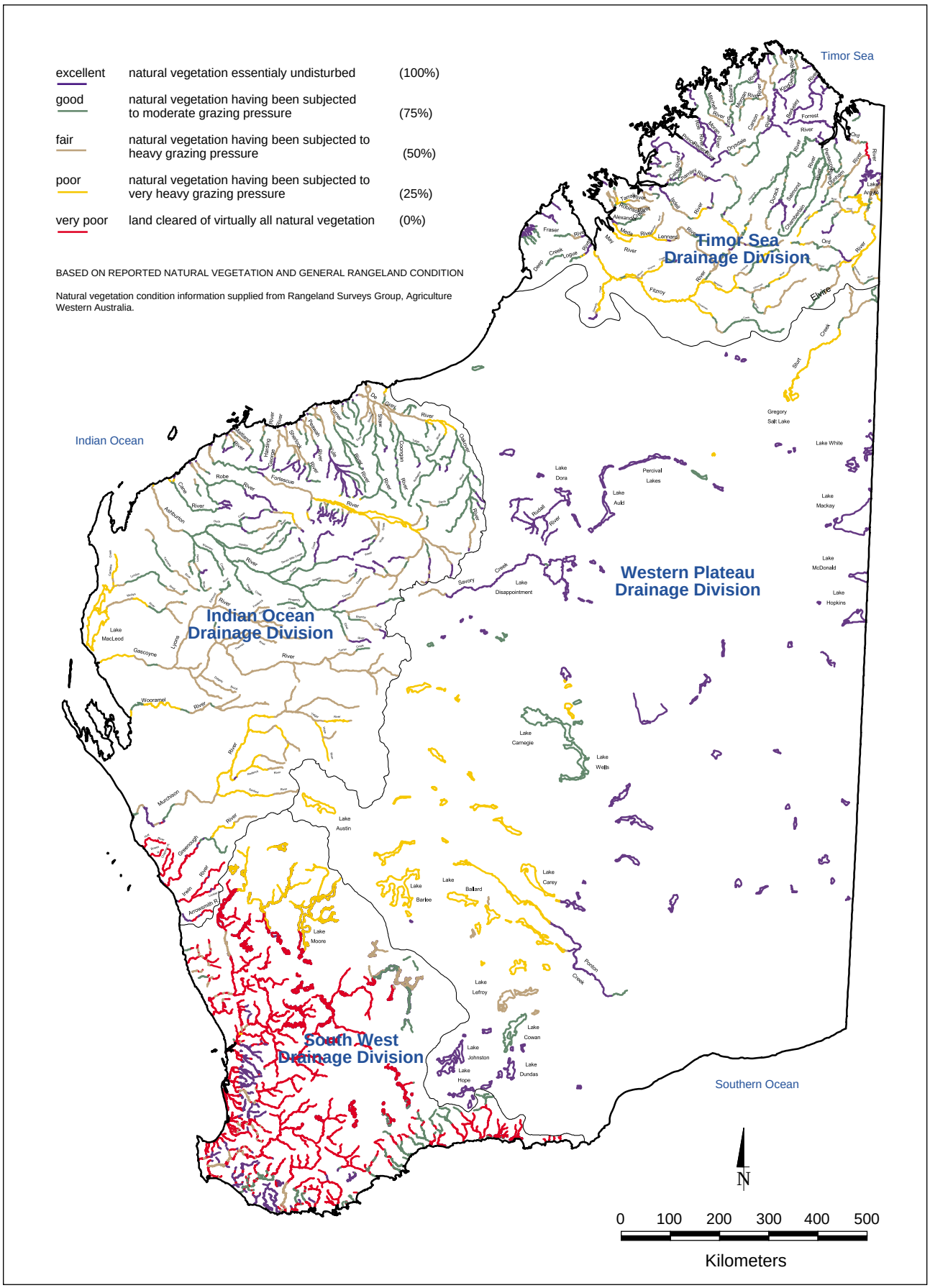


Figure 18. *The health of rivers based on the Condition of fringing vegetation in Western Australia (based on Water and Rivers Commission, 1997a)*

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 5 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 Western Australia 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 wildlife, 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.

Objectives

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.

Indicators

Condition

Indicator 19.1

Trends in nutrient concentrations

Information to support this indicator is being collected but is limited to a small number of waterbodies (Government of Western Australia, 1997a).

Indicator 19.2

Reported incidence of algae blooms and fish kills

Information to support this indicator is being collected but is limited to a small number of waterbodies (Government of Western Australia, 1997a).

Indicator 19.3

Total phosphorus and total nitrogen concentrations compared with EPA guidelines for the protection of aquatic ecosystems

Information to support this indicator is being collected and is reported in the *State of the Environment Reference Group Draft Working Papers, Inland Waters*. These guidelines should not be applied strictly as they only provide a general indication of nutrient concentrations that should be expected in various waterbodies.

Pressure

Indicator 19.4

Loads of phosphorus and nitrogen entering waterbodies (including proportion from industry point sources)

See Figure 19.

Indicator 19.5

Fertiliser application in rural and urban catchments

See Indicator 15.2. Currently, information is not available at a catchment scale.

Indicator 19.6

Length of healthy corridors of fringing vegetation as a proportion of total substantial streamline length

See Indicator 18.1.

Indicator 19.7

Proportion of urban areas that are unsewered

Discussed in section on Pressure below.

Response

Indicator 19.8

Proportion of towns with reticulated sewerage

This information is currently not available to be reported in this form.

Indicator 19.9

Number of farms and towns with implemented plans for water sensitive design

Information to support this indicator will be developed with the implementation of the SoE reporting framework.

Indicator 19.10

Extent of revegetation along fringing vegetation zones

This information is currently not available to be reported in this form.

Indicator 19.11

Proportion of affected catchments with implemented integrated catchment management plans

This information is currently not available to be reported in this form.

Suggested Responses

- Develop a framework for determining environmental values and solutions to eutrophication in Western Australia, based on the National Water Quality Management Strategy by 1998 (Agriculture and Resource Management Council of Australia and New Zealand & Australian and New Zealand Environment and Conservation Council, 1994). Determine environmental values by 2000.
- A Eutrophication Action Plan should be developed which includes restoration programs for all affected environmental regions as part of strategic environmental plans. These should provide support for integrated catchment management initiatives and incorporate a community education program.
- A process for establishing and reviewing best land management practices should be developed. Best land management practices (including water sensitive urban design principles) should be implemented by 50 per cent of land-users by 2010 and 100 per cent by 2020.

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 nutrients causing eutrophication.

Algal blooms need phosphorus and nitrogen to occur. The supply of available phosphorus is often most limiting and controls the occurence of algal blooms in most inland waters in the south west of Western Australia. 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 in inland waters, however, 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 soils of low fertility which support plants that are adapted to low nutrient levels.

In other areas where soils are heavier and nutrients are bound to soil particles, soil erosion plays a leading role in eutrophication. 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 release of nutrients from sediments continues to fuel algal blooms.

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

Best land management practices can be defined as the best practicable methods of meeting land resource management objectives (Environmental Protection Authority *et al.*, 1994).

Condition

The Select Committee into Land Conservation (Legislative Assembly, 1991a) reported that in the south west of Western Australia 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.

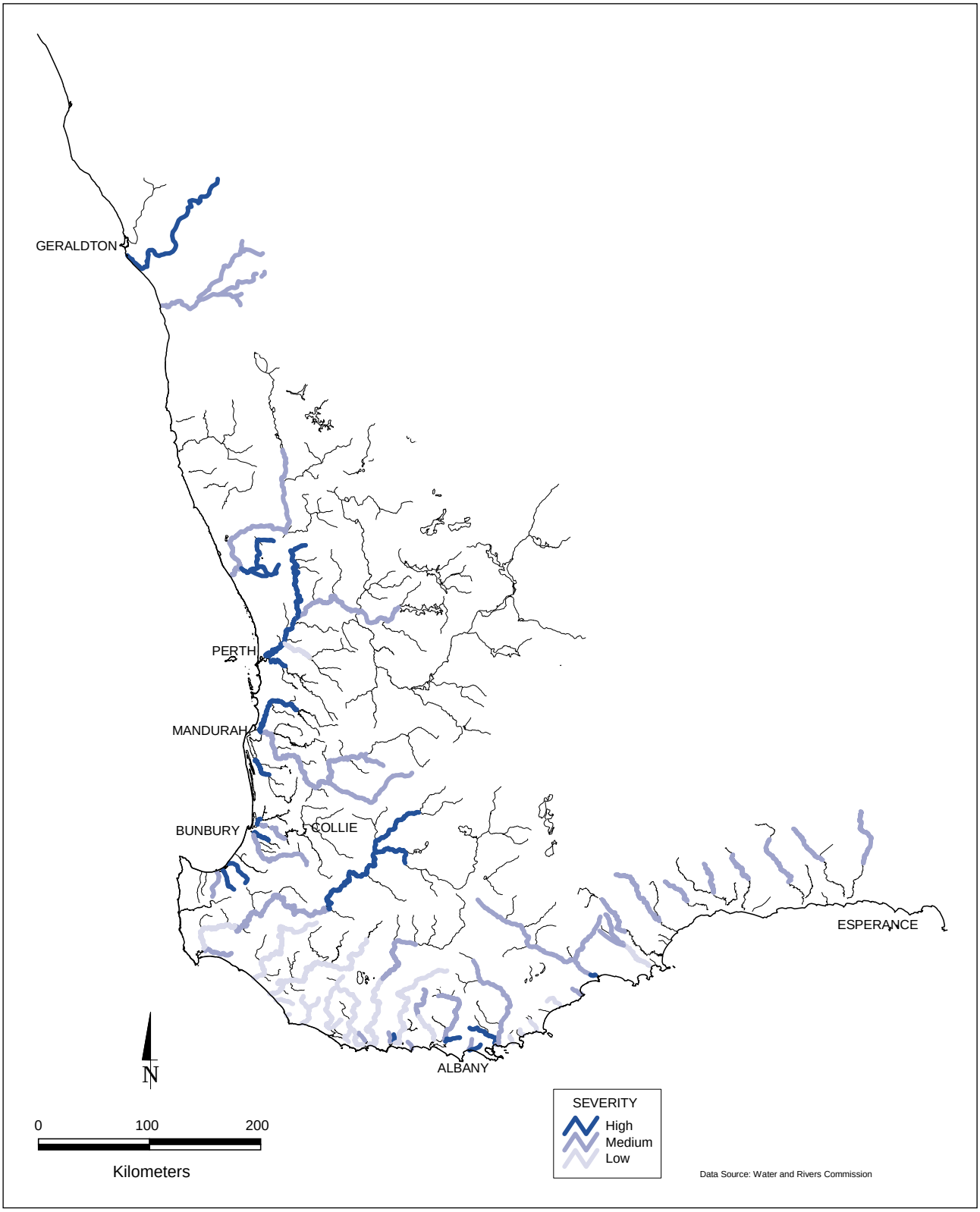


Figure 19. *Severity of nutrient loads to various waterbodies in the State (after Legislative Assembly, 1991a).*

In the Peel-Harvey Estuary the three main tributaries discharge 90 per cent of their river flow during the four months of winter and early spring. It is during these periods that the bulk of nutrients and sediments enter the system after draining the mainly cleared rural lands (Rose, 1998). The peak nutrient concentrations in the Peel-Harvey Estuary depend on concentrations in river inflow and the Dawesville channel did not affect these (D. A. Lord and Associates, 1997). Therefore little difference was found between pre-Dawesville and post-Dawesville channel water quality nutrient concentrations in the winter months, possibly because the internal nutrient load is being removed from the system. However, during the remaining months of the year the organic nitrogen and phosphorus concentrations were reduced.

Pressure

The most important sources of nutrients are fertilisers from broad acre applications; fertilisers leached from horticultural practices; nutrient-rich run-off 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 that more fertiliser results in a greener garden. Excess fertiliser is leached from soil into groundwater or carried as run-off 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, the river moves more slowly and the 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. Septic tanks are thought to contribute significantly to the eutrophication of groundwater and an infill sewerage program to replace septic tanks in the metropolitan region is in its fourth year. Approximately 20 per cent of the metropolitan region remains unsewered (Indicator 19.7).

Figure 19 presents the severity of nutrient loads to various waterbodies in the State.

Current Responses

Environmental Protection Policies (EPP) and Statements of Planning Policy have been used to reduce nutrient pressure on some inland waters. Since 1992, the Metropolitan Region Scheme has been amended to protect areas within part of the Jandakot Water Pollution Control Area. A new zone has been developed to protect groundwater supplies which has extended a water catchment reserve over existing regional reserves in the Jandakot Water Pollution Control Area. A State Groundwater EPP is currently in development and the Swan-Canning EPP is approaching finalisation. The Peel Inlet-Harvey Estuary EPP has been in place since 1992.

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 Harbours river systems. Other groups are in the process of developing similar plans for addressing eutrophication in other rivers or smaller catchments through conservation strategies.

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.

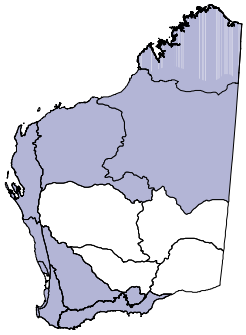
Water sensitive urban design guidelines provide a framework and comprehensive set of best management practices for reducing nutrient inputs to waterbodies from urban areas.

Implications

The relationships between inland waters and the nearshore marine environments into which they flow are extremely important for protection of the marine environment. Nitrogen inputs have been causing eutrophication of nearshore environments.

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

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



Sedimentation

Environmental Status: ✪ ✪ ✪

Conclusion

The extent and severity of river, estuary and wetland sedimentation have 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.

Indicators

Condition

Indicator 20.1

Sedimentation rates of river pools and estuaries

Information to support this indicator is currently unavailable.

Indicator 20.2

Linear length of channel sedimentation as interpreted from aerial photographs and remote sensing data

Information to support this indicator is currently in development.

Indicator 20.3

Historical trends and current rate of sediment accumulation in selected pools and estuaries or inlets from analysis of core samples

Information to support this indicator will be developed with the implementation of the SoE reporting framework.

Indicator 20.4

Fringing vegetation assessment as tested using aerial photographs and satellite imagery in the Wild Rivers Project (Water Authority of Western Australia, 1995b)

See Figure 20.

In the future, macroinvertebrate sampling through the Monitoring River Health Initiative may be able to show trends in the ecological effects of sedimentation.

Pressure

Indicator 20.5

Proportion of drainage lines (rural and urban) which are not protected from stock and streamlined with fringing vegetation

This indicator remains in development and information to support it is not currently available. An indicator that combines this figure with drainage density and volume in urban and rural areas would provide a useful catchment-scale pressure indicator.

Indicator 20.6

Sediment loads of representative urban and semi-rural drains

Information to support this indicator will be developed with the implementation of the SoE reporting framework.

Indicator 20.7

Proportion of farms on which best management practices, for example, minimum and no till farming, are not being used.

Information to support this indicator will be developed with the implementation of the SoE reporting framework.

Response

Indicators of the effectiveness of responses to sedimentation need to be developed as part of the SoE reporting framework.

Suggested Responses

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 the following actions:

- Establish vegetated waterway protection corridors (see Loss of Fringing Vegetation section).
- Restore river pools in the most affected rivers (where pools have been completely filled) by 2010.
- Minimise the discharge of sediment from rural and urban drains so as to be at ecologically sustainable levels by 2020.
- In consultation with the community, ensure best land management practices are adopted by 50 per cent of land users by 2010 and 100 per cent of land users by 2020.
- As part of the long-term program for mapping and assessing the northern rivers of Western Australia major sediment sources should be identified and rehabilitation plans implemented.

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

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 run-off 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, for example, 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 20 shows the rivers currently known to be most affected by sedimentation in the south west of Western Australia.

Sedimentation and erosion can be severe in the north of Western Australia. Almost all human-induced sedimentation has resulted directly from practices of the pastoral industry such as over-grazing and the introduction of feral animals. Sediment has been accumulating in Lake Argyle since it was created by the Ord River dam in 1971 at an average rate of 24 million cubic metres per year, thus reducing the useable storage by 600 million cubic metres, a little over 10 per cent of the original volume in 26 years (Water and Rivers Commission, 1997a). Rehabilitation of areas of the Ord catchment degraded by pastoral activities has not been effective.

The 1992 SoE Report estimated that:

- 3–4 m of sediment scours the Fitzroy River main channel during peak flows;
- a single summer flood brought 100,000 tonnes 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-western 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 most bank erosion. Information on fringing vegetation zones is reported in the Loss of Fringing Vegetation section.

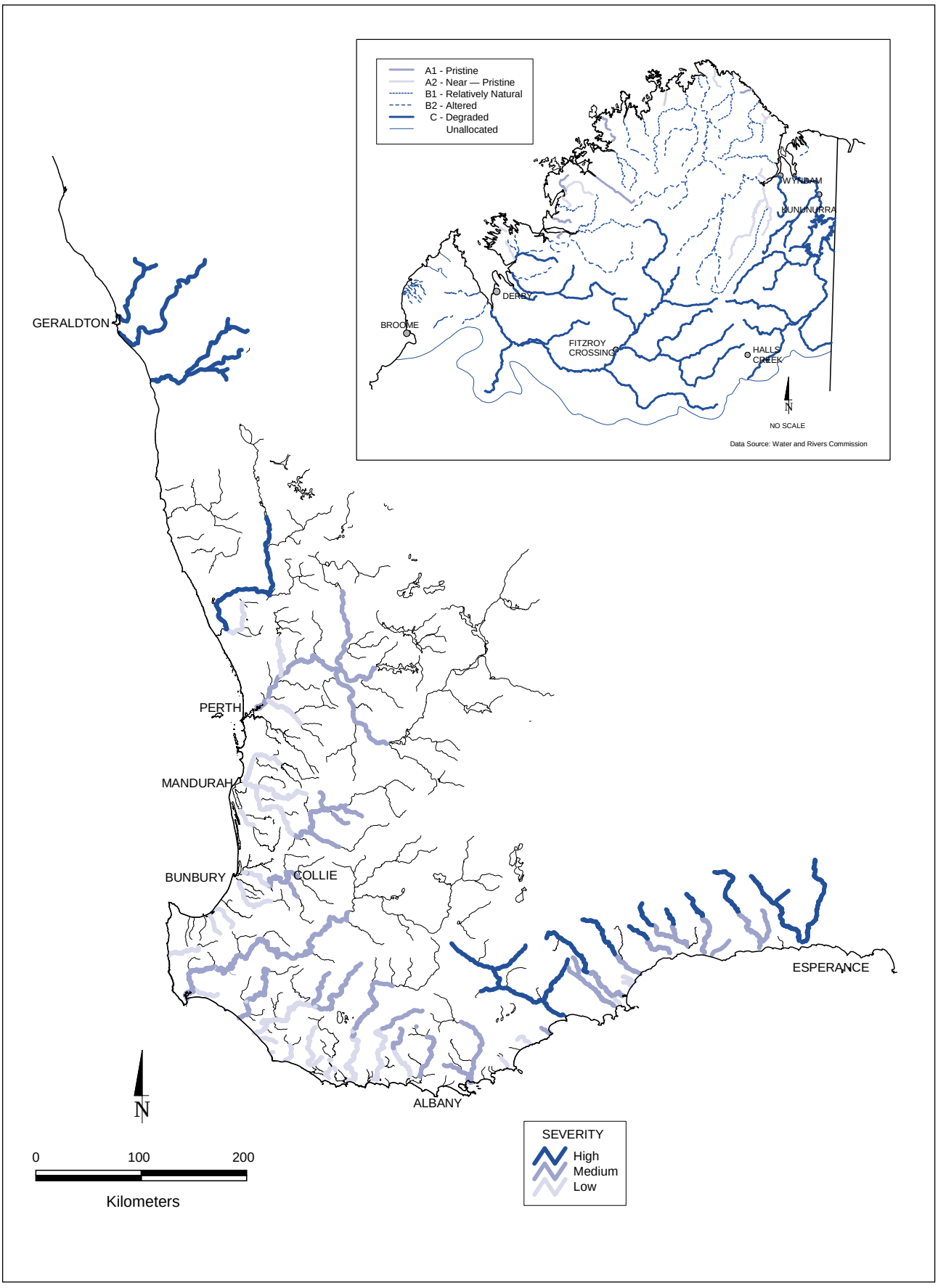


Figure 20. *Severity of sedimentation in rivers of the State currently known to be most affected by sedimentation based on available information (Source: Water and Rivers Commission).*

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 the Soil Erosion section. In severe cases the natural rate of erosion increases more than 1000 fold and waterbodies rapidly fill with sediment (CSIRO, 1992).

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.

Fire can lead to 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 appear to have increased dramatically in recent years. Although data are sparse in Western Australia, it seems likely that fires and fire frequency are causing an accelerating and perhaps irreversible impact upon the natural vegetation of the region and therefore upon soil erosion and sedimentation levels.

Large scale soil disturbance and exposure is the main cause of sedimentation and this was rare before Europeans arrived in Western Australia (Olsen & Skitmore, 1991).

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 Responses

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. The effectiveness of these measures should be evaluated.

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 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 have been fenced to prevent stock access. Agriculture Western Australia 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.

The Water and Rivers Commission has developed a draft policy for the protection of waters from pollution in Western Australia to "...protect water resource quality to maintain existing and potential environmental, social and economic values throughout WA" (Water and Rivers Commission, 1997b).

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.

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

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 Western Australia 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 single or cumulative sources in future development.

Indicators

Condition

Indicator 21.1

Contaminant concentration as compared with EPA guidelines (Environmental Protection Authority, 1993) or specified environmental value criteria

Information to support this indicator is presented in the *SoE Reference Group Draft Working Papers, Inland Waters* and will be further developed with the implementation of the SoE reporting framework.

Indicator 21.2

Assessment of stream health from the Monitoring River Health Initiative

The Monitoring River Health Initiative is refining indicators of stream health.

Indicator 21.3

The number of wetlands and length of rivers affected by leaching of acid sulphate soils resulting from mining activities

Information to support this indicator will be developed with the implementation of the SoE reporting framework.

Pressure

Indicator 21.4

Number of point sources of contamination over time

Information to support this indicator will be provided with the implementation of the National Pollutant Inventory.

Indicator 21.5

Quantity of contaminants emitted annually from point and diffuse sources

Information to support this indicator will be provided with the implementation of the National Pollutant Inventory.

Response

Indicator 21.6

Proportion of waterbodies where environmental value criteria have been assigned

Information to support this indicator is currently unavailable.

Indicator 21.7

Proportion of waterbodies where environmental value criteria have been met

Information to support this indicator is currently unavailable.

Suggested Responses

- The effectiveness of responses to ban or restrict some pesticides has not been assessed and could be linked to the Monitoring River Health Initiative.
- 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. As part of this strategy, site specific management plans should be implemented for contaminated groundwater plumes.
- A strategic system of monitoring contaminant loads into major waterbodies subject to significant human pressure to be in place by the year 2000.

Description

For the purposes of this section, contaminants include chemical pollutants (Environmental Protection Authority, 1993) other than nutrients, salts and sediment which are addressed as separate issues because of their significance (see sections on 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 depend 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 in 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 per cent of samples (Indicator 21.1).

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) (Indicator 21.1).

The extent of contamination in the Kwinana industrial area is extreme. A number of plumes containing pesticides, herbicides, heavy metals, hydrocarbons and phenolic compounds have been identified to the extent that pristine quality groundwater is unusual rather than typical. Much of the groundwater contamination is historical and it is unlikely that the quality can be remediated to its original standard due to the enormous costs and practical difficulties. The contaminated groundwater plume emanating from the Nufarm site (2,4-D and 2,4,5-T) is expected to reach Cockburn Sound within 20 to 30 years (Department of Environmental Protection, 1996c).

It is not known how many wetlands or river systems are being affected by the leaching of acid soils from mining operations.

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 to maintain fire breaks and control weeds. In timber plantations perennial and annual weeds are often controlled with herbicides. Minimum tillage for broad acre farming is leading to an increased use of herbicides for weed control. The impact of this trend on inland waters is not being monitored.

Herbicides to control weed infestation near waterbodies are used in sufficient quantities to cause short-term contamination.

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.

Urban stormwater drains also transport substantial chemical residue from roads and surrounding land-uses. Dumping of toxic substances such as motor oil and chemical waste into drains also occurs.

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.

If inadequately managed, mining activities such as the use of tailings dams and disturbance and drainage of highly acidic soils containing heavy metals can contaminate inland waters and damage local ecosystems.

Recent monitoring suggests the continued illegal use of DDT in a section of the Ord River Catchment (Water Corporation, in press). The significant increase in horticulture in the Ord River Catchment and throughout the Kimberley is a major pressure on the region's water resources. Contamination must be prevented in future development.

Current responses

The use and disposal of chemicals has been progressively regulated. For example, organochlorine chemicals that have been widely used as pesticides (such as DDT, dieldrin and heptachlor) have been banned following many years of use after their adverse environmental impacts were identified.

In the past, a rigorous precautionary approach was not applied when accepting new chemicals for use in the environment. In June 1987, organochlorine pesticides were de-registered for all agricultural uses and in June 1995, the remaining urban uses of organochlorine pesticides were de-registered. The regulation of pesticides in Western Australia is managed jointly by the Health Western Australia and Agriculture Western Australia, through various pieces of legislation. Both agencies actively promote responsible pesticide use in 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, 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 integrated pest-management, permaculture and organic farming practices.

Environmental Protection Policies (EPP) and a Statement of Planning Policy are being developed to help prevent contamination in some of Perth's valuable groundwater resources. A statewide groundwater EPP has been released in draft form 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. This introduced a new zone for the protection of groundwater resources within part of the Jandakot Water Pollution Control area and extended a Water Catchment reservation to Crown land in the groundwater protection area that is reserved under the Metropolitan Region Scheme.

The WRC has developed a draft policy for the protection of waters from pollution in Western Australia. (Water and Rivers Commission, 1997b).

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.

MARINE

For the purpose of this report and for ease of interpretation, 'marine environment' refers to the intertidal zone, nearshore and open ocean environments but excludes estuaries. Australia has responsibility for managing one of the largest exclusive economic zones, fishing zones and continental shelves in the world. In Western Australia there are 12,500 km of coastline that require management and protection.

Western Australian marine waters are generally low in nutrients and biological productivity. However, many inshore areas tend to be dominated by highly productive mangroves, seagrass meadows and coral communities which have adapted to low-nutrient waters. A detailed state of the marine environment report was completed in 1995 (Commonwealth of Australia, 1995a).

The dominant factors that affect the marine environment are degradation of habitat, contamination, the introduction of exotic species and harvesting of marine species (discussed in the section on Fisheries).

A number of other environmental issues discussed in this report also affect the marine environment. These include the Enhanced Greenhouse Effect and Stratospheric Ozone Depletion. It is likely that changes in climate and solar radiation levels are having ecological effects but these are largely unknown.

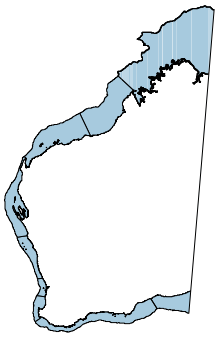
The combined effects of multiple environmental issues on a single environment can be significant. It is difficult to report on these cumulative effects due to lack of knowledge. A classic case is the Cockburn Sound environment, which is affected by all the key issues identified in this report.

The marine environment is the ultimate receiving environment of most surface water. The quality of this water reflects the activities and environmental attributes of the catchment through which it flows. Landuse practices can strongly influence river discharges, for example, soil and nutrients can be discharged to nearshore bays and sounds causing water quality deterioration. Groundwater can also carry land-based pollution into the marine environment. In addition, there are direct discharges such as sewer outfalls and industrial outfalls, and accidental discharges such as spills and shipping accidents.

The degradation of marine habitat is like clearing of vegetation on the land, leading to reductions in the area of seagrass, corals, mangroves or other habitats. Much of this is a direct result of human activity, for example, some fishing practices, mining, port development, shipping channels, exploration and shore-based activity such as aquaculture and salt production.

While it is recognised that environmental issues do not occur in isolation or have single causes or effects, for clarity and to aid understanding, the key issues affecting the marine environment are examined separately.

For each issue, an objective is stated and indicators are given that endeavour to reflect the severity and extent of the issue (condition indicator), the cause(s) of the issue (pressure indicator) and society's response to managing the issue by reducing the causes and/or by rehabilitation of the marine environment (response indicator).



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.

Objectives

- To ensure there is no further significant human-induced loss or degradation of marine habitats and that the management of all marine habitats is ecologically sustainable.
- To protect and enhance all environmental values of marine habitats.
- To document and monitor the condition of Western Australia's marine habitats.
- To ensure the rehabilitation of degraded marine habitats.

Indicators

Condition

Indicator 22.1

Area of various habitat types

Information to support this indicator will be collected with the implementation of the SoE reporting framework.

Indicator 22.2

Health of marine habitats

Indicators of the quality of marine habitats are yet to be agreed.

Pressure

Indicator 22.3

Number and extent of threatening processes

Information to support this indicator will be collected with the implementation of the SoE reporting framework.

Response

Indicator 22.4

Comprehensiveness, adequacy and representativeness of the marine conservation reserve system

Information currently unavailable

Suggested Responses

- Establish a representative system of marine conservation reserves in line with the Government's *New Horizons* 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.
- Identify areas of increasing pressure, damage or threat and implement regional strategic action plans for their protection and rehabilitation (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.
- Continue to implement the recommendations from the *Southern Metropolitan Coastal Waters Study* (Department of Environmental Protection, 1996c) in conjunction with the SoE Report. The next SoE Report should audit progress on these recommendations.
- Based on the precautionary principle and the objectives in this report, the Environmental Protection Authority should complete the development of a consistent set of guidelines for environmental impact assessment for the protection of the State's marine benthic primary producer habitats.

Western Australia has a wide range of habitat types which are crucial to the survival of marine animals. Photographer: A. Storrie.

Description

There is large diversity of marine habitats in Western Australia. The main types of marine habitats of concern in Western Australia 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 Maintaining Biodiversity.

Condition

The coastline of Western Australia supports about 20,000 square kilometres 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. Cockburn Sound is the most degraded marine environment in Western Australia, having experienced the second largest loss of seagrass in Australia (80 per cent) (Commonwealth of Australia, 1995a).

The remoteness of many of Western Australia'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 and cover an area of approximately 2517 square kilometres. Most of the mangrove forests are in good condition. In some places, for example, the Pilbara, the mangrove forests have both local and global significance. Some areas have been lost as a result of salt farms, ports and road works and industrial/urban landfill.

There are limited data on Western Australia's 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 communities of Cockburn Sound decrease in diversity from north to south and this may be related to pollution effects (Department of Environmental Protection, 1996c).

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 Perth Metropolitan and Pilbara 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 Contamination of the Marine Environment section);
- 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; and
- direct physical damage caused by recreational and commercial boating activities including anchor and trawling damage, mostly in the Kimberley, Pilbara, Shark Bay, Perth Metropolitan and Geographe Bay areas. Trawling nets remove sponges and other attached organisms from the sea floor.

With growing land and marine-based tourism development in Western Australia and the regionalisation of population growth, these impacts are likely to increase without adequate protection and management.

The interaction between land-based activities, the impact of these on ground and surface water and the ultimate movement of these waters into nearshore marine environments is crucial to marine management. In Western Australia, much of the pollution of the marine environment and slow chronic degradation of marine habitats is caused through this interaction.

Current Responses

Surveys and monitoring studies have steadily increased our knowledge of marine habitats and biodiversity. Petroleum companies, CALM, DEP, Murdoch University, the University of Western Australia, CSIRO, WA Museum, the Australian Institute of Marine Science, Fisheries 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. The DEP has initiated a major study of the North West Shelf environment which will provide valuable information to protect the area.

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 marine regions (Department of Environmental Protection, 1996a).

A statewide system of marine conservation reserves is being established under the Conservation and Land Management Act 1984 (WA). Amendments to this Act in 1997 established a Marine Parks and Reserves Authority as well as a Marine Parks and Reserves Scientific Advisory Committee.

The EPA is preparing a Mangroves Protection Environmental Impact Assessment Guidance Statement.

The State Government is participating in the development of the Commonwealth Government's Oceans Policy.

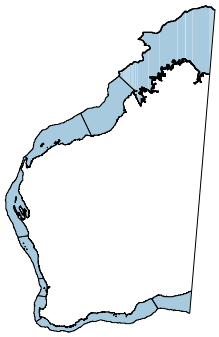
There are several other current responses to degradation of marine habitats. For example, the Shark Bay Marine Park protects some of the most important seagrass meadows in Western Australia. Fisheries WA is carrying out seabed surveys to delimit areas for trawling in Shark Bay.

Implications

As the State develops its industrial and resource sectors increased pressures will be placed on marine habitats. Sounds, archipelagos and embayments suitable for industrial and port development because of their protected waters are often also sites of conservation significance and social value.

Our knowledge of marine habitats is scarce and any loss of biodiversity could significantly affect existing resources such as fish stocks.

See also Maintaining Biodiversity and Fisheries in this report.



Contamination of the Marine Environment

Environmental Status: ✪ ✪ ✪

Environment 1998 Western Australia

Conclusion

Contamination of the marine environment is most pronounced in the Perth Metropolitan marine region. Past actions are beginning to deliver reductions in some pollutant discharges but as Perth's population increases further steps will need to be taken.

Coastal waters outside the Perth Metropolitan marine region are largely uncontaminated, with reduced environmental quality affecting only local areas. However, most ports, marinas and slipways are likely to be contaminated. Discharges from estuaries, drains and groundwater will also introduce contaminants to the marine environment. Without a co-ordinated, ecologically sustainable approach to management and planning, contamination will increase along the Western Australian coastline.

Objective

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

Indicators

Condition

Indicator 23.1

Proportion of the marine environment meeting environmental value requirements

Environmental values have not yet been determined. A surrogate indicator is presented in Table 14.

Pressure

Indicator 23.2

Discharges to the marine environment by contaminant type

Discussed in Pressure section below.

Response

Indicator 23.3

Response indicators are in development.

Suggested Responses

- Implement the recommendations of the *Southern Metropolitan Coastal Waters Study*.
- Develop a strategy on discharges to the marine environment with interim targets to progress the long-term goal of zero discharge from industrial sources and the appropriate and sustainable management of ocean outfalls.
- A statewide inventory of contaminant sources should be developed and maintained by 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. Health implications of current tributyltin levels in shellfish need to be quantified.
- The Environmental Protection Authority should formally designate environmental values, objectives and environmental quality criteria for the Perth metropolitan marine region by 1999. Designation of environmental values and objectives for the remainder of the State should occur by 2001.
- A contaminant management strategy should be developed for Cockburn Sound and Sepia Depression (west of Garden Island) by 1999.
- The State Government should become much more proactive toward eliminating tributyltin (TBT) paints from ships, and should seek a review of the Australian and New Zealand Environment and Conservation Council recommendations on anti-fouling paints for vessels over 25 m.
- The State Government should establish a formal framework to co-ordinate environmental management within Perth's metropolitan marine region and between these waters and their land catchments. This should be used as a pilot program for expansion to other areas under pressure from domestic and rural discharges.

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 from sewage, agricultural run-off, 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 marine region is 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 14. Organic pollutants such as pesticides and hydrocarbons are low. 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.

Table 14. *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	Negligible change
Northern beaches	Negligible change
Cape Peron/Sepia Depression	Slight deterioration

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 marine region 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 at various levels in all major ports in Western Australia.

Outside the Perth metropolitan marine region sewage discharges to the ocean have mostly ceased except for some small plants in the north west. There are, however, local cases of contamination from effluent disposal. For example, in Coral Bay contaminated groundwater from sewage leach drains is moving into the bay. Nutrient discharge from rivers, estuaries and agricultural drains occurs in the south west of Western Australia. 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, however, to a certain extent these are natural processes.

Pressure

Sources of nutrients to the Perth metropolitan marine region 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. Unless wastewater treatment and catchment management practices improve this waste load is expected to grow significantly as Perth's population increases. Elsewhere in Western Australia, most outfalls have been removed. Spills and systems failure remain as potential pressures.

Stormwater run-off is a significant source of nutrients from urban areas. In rural areas agricultural run-off and flows of groundwater can contribute to the load of contaminants in waterways. Eventually this water makes its way to the ocean.

Unless wastewater treatment and catchment management practices improve heavy metal inputs are likely to increase by a factor of two or three over the next 20 years in Perth metropolitan waters (Indicator 23.2).

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

Current Responses

The *Southern Metropolitan Coastal Waters Study* conducted by DEP (Department of Environmental Protection, 1996c) and the *Perth Coastal Waters Study* (Water Authority of Western Australia, 1995a) conducted by the Water Corporation have made major advances in our understanding of the marine environment.

The Environmental Protection Authority is conducting a public involvement process to assist in formalising environmental values, objectives and environmental quality criteria for the Perth metropolitan marine region. It also intends to develop an Environmental Protection Policy for the State's Coastal Waters.

The Water Corporation is committed to funding improved treatment of wastewater discharged via the Cape Peron outfall which will reduce suspended solids, bacteria, nutrient and metal loads.

The use of tributyltin in antifouling paint has been banned since 1991 on vessels less than 25 m. Recent changes to the DEP licencing system requires facilities using TBT to be licensed and thus controlled.

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

Existing industry is continuing to reduce its discharges to the marine environment. Moreover, through the Australian and New Zealand Environment and Conservation Council's strategies 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.

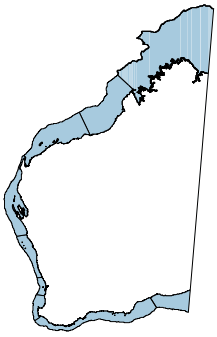
In Coral Bay, an infrastructure plan has been developed and funded by government to reduce nutrient pressure on the Bay.

Implications

The issue of contaminants in the marine environment involves a wide cross-section of society. For diffuse sources, 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

See Section 6 of the SoE Working Group Draft Reference Papers for more information on Contamination of the Marine Environment.



Introduction of Exotic Marine Species

Environmental Status: ✪ ✪ ✪

Environment 1998 Western Australia

not causing undetected problems.

Conclusion

Exotic marine organisms have been introduced to Western Australia 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 but international experience suggests that the potential for significant environmental impact is high.

Objective

To ensure that there are no further introductions of exotic species and that existing introductions are controlled and, where possible, eliminated.

Indicators

Condition

Indicator 24.1

Number, distribution and abundance of introduced marine species

Information is restricted as to the number of exotic species.

Pressure

Indicator 24.2

Tonnage of foreign ballast water discharged at major ports

See Figure 21.

Response

Indicator 24.3

Changes in the condition and pressure indicators (above) over time

Trends in these indicators are currently unavailable.

Indicator 24.4

Proportion of the State where baseline studies for introduced marine species have occurred

Information is being collected to support this indicator but is not currently in this form.

Indicator 24.5

Proportion of recommendations adopted regarding ballast water and anti-fouling practices from Australian and New Zealand Environment and Conservation Council (1996) and the *Draft Australian Ballast Water Management Strategy.*

An audit on the proportion of these recommendations implemented is needed before this information can be reported.

Suggested Responses

- Complete baseline studies especially in areas of greatest pressure to determine the distribution and abundance of existing exotic species.
- Adopt the recommendations regarding ballast water and anti-fouling practices in *Maritime accidents and pollution: Impacts on the marine environment from shipping operations* (Australian and New Zealand Environment and Conservation Council, 1996).
- Once final, implement the *Australian Ballast Water Management Strategy*, and assist in reviewing and updating that strategy.
- Conduct research into the control and eradication of exotic marine species.

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 Western Australia (Furlani, 1996). Twenty one of these are known to have been introduced into Perth metropolitan waters, the most highly visible being a large polychaete worm (Sabellidae Family). 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. It is capable of excluding and out-competing native species (Chaplin & Evans, 1995).

Limited information is available on the distribution of these species or their effects on the local environment. It is likely that other unidentified species have been introduced with unknown environmental impact.

Pressure

Ships discharge ballast water to take up their cargo. This water usually has its origin outside Western Australia. 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 Western Australia originates in the Asia Pacific region with 58 per cent coming from Japan. The Pilbara receives about 50 per cent of ships to Western Australia. 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 the oil terminals off Onslow. Due to the nature of the receiving waters, Esperance is also a high risk port.

Current Responses

Surveys by CSIRO and the Australian Quarantine Inspection Service (AQIS) are currently underway to establish the number of introduced species and their distribution in Western Australia.

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 Western Australia, a Memorandum of Understanding has been developed between Fisheries WA and DEP on the translocation of live aquatic non-endemic species into or within Western Australia.

Implications

The risk is that introduced species will establish and cause significant damage to local biodiversity. They may also pose a threat to existing or future uses of the marine resources of an area. None of these aspects has been quantified for Western Australia. The cost of removing an introduced species once it is established

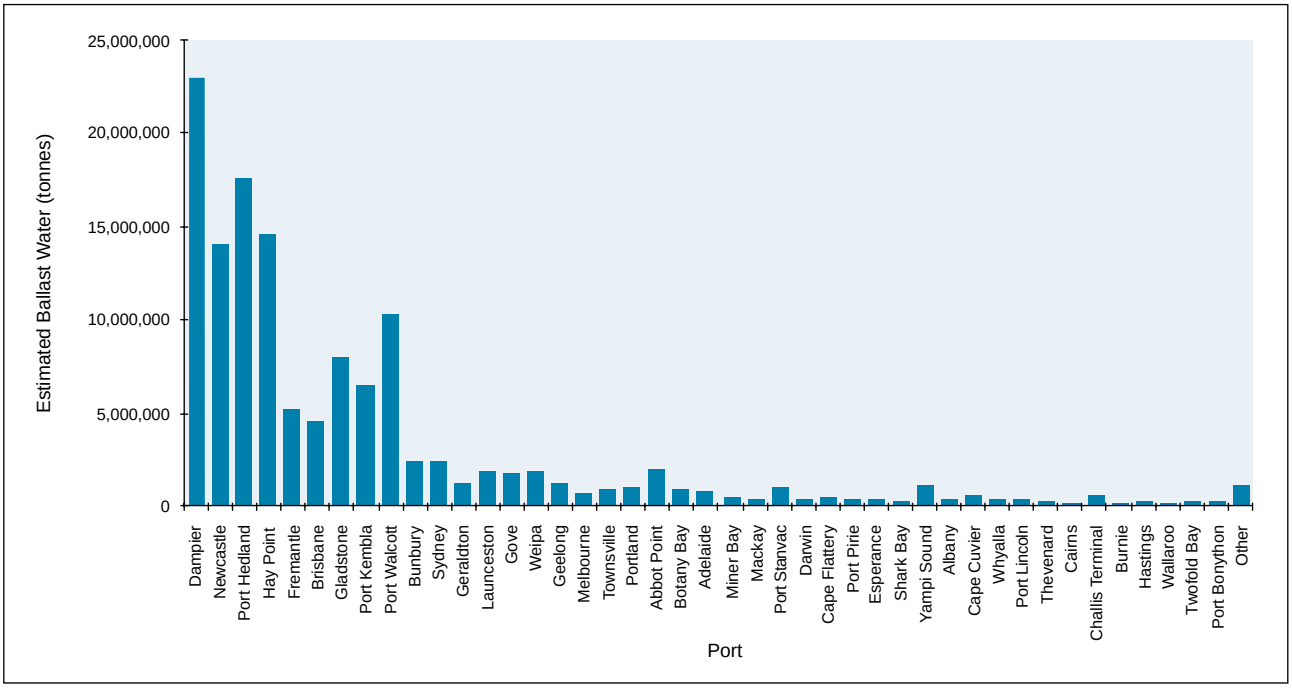


Figure 21. *Estimated ballast water receipts by Australian ports (using ballast water capacity estimated at 38% of DWT for all ships) 1996. (Source: Department of Transport).*

See Section 6 of the SoE Reference Group Draft Working Papers for more information on the Introduction of Exotic Marine Species.

PROGRESS TOWARDS ECOLOGICALLY SUSTAINABLE DEVELOPMENT

Ecologically Sustainable Development in Western Australia

In 1987 the United Nations called upon all jurisdictions to shift to a sustainable form of development (World Commission on the Environment and Development, 1987).

This led in 1992 to one of the most significant conferences of world leaders in the 20th Century, the United Nations Conference on Environment and Development. The Conference resulted in the signing by 154 nations of a number of major documents: the Convention on Biological Diversity; Framework Convention on Climate Change; Agreement on Forest Principles; Rio Declaration and Agenda 21. Agenda 21 is a comprehensive framework for sustainable development for the coming century. Western Australia responded to the call for sustainable development by endorsing a National Strategy for Ecologically Sustainable Development in 1992.

Ecologically sustainable development (ESD) involves "...using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased" (Commonwealth of Australia, 1992b).

A framework for tracking progress towards ESD

Indicators of sustainability have been proposed at an international scale by various institutions such as the World Bank and the Commission for Sustainable Development. Sustainability indicators are being developed for various natural resource use sectors at the national level through a range of bodies. These include: the National Collaborative Project on Indicators for Sustainable Agriculture for the Standing Committee on Agriculture and Resource Management; the Montreal Process on Indicators for Sustainable Forest Management; and Australian Bureau of Resource Science work on indicators for sustainable fisheries for the Ministerial Council on Fisheries and Forestry of Australia.

An initial assessment of our progress towards ecologically sustainable development was conducted by the State of the Environment Advisory Council (1996) which concluded that "...despite positive achievements to date, some serious adverse trends need urgent attention". There is now a significant move to ensure collaboration in the development of SoE indicators in all jurisdictions with broader development of sustainability indicators that audit the implementation of the objectives and guiding principles of ecologically sustainable development.

The key natural resource sectors for Western Australia are presented in the next section. The status of development and implementation of sustainability indicators is shown where relevant.

Agriculture

Natural Resource Use Sectors

Conclusion

Agriculture currently contributes about 20 per cent of the total value of Western Australia's 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 (such as overgrazing, eutrophication by fertilisers, inappropriate stubble burning and excessive cultivation) are still degrading the land and waterways.

Some of the major environmental problems, such as lack of deep-rooted perennial vegetation, are the result of past practices. While further clearing has almost halted in rural areas, the planting of new vegetation will take time. It is likely that the development and widespread adoption of more ecologically sustainable agricultural systems (for example, farm forestry) will produce an agricultural landscape that is quite different to that seen today.

Objective

To achieve ecologically sustainable use of agricultural lands in Western Australia by:

- developing and identifying agricultural systems designed to maintain or improve the condition of the State's natural resources;
- facilitating the widespread adoption of best management practices which minimise environmental impact while improving profitability; and
- facilitating land-use changes within agriculture.

Indicators

Most indicators to track progress towards agricultural sustainability are still undergoing development and testing. Examples include the following.

- Economic: percentage of agricultural enterprises with positive farm business profit; annual rates of return of agricultural enterprises; real average increases in net farm income; total factor productivity; farmers' terms of trade; real increase in farm business equity.
- Social: adoption of best management practices; extent and quality of rural and regional infrastructure; land manager capability and capacity to change; level of farmer education.
- Ecological: change in perennial cover in rangelands; percentage of agricultural and nearby land with deep-rooted perennial vegetation; extent and changes of dryland salinity; dust storm frequency; changes in soil condition, including soil acidity; changes in groundwater levels; extent and quality of nutrient run-off into waterways.

Suggested Responses

In the past, agricultural research has looked to increase farm profit through increased 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 allow farmers to make a living.

No single approach will work. In agricultural areas, improvements in sustainability will come from combinations of best management practices, for example, minimum tillage, and land-use changes, for example, integrated farm forestry. The strategic development of new industries and markets, such as for canola, durum and noodle wheats and live cattle will improve economic sustainability.

Implementation of the *WA Salinity Action Plan* (Government of Western Australia, 1996) coupled with research and development by Agriculture Western Australia, evolution of farming systems and provisions of technical and catchment support services will be vital. Much of the focus for the Sustainable Rural Development Program within Agriculture Western Australia is on Integrated Catchment Management. This approach explicitly recognises that farms cannot be managed sustainably in isolation and that all stakeholders, including many off-farm, have a role to play.

In the rangelands of Western Australia flexible and innovative approaches to land-use options are required which tap the wilderness, conservation and heritage values of these lands. One major initiative, the Gascoyne–Murchison Rangeland Strategy (Government of Western Australia, 1997c), will over the next five years:

- broker lease adjustments;
- provide better access to business planning;
- assist in the implementation of total grazing management infrastructure and practices;
- foster pastoral industry self-management;
- raise awareness of rangeland issues;
- facilitate the research, development and adoption of industry diversification;
- work towards a regional approach to rangeland environmental objectives; and
- co-ordinate the assistance of a number of government agencies and funding bodies.

Regulatory activities, mostly undertaken under the *Soil and Land Conservation Act 1945* (*WA*), will continue to be important. The success of the inter-agency Memorandum of Understanding for land clearing has led to the initiation of a similar approach for drainage in agricultural areas. Regular pastoral lease reports are conducted for the Pastoral Board on an ongoing basis.

Description

The wheatbelt of Western Australia supports broad acre, rain-fed farming across a wide range of soil types. Farmers grow wheat and other cereals, lupins, wool, meat, oil seeds and pulse crops. Most grain properties are in a strong financial position (ABARE Farm Surveys, 1997). Change to more ecologically sustainable agriculture will include the return of increasing proportions of the catchment to deep-rooted perennial vegetation and the development and adoption of high water-use farming systems. The control of wind and water erosion in susceptible areas will include more widespread adoption of minimum and zero tillage. Increased use of lime will help ameliorate the effects of soil acidity.

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. High rainfall means the rate of spread of secondary salinisation is high, therefore, farming systems that make maximum use of water will become necessary. Relatively steep slopes will mean that farming practices which minimise water erosion need to be widely adopted.

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 a year are being planted to commercial trees, particularly Tasmanian bluegums and pines. Changes in land use and the matching of land capability to land use will help to meet the principles of ecologically sustainable development.

The pastoral (cattle and sheep) industry of Western Australia occupies about 38 per cent of the State or about 950,000 square kilometres. Appropriate pastoral management practices include the matching of stocking rate to land capability; the better control of stock distribution through well maintained fencing; the spreading of stock between many watering points; the management of non-domestic grazing animals and infrastructure development based on land systems rather than square paddocks containing mixtures of many country types.

The intensive agricultural industries, which include horticulture, dairying, piggeries and feedlots, are found from Kununurra in the north to Albany in the south. Sustainable management practices are highly variable but include the appropriate rate and timing of fertiliser application; management of waste; the adoption of integrated pest management practices; and the sensible use of pesticides.

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 per cent of the productive land becoming salty. Rivers also become salty. The rising salt water also damages rural infrastructure such as road culverts, grain handling facilities and buildings in towns.

Clearing in agricultural areas has largely ceased over the last few years but the halt to clearing has come decades too late. The effects of earlier clearing will be seen for many years to come.

Soils are becoming acid more quickly as a result of farming practice. This means applied fertiliser is less effective and crop yields are lower. Soil structure decline, subsoil compaction and water repellent soils are widespread, affecting up to 34 per cent of agricultural land. Loss of topsoil through unwise cultural and grazing practices is easy to see but affects only a small area. It is difficult to quantify the broad scale insidious loss of soil. The number of native plant and animal species in the wheatbelt has been greatly reduced through land clearing and other agricultural practices.

Herbicide resistance is making it increasingly difficult to control weeds in cropping areas. Weeds pose a threat to the biological diversity of remnant vegetation and conservation reserves. In northern Australia, introduced weed species can impact both agricultural production and the tropical ecosystems. In the pastoral shrublands, increases in density of native woody vegetation are leading to a 'woody weed' problem.

In pastoral areas, some management practices are ecologically unsustainable. There has been widespread soil erosion and loss of perennial grasses and shrubs. Uncontrolled access of stock has caused damage to critical wildlife habitats and siltation of rivers. There are now indications, summarised in the recent National Collaborative Project on Indicators for Sustainable Agriculture Report (Anon., 1998) that the land is now being managed in a more suitable way. Few properties in the sheep areas are providing enough money to cover reasonable living expenses. This makes it difficult to maintain or replace aging infrastructure, which will have long-term detrimental effects on the sustainability of the industry.

Intensive agricultural industries have highly localised impacts on the environment. Odours, 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 urban development and compete for scarce farm land.

Challenges to Ecologically Sustainable Development

To assure a prosperous future for agriculture, land management practices in agricultural and pastoral lands must change. There is good evidence that this is happening. The Landcare movement has successfully raised awareness of land degradation and demonstrated that changes 'on-ground' can be successful. In the longer term, the agricultural sector will need to address the issue of declining fossil fuel reserves.

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 more to do with 'public good' than direct, individual landholder benefit. Fixing our damaged waterways and conserving biological diversity in the rangelands are two examples. Much remains to be done.

A comprehensive approach is required that covers problem identification; research and development; the application of this research and development to improved management practices; land-use changes where necessary; better options for economic, natural resource and biodiversity outcomes (including direct financial assistance for the 'public benefit'); an emphasis on social and economic issues as well as environmental issues; and the adequate monitoring of outcomes for necessary feedback. The best current example of this is the *WA Salinity Action Plan*.

Current Responses

Agriculture Western Australia has the primary responsibility for assisting land managers to achieve sustainable use of agricultural and pastoral lands, although other agencies also play important roles. Recent changes in Agriculture Western Australia have raised the profile of sustainable land use and 47 per cent of its budget is allocated to resource protection and sustainable rural development. The provision of high quality basic resource information is an important component of this program as is monitoring and evaluation of progress towards rural sustainability. The research and development of more sustainable farming practices such as high water-use farming systems, improved stubble management and no till cropping continues with support from industry.

At the international scale, Australia is committed to a number of conventions that focus on ecologically sustainable agriculture. At a national scale sustainable agriculture is guided by several key strategies reflecting both national and international imperatives. While few are prescriptive, they provide an agreed context in which State issues can be addressed. Western Australia is a key player in many of these national approaches including the National Dryland Salinity Program; draft guidelines for rangeland management; the National Pollutant Inventory; the National Land and Water

Resources Audit; and protocols for the collection and presentation of basic resource data.

There has been significant policy response in Western Australia through the natural resource management strategy attached to the Natural Heritage Trust (formerly National Landcare Program). The review of rural land-use planning policy will help ensure that rural and agricultural lands are used wisely. Regional initiatives for natural resource management are well developed for the Swan-Avon and the Blackwood catchments, the South Coast Region and the Gascoyne-Murchison area. A policy for managing the rangelands is nearly finished.

A recent inter-agency Memorandum of Understanding on Land Clearing has clarified the roles and responsibilities of agencies, set up agreed protocols for decision making across jurisdictions and ensured that any future land clearing in Western Australia for agricultural purposes greater than one hectare will only be granted permission where it can be demonstrated that the adverse environmental effects are likely to be minimal.

Implications

Protection of the resource base is essential to ensure continued viability of agricultural and rural communities. Ecological sustainability provides the basic framework for 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 and severely salt-affected cropping land.

Demonstrating sustainability is becoming an increasingly important economic driver, necessary to access international markets and receive premium prices. Those countries and industries that can show that their products are safe to eat and have been produced to ecologically sustainable, best practice principles (in other words, Clean and Green) are likely to enjoy an increasing market advantage.

Without careful management grazing in rangeland areas can lead to erosion, sedimentation and significant impacts on biodiversity (Photograph courtesy of Agriculture Western Australia).

Energy

Natural Resource Use Sectors

Conclusion

Western Australia has very large fossil fuel resources and growing industries based on gas exports and the use of gas for mineral processing. International agreements to limit greenhouse gas emissions (see section on Enhanced Greenhouse Effect) could put pressure on this growth. In the first instance, this is likely to encourage more efficient technologies and a switch to gas from coal. In the longer term, technologies for using renewable energy may allow substitution for fossil fuels.

At present only a very small amount of renewable energy is used. While there is scope to increase this proportion, energy demand can at present be reduced more cost effectively by more efficient equipment and changed patterns of use. Strategies to reduce greenhouse emissions from energy should focus on both energy efficiency and renewable energy.

As the transport and manufacturing sectors are the largest energy users they will need to be addressed in order to change total energy use.

Environmental pressures on energy other than those related to greenhouse are not high. The most significant arises from the smog and haze in urban areas caused by oxides of nitrogen (NOx), mainly from vehicles, and smoke from domestic fires.

Objective

To promote more efficient use of energy by consumers in Western Australia and to increase the use of renewable energy where viable.

Indicators

The four indicators are (Office of Energy, 1998):

- Final energy use by type of fuel (Figure 22);
- Final energy use by type of fuel – Transport (Figure 23);
- Final energy use by type of fuel – Manufacturing (Figure 24);
- Primary energy demand per real dollar GSP – WA (Figure 25).

Suggested Responses

Develop as part of the State Greenhouse Response Strategy, a policy that addresses the more efficient use of energy and the increased use of renewable energy. This will include the Government's response to the Commonwealth intention to increase by 2 per cent the amount of electricity sourced from renewables and to introduce efficiency standards for electricity generating equipment.

Description

Western Australia presently depends largely on gas, oil and coal for its energy. Although Western Australia has large resources of coal, it is not of a quality suitable for export. Western Australia is a significant exporter of petroleum products. In 1997 exports of liquefied natural gas (LNG) totalled 404 petra joules (PJ) and net exports of crude oil and condensate of 270 PJ whereas primary energy use in the State of these products was 276 PJ and 231 PJ respectively. State resources of liquid fuels are less than those of natural gas.

At present only 3 per cent of the accounted final energy use is from the renewable resources, solar and wood. Most of this is for domestic heating in open fires and is being discouraged because the ensuing smoke affects air quality in urban areas. Accounted energy use does not include passive uses of solar energy such as drying salt or warming houses.

Less than 1 per cent (93 gigawatt hour) of electricity sold by Western Power comes from renewable sources. These are as follows:

40 gigawatt hour	Landfill Gas
40 gigawatt hour	Ord Hydro
6 gigawatt hour	Wellington Dam Hydro
7 gigawatt hour	Esperance Wind
0.04 gigawatt hour	Kalbarri Photovoltaic

Western Australia has plentiful sunshine, good winds in the south and west of the State, several suitable sites for tidal and hydro power in the north and potential for wave power around the coast, particularly in the south. The challenge is to encourage these technologies to reach a stage where they are commercially competitive and to develop an energy system which will facilitate the entry of renewable resources.

Transport is the single largest energy end-use sector and uses almost exclusively liquid fuels. Manufacturing is almost as large, using 70 per cent gas, 12 per cent electricity and 13 per cent coal. The residential and commercial sectors are relatively small.

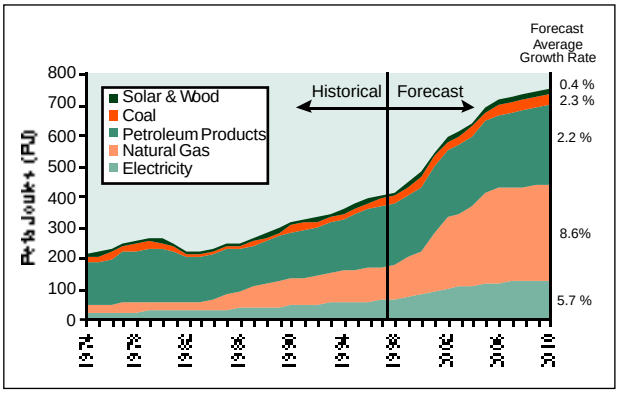


Figure 22. *Final energy use by type of fuel - WA (Source: Office of Energy).*

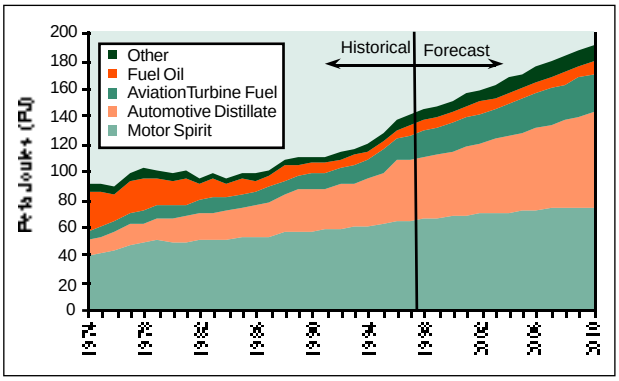


Figure 23. *Final energy use by type of fuel - Transport (Source: Office of Energy).*

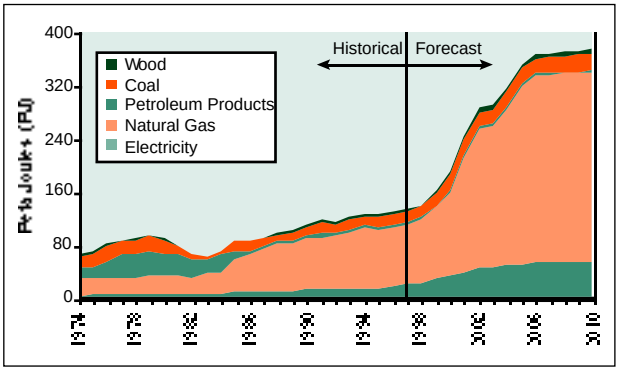


Figure 24. *Final energy use by type of fuel - Manufacturing (Source: Office of Energy).*

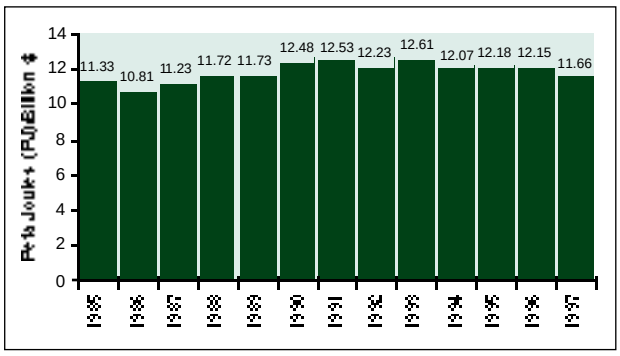


Figure 25. *Primary energy demand per real dollar GSP - WA 1995-96 prices (Source: Office of Energy).*

Environmental Impacts

All energy use and extraction comes with some environmental penalty. These range from the risk of oil spills to land degradation from open cut mining (see the section on Mining and Petroleum Production) and atmospheric and land pollution.

Renewable energy resources can also have undesirable environmental effects. Damage to existing ecosystems can occur from tidal barrages or dams. There has been considerable opposition to wind turbines throughout the world on the grounds of visual pollution and noise and even solar water heaters are sometimes considered to be ugly and detrimental to neighbourhood house values and are prohibited in some areas. Open wood fires in metropolitan houses are a significant cause of haze.

Because Collie coal is low in sulphur and gas is a clean burning fuel, the principal environmental issues arising from energy use are smog and haze caused by oxides of nitrogen (NOx) and particulates. Vehicle exhausts and smoke from domestic fires are the principal contributors, although industry, including electricity generation, contributes to NOx (see Atmosphere section).

Challenges to Ecologically Sustainable Development

Other challenges to sustainable energy are resource depletion and greenhouse gas emissions.

The Western Australian resources of fossil fuels are not indefinitely sustainable, but they are large. It is estimated that the present rate of extraction of coal can be sustained for over 1000 years. Resources of gas and other petroleum products are generally not proven until extraction is required, but there is confidence that there are over 50 years of gas reserves. Given the difficulty in predicting technology change beyond 20 or 30 years, resource depletion cannot be considered a significant threat at this stage.

The issue of greenhouse gas emissions is significant and is dealt with in the section on the Enhanced Greenhouse Effect. A restriction on the use of fossil fuels, particularly coal, will require alternatives to be developed. These alternatives include reducing consumption and using sources which do not emit greenhouse gases.

By increasing the efficiency with which energy is used, primary consumption can be decreased without any reduction in quality of life or industrial output. This efficiency can be achieved in two ways. The efficiency of conversion can be increased using more efficient plant and equipment, better controls and increased use of waste heat. Efficiency can also be increased by adopting other practices or different priorities, for example, telecommuting, using public transport, choosing more compact but more comfortable houses or cars and using daylight instead of artificial light in commercial buildings.

Advantages can also be gained by fuel switching. As gas resources are huge, a switch to using Compressed Natural Gas (CNG) in buses, trucks and light commercial vehicles could provide both resource and environmental benefits. Significant savings can also be gained with co-generation, or the combined production of process heat and electric power from the same source.

The second alternative is to introduce appropriate renewable energy sources. Because the cost of supplying power from diesel generators in the isolated grids of Western Australia is so high there is scope for introducing renewable energy without too large a cost penalty in these areas. This has been illustrated with wind power generation at Esperance.

Current Responses

The Office of Energy has a number of programs to promote the efficient use of energy and the increased use of renewable energy where viable. These programs aim to encourage economically viable actions which are not taken because of market impediments or other reasons. They include:

- a telephone information service providing information on energy use for householders;
- publication of information brochures and a magazine;
- house energy rating scheme;
- technical and financial support for energy management in the public sector;
- support for research, development, demonstration and education through the Alternative Energy Development Board;
- a rebate for purchasers of renewable energy Remote Area Power Supply systems in isolated areas; and
- organising the Energy Efficiency Awards.

Implications

The forecast energy growth is within the available resources but will increase the greenhouse gas emissions and other gaseous and particulate pollutant emissions. A concerted effort in the residential and commercial sectors must be accompanied by strong measures in the transport, manufacturing, mining and agriculture sectors.

Fisheries

Natural Resource Use Sectors

Conclusion

Annual assessments of fish stocks, levels of fishing activity and trends in fish catches indicate that, with only a few exceptions, Western Australia's major commercial fisheries stocks are being managed at sustainable levels. In 1995/96, 16 of the 21 commercial fisheries had breeding stock levels that were adequate to maintain present stocks (see *State of the Environment Reference Group Draft Working Papers*).

Fishing pressure from recreational fishing is increasing and will be taken into account in future management decisions. Gaps in information are being addressed in order to assess whether the State's fisheries are being managed in an ecologically sustainable manner.

Objective

To ensure that the State's fish resources are harvested at sustainable levels while minimising any environmental effects.

Indicators

Indicators of ecologically sustainable fisheries are being developed at a national level in consultation with the States. Table 15 presents a summary of the status of each major fishery in Western Australia.

Table 15. *Stock and exploitation status for major commercial fisheries (Source: Fisheries Western Australia).*

Fishery	Assessment complete	Exploitation status	Breeding stock levels	Catch (t)	Year
INVERTEBRATES **A. Rock lobster**					
Western rock lobster	Yes	Fully exploited	Increasing	9784	95/96
Esperance	Yes	Limited data	Adequate	100	95/96
B. Prawns					
Shark Bay	Yes	Fully exploited	Adequate	1880	96
Exmouth Gulf	Yes	Fully exploited	Adequate	771	96
Onslow	No	Limited data	Limited data	94	96
Nickol Bay	No	Fully exploited	Limited data	164	96
Broome	No	Not available	Limited data	83	96
Kimberley	No	Not available	Limited data	477	96
FIN FISH **A. Tropical fin fish**					
Kimberley gillnet & barramundi	Yes*	Fully exploited	Adequate	46	95/96
Pilbara trap and line	No	Fully exploited	Limited data	727	96
Kimberley trap and demersal	No	Fully exploited	Limited data	955	96
Lake Argyle catfish	Yes	Fully exploited	Decreasing	129	95/96
Pilbara trawl	Yes*	Over exploited†	Limited data	3201	96

Fishery	Assessment complete	Exploitation status	Breeding stock levels	Catch (t)	Year
B. Estuarine and coastal embayments					
Shark Bay beach seine & mesh net	Yes*	Fully exploited*	Adequate*	99 (whiting)	96
Exmouth Gulf beach seine	No	Not available	Not appropriate	70	96
Estuarine fisheries	Yes*	F/O exploited	Not appropriate	882	96
Cockburn Sound	No	Not available	Not appropriate	872	96
Princess Royal Harbour/ King George Sound	No	Not available	Not appropriate	71.3	96
C. Temperate marine					
Western Australian salmon	Yes	Fully exploited	Adequate	2523	96
South west trawl	No	Not Available	Not Available	85	96
Shark Bay snapper	Yes	Fully exploited	Adequate	454	96
Southern demersal gillnet & longline	Yes*	F/O exploited	Decreasing	883	95/96
Australian herring trap	No	Fully exploited	Adequate	804	96
West coast demersal gillnet & longline	Yes*	F/O exploited	Decreasing	421	95/96
D. Pelagic					
West coast purse seine	Yes	Fully exploited	Adequate	3920	96
Albany/King George Sound purse seine	Yes	F/O exploited	Decreasing (low)	4370	96
Bremer Bay purse seine	Yes	Fully exploited	Decreasing	2340	96
Esperance purse seine	Yes	Under exploited	Adequate	1330	96
Mid-west purse seine	No	Not available	Not available	Cannot report	96
MOLLUSCAN A. Pearl oyster fishery					
Pearl oyster fishery	Yes	Fully exploited	Increasing	592,000 oysters	96
B. Abalone					
Abalone Zone 1 and Zone 2	No	Fully exploited	Adequate	216	96
Roe's abalone	No	Fully exploited	Adequate	121.2	96
C. Scallops					
Shark Bay	Yes	Fully exploited	Adequate	364	96
Abrolhos Islands and Mid-west trawl	No	Fully exploited	Adequate	229	96

Footnotes:
† Some Species Only
*For Key Species Only
F/O Fully or Over Exploited

continued from previous page

Suggested Responses

Fisheries WA will continue to assess the status of targeted fish stocks as indicators of sustainable fishing. This is achievable by using 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.

Fisheries WA is further developing its capacity for managing the State's fish resources at sustainable levels by incorporating ecologically sustainable development principles. As a result, Fisheries WA intends to assess the environmental effects of activities associated with fishing activities by reviewing all fisheries on a regional basis. Environmental management measures being investigated include by-catch reduction techniques and reduction of commercial fishing effort through a variety of mechanisms including licence buy-back schemes. Fisheries WA has identified growing recreational fishing effort as an important issue that will be taken into account in the overall management of fish stocks.

The challenge of assessing the ecological effects of fishing and working toward enlarging the body of information available for the environmental assessment of fishing is being addressed. Fisheries WA is also involved in the process of developing environmental indicators for fishing on a national level.

Sustaining fish habitat is considered an integral part of sustaining fisheries. One of the management tools made available by the *Fish Resources Management Act 1994* (*WA*) is the establishment of Fish Habitat Protection Areas which provide special protection and management for fish and their habitats. This will complement provisions in the *Conservation and Land Management Act 1984* (*WA*) for the establishment and management of a marine reserves system.

Description

Western Australia's fish 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) have a combined value of 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 per cent of the State's population and contributing more than $400 million a year to the State's economy.

A diverse range of aquaculture ventures continues to develop throughout the State, however, the culture of pearl oysters in Western Australia is the most successful. Pearl production in Western Australia is worth about $150 million a year.

Environmental Impacts

Most fishing methods in Western Australia have limited effect on the environment. Methods that may significantly affect the environment, for example, dredging and pelagic drift gill-netting, are banned. Other methods, such as trawling, that alter the benthic environment are restricted to certain areas. Currently, many of these impacts cannot be quantified (see SoE *Reference Group Draft Working Papers*).

At present there are less than 100 trawlers operating in a series of discrete managed fisheries within the total Western Australian fishing fleet of around 2000. The numbers of these trawl licences will be reduced over time. Areas available to trawling within each trawl fishery management area are also restricted. There are significant demersal gill netting closures in areas of high abundance of vulnerable species such as dugong (for example, Shark Bay and Ningaloo).

Fishing does change the overall abundance of the target species and in some cases species which are closely related in the food chain. Quantifying these changes is extremely difficult as the effects from fishing are difficult to isolate from other human induced effects and natural environmental variation. For example, the strength of the Leeuwin Current is a natural environmental factor which has been shown to have a significant effect on many of Western Australia's fish stocks.

Pollution, loss of habitat, sedimentation from dredge spoil and agricultural run-off can impact heavily on fish stocks, primarily in nearshore waters and estuaries. Nutrient enrichment of some Western Australian estuaries continues to be a problem. Construction of dams and other physical barriers threatens the abundance and distribution of many freshwater native fish species, particularly in the south west of the State.

The introduction of exotic marine organisms from ballast water and via the aquarium industry remains an area of concern.

Challenges to Ecologically Sustainable Development

Population growth and the resulting human-induced environmental changes continue to threaten Western Australian fisheries, particularly those in nearshore waters. In an effort to minimise these effects, Fisheries WA provides environmental and fish stock management advice to many other State agencies and development groups.

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. Quantifying these effects is a difficult but major role for Fisheries WA scientists. In assessing fish stocks and levels of effort in a fishery, managers and researchers take these factors into account and can adjust Fisheries Management Plans accordingly.

The extent of illegal fishing by commercial fishers or illegal and inappropriate fishing by recreational fishers is difficult to quantify. It is thought that significant amounts of the higher value species such as abalone, rock lobster and dhufish are sold illegally. Fishing for marron out of season, illegal gill netting and the taking of high value reef fish are currently issues for compliance officers and recreational fishing managers.

Regional recreational fishing surveys and reviews are currently underway in an effort to better manage the resources targeted by recreational fishers.

Current Responses

Fisheries WA uses a range of techniques to manage the State's fish stocks. In the commercial fishery, controls are placed on: the number and size of boats; the area of the fishery; the amount or type of fishing gear; the times fishing is allowed; and amount of fish that can be caught.

These management arrangements have been successful largely as a result of research, field operations and management co-operation with industry. The maximum number of commercial vessels was limited in 1983, and is being reduced by industry/government buy-back schemes.

At the national level the Commonwealth and States are collaborating to develop a Fishery By-catch policy which will be used in future management of Western Australian fisheries.

Managing the recreational fishery is more difficult because of the increasing number of fishers. Controls include restrictions on the number and size of fish caught and in some cases the times and areas fished.

Regional management plans are also being developed with the local recreational community-based Recreational Fishing Advisory Committees. There is strong community involvement and support for regulation and education, placing an emphasis on sustaining fish stocks as well as valuing the fishing experience.

At a national level and as part of the ecologically sustainable development guidelines, *Recreational Fishing in Australia: A National Policy* (Commonwealth of Australia, 1995b) was developed to improve the management of recreational fishing stocks.

Fisheries WA has also consulted with other States and Territories to develop *A National Strategy on Aquaculture* which includes standards and controls to ensure the environment is protected.

The introduction of exotic marine species is an area of concern. Ballast water from international shipping is controlled by the ports under the Australian Quarantine Inspection Service (AQIS). Voluntary guidelines put out by AQIS have been largely accepted by the International Maritime Organisation and may become mandatory in 1999.

There is a national quarantine barrier for the introduction of marine aquarium fishes regulated by AQIS. Aquarium fishes transferred from the eastern States into Western Australia require prior approval by Fisheries WA. A translocation policy for Western Australia has recently been released for the translocation of fishes for aquaculture and recreational fish stock enhancement. A Memorandum of Understanding between the EPA and Fisheries WA has been developed to minimise the risk to terrestrial and aquatic environments where translocation occurs.

The Fish and Fish Habitat Protection Program has recently been established and Fisheries WA 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 and within the sectors leading to increases in the exploitation of fish stocks. There is also a continuing need for management to adjust for improvements in fishing technology and to encourage industry to adopt more refined techniques.

The application of ecologically sustainable development principles will be more explicitly applied, using measurable and meaningful performance indicators. These performance indicators are still subject to development and debate.

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

Forestry

Natural Resource Use Sectors

Conclusion

Wood is produced in Western Australia from public and private native forests and plantations in the south west of the State. Wood production is a matter of often intense public debate, especially in relation to public native forests, and old growth forests in particular. In these forests, a system of representative reserves and the provisions of management plans under the *Conservation and Land Management Act 1984* (*WA*) are designed to ensure ecologically sustainable forest uses. The design of a comprehensive, adequate and representative forest reserve system and mechanisms for ecologically sustainable forest management are currently under review by the Commonwealth and State governments, leading to the development of a Regional Forest Agreement (RFA) for Western Australia.

Objective

Western Australia's public native forests are to be managed in consultation with the community so that they provide the values required by society while sustaining indefinitely their biological and social diversity (Lands and Forest Commission, 1994). This objective is based on the provisions of the *Conservation and Land Management Act 1984 (WA)*, which states that indigenous State forests and timber reserves must be managed for one or more of the following purposes: conservation, recreation, timber production on a sustained yield basis, water catchment protection, or other purposes prescribed by regulations.

The objective for State forests or timber reserves planted with exotic species is to achieve the optimum yield in production, consistent with the satisfaction of long-term social and economic needs.

The objective for national parks and conservation parks is to fulfil as much of the demand for recreation by members of the public as is consistent with the proper maintenance and restoration of the natural environment, the protection of indigenous flora and fauna and the preservation of any features of archaeological, historic and scientific interest.

The objective for nature reserves is to maintain and restore the natural environment, and to protect, care for, and promote the study of, indigenous flora and fauna, and to preserve any features of archaeological, historic or scientific interest.

Objectives for privately-owned forests and plantations depend on the owners, and range from maximum economic return from plantations through protection of agricultural land, crops and livestock to preservation of natural conservation values.

Forest conservation and management objectives have also been set at a national level. The *National Forest Policy Statement* (Commonwealth of Australia, 1992a) has the following objectives:

- retaining the unique character of Australian forests, their integrity and biological diversity by both reservation and off-reserve management;
- increasing the total area of forest;
- managing forests for all their values and uses so as to optimise benefits to the community;
- ecologically sustainable management of private forests that complements the conservation and commercial objectives of public forests;
- sustainable forest-based industries founded on excellence and innovation, expanding to contribute further to economic and employment growth;
- efficient, environmentally sensitive and sustainable forest use;
- forest management that is effective and responsive to the community; and
- community understanding of the values of forests and sustainable forest management and participation in decision-making relating to forest use and management.

The *National Strategy for Ecologically Sustainable Development* (Commonwealth of Australia, 1992b) includes three objectives related to forests:

- to manage and utilise Australia's forest estate for all forest values on an ecologically sustainable basis;

- to maintain ecological processes within the forests, maintain biodiversity and optimise benefits to the community from all uses, within ecological constraints; and
- to enhance the quality of life for successive generations of Australians by protecting and enhancing all of the values available from Australia's forests and development of ecologically sustainable and internationally competitive forest products industry.

Indicators

Gross indicators of change in forests, such as areas of forested land (Table 16), areas harvested and regenerated, areas burnt by wildfire or prescribed fire, areas of plantation established and timber volumes produced (Table 17) are easily obtained and reported. Such data are reported annually (Department of Conservation and Land Management, 1997 and previous).

Other indicators of ecological change include measures of soil fertility or erosion and population levels of individual species within the forest. In general, data for such indicators are more difficult to measure and assemble into meaningful indicators at a regional level. This task is being addressed nationally and internationally as criteria and indicators for sustainable forest management and was reported upon by Australia in 1997 (Commonwealth of Australia, 1997a).

Suggested Responses

Fundamental elements of sustainable development are a secure and managed reserve system and management regimes off-reserve which maintain the ecological processes sustaining the forest. The foundations of these elements exist in Western Australia. Following the current comprehensive regional assessment of the level of reservation of biodiversity, old growth and wilderness values; forest management practices; and social and economic values in the south west (Commonwealth of Australia & Western Australian Government, 1998), the State and Commonwealth governments will develop and sign a Regional Forest Agreement which will provide the basis for sustainable development over the next 20 years.

Table 16. *Reservation status of forest ecosystems in southwest region (Source: Commonwealth of Australia & Western Australian Government (1998) Comprehensive Regional Assessment).*

	Jarrah (mixed with marri and tingle)	Karri (mixed with jarrah and tingle)	Wandoo	Other
Estimated pre-1750 area (ha)	2,783,900	250,500	526,200	593,800
Current area all tenures (ha)	1,813,600	201,500	218,700	411,000
Proportion of pre-1750	65%	80%	41%	69%
CALM-managed area (ha)	1,542,100	180,500	137,300	334,900
Existing and proposed conservation reserves (ha)	377,800	55,600	75,700	221,500
Proportion of CALM-managed	25%	31%	55%	66%
Informal reserves (ha)	159,100	27,700	9,700	112,600
Proportion of CALM-managed	10%	15%	7%	34%
Other CALM managed land (ha)	1,005,200	97,200	51,900	800
Proportion of CALM-managed	65%	54%	38%	–
Other public land (ha)	51,800	2,500	19,000	21,300
Private land (ha)	219,700	18,500	62,400	54,800

Table 17. *Wood production (cubic metres) from the south west region 1996-97 (Source: Department of Conservation and Land Management (1997) Department of Conservation and Land Management Annual Report).*

		Native forest	Plantations
Sawlogs	- public - private	669,852 7,505	254,269 43,763
Non-sawlogs (chiplogs, industrial wood, firewood)	- public - private	764,067 61,914	341,153 168,982
Total		**1,503,338**	**808,467**

Both the public and private sector are contributing to additional plantations on agricultural land which will supply increased timber volumes in the future as well as assisting in redressing water balances in cleared agricultural landscapes. Nationally, the Plantations 2020 vision sets a goal of trebling the nation's plantations by 2020.

Research needs to continue into the interactions between different pressures on the forest and their impacts, leading to refinements in management over time.

Description

The Comprehensive Regional Assessment (CRA) (Commonwealth of Australia & Western Australian Government, 1998) provides a complete overview of the forest region, including areas of reserves, biodiversity, old growth, wilderness, heritage and social and economic values.

Approximately 65 per cent of the jarrah/marri forest, 80 per cent of the karri/marri forest and 41 per cent of the wandoo forest that existed before European settlement remain in the south-western forest region (Commonwealth of Australia & Western Australian Government, 1998). Eighty nine per cent of the existing forest is retained under control of the Crown (State forests, national parks and other conservation reserves). The remaining 11 per cent of native forest is in private ownership and subject to clearing controls under State legislation (for example, *Soil and Land Conservation Act*). Private landowners are encouraged to manage their forests in a sustainable manner.

In addition to native forests, there are extensive plantation forests established in the south west. There are 91,000 ha of softwood plantations comprising 70,785 ha on public land and 20,222 ha on private land. There are 57,000 ha of hardwood plantations of which about half is publicly owned.

Forests are managed for many diverse values and industries including: nature conservation and protection of biological diversity; tourism and recreation; honey production; wildflower picking; craftwood supply; timber production; water catchment protection; and mining. Tourism, water production and mining are addressed in other sections of this report.

In terms of timber, plantations supply sawlogs, pulp logs and industrial wood which is used to make particleboard and medium density fibreboard. Major plantation processing industries are located near Bunbury and Perth. Native forests supply sawlogs of various grades and species, and timber which cannot be used for sawing is used for pulpwood (woodchips), industrial firewood (to make charcoal for silicon manufacture), domestic firewood, fencing timbers and industrial wood (particleboard). Processing takes place at numerous locations from Perth to Pemberton (Commonwealth of Australia & Western Australian Government, 1998).

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. Some activities, such as road-building and clearing for agriculture or mining, can result in long-term or complete disruption to forest ecosystems, depending on their scale and opportunities for rehabilitation. Tourism and recreation developments must be carefully managed to minimise impacts on the forest environment.

Harvesting the forest for wood products results in changes to forest structure, depending on the silvicultural methods employed. These include selective cutting; thinning (to promote growth on remaining trees); shelterwood (to establish natural regeneration in jarrah forest); and clear-felling followed by regeneration of an even-aged forest.

Silvicultural techniques in public forests aim to regenerate the original species mix, and to maintain a range of forest structures in the regenerating forest to maintain biological diversity (Lands and Forest Commission, 1994). Changes to old growth forest (that which is ecologically mature where the effects of disturbance are now negligible) are most contentious, in that while regenerated forests can grow old again, they may not regain the element of 'pristineness'. Old growth forest has been specifically addressed in the CRA (Commonwealth of Australia & Western Australian Government, 1998) and will be taken into account when establishing appropriate reserve levels in the final RFA.

Fire is a natural part of the ecosystem in these forests, and has also been reviewed in the CRA. Prescribed burning is practised in areas of forest to protect the forest and community lives and property from the catastrophic impacts of wildfire. Community concerns centre on the frequency and timing of fires, and the smoke they produce. Research continues into the historic frequency of fires in the forest, and procedures for improved forecasting of smoke trajectories have been implemented and are reviewed annually.

Challenges to Ecologically Sustainable Development

The most significant challenges to the ecologically sustainable development of the forestry sector include activities which result in permanent loss of forests, or in plant diseases such as dieback *(Phytophthora cinnamomi)* which impair the capacity of the forest to grow and regenerate.

In the 1970s, large areas of forest were declared 'quarantine' or 'disease risk' areas. This strategy restricted vehicular access, while allowing for more detailed mapping of dieback presence. Mapping confirms that the forest contains a mosaic of healthy and infested areas, and that access needs to be restricted under a system of permits to limit spread of infected soil and plant material. Operations in the forests are permitted under a system of hygiene controls. Dieback is not just a disease of forest areas, and the Government recently endorsed all recommendations of the Western Australian Dieback Review Panel (1996) and created a Dieback Consultative Committee to assist in implementing the recommendations over the southern half of the State.

The challenge of meeting all of the community's needs from the forests is met by a system of conservation reserves and a range of management practices off-reserve, such as long rotations and smaller cutting areas. These are outlined in the *Forest Management Plan 1994–2003* (Lands and Forest Commission, 1994) and are being further reviewed during the course of the RFA.

Increasing demands for timber are met by increasing plantations, along with value adding of native forest timbers. Changing community values and aspirations concerning forests are accommodated by reviewing forest management plans on a cycle of ten years (or less) and making adjustments as required. Current plans foreshadow a change to the level of sawlog harvest from jarrah forest which is required due to the large areas of jarrah regenerated early in the century and now in immature growth stages. While this does not affect the total gross bole volume growth, it does influence the proportions of logs in larger sizes which are available to harvest.

Current Responses

A range of responses are in place which contribute to sustainable forest management, including management planning; translocation of native fauna populations; management of *Phytophthora cinnamomi* and feral predators; research and development of plantations; and management of fire, as well as legislative procedures.

Procedures are in place to protect water (cutting areas, stream reserves), conservation values (cutting areas, stream reserves, habitat trees and logs) and amenity values (road reserves, visual resource management) during timber harvesting and regeneration.

The *Forest Management Plan 1994–2003* provides for a balance of age classes and the maintenance of older (mature and senescent) stands throughout the landscape.

Implications

Forest management continues as a contentious issue in the community. Advocates are often polarised between the view that timber should only be sourced from plantations, and the view that timber harvesting from native forests is a reasonable use of a renewable resource which generates considerable income and employment within the region. Government policy is to maintain and foster a balance of uses, including tourism, from the State's forests through a system of conservation reserves and complementary off-reserve management. The continuing development of criteria and indicators at a regional level will assist in evaluating and reporting on the achievement of sustainable forest management.

Mining and Petroleum Production

Natural Resource Use Sectors

Conclusion

In the past, mineral and petroleum operators were less aware of the effects of their activities on the environment and in some instances caused environmental degradation. In recent times industry has produced a good record of environmental performance and management. In many cases operators have gone beyond mere compliance to legislative requirements and contributed to the sustainability of our natural resources. To ensure future access to these resources, industry's level of performance and commitment to environmental management will need to be maintained and improved over time.

Objective

To ensure that sound environmental practices are undertaken during and after exploration and production operations on an ecologically sustainable basis while providing optimum economic and social benefits to the community.

Indicators

- Number and area covered by mineral and petroleum tenements
- Area of mineral and petroleum tenements disturbed and rehabilitated
- Number of project approvals
- Rate of resource depletion
- Greenhouse gas emissions from the sector
- Proportion of environmental audits that show compliance
- Adoption of environmental codes and practices
- Proportion of companies mining in WA producing public environmental reports.

Suggested Responses

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. Because of the wide range of activities associated with exploration and production and the diverse environments encountered in the State, environmental management responses must be specifically tailored to the activity proposed.

Further effort towards ecologically sustainable practices is required in many key areas of mining and petroleum production including management and rehabilitation of mined out voids, tailings management, management of potentially acid forming materials, toxicological studies and defining ecological risk. These issues are being addressed through research initiated under the auspices of the Minerals Environmental Liaison Committee (MELC), which is a government chaired committee representing government and conservation organisations; and the Minerals and Energy Research Institute of Western Australia (MERIWA) which is a government funded statutory authority.

A review of the environmental performance of the gold mining industry and the heavy mineral sands industry was undertaken by MELC in 1994 and 1995 respectively with recommendations made to the Minister for Mines in 1996 final reports. These recommendations identified that tailings management was the most important issue for continued study in these industries.

The research projects of MERIWA relate to geoscience, mineral processing, hydrocarbons, engineering and environmental rehabilitation. Most research is undertaken by universities and consultants with sponsorship from both the mineral and petroleum sectors. Results of the research are utilised by the industry to improve its performance. Examples of recent MERIWA

projects include smoke enhanced germination of native species for minesite rehabilitation and research into the control of dieback disease using phosphite fungicide.

Results from monitoring and annual environmental audits provide additional information on the extent of the pressures on the environment, how industry is responding to these pressures and what further action is required by both industry and government.

Description

Minerals and petroleum are non-renewable resources. However, with adequate environmental safeguards and management, it is possible to extract and develop these resources in a way that will bring benefit to present and future generations. To satisfy the principles of ecologically sustainable development, the future needs for these resources must be recognised through efficient resource use and ongoing exploration using the best available technology.

With only 10 per cent of the Australian population, Western Australia accounts for 40 per cent of the total production of Australia's minerals and petroleum. Major commodities produced in Western Australia include bauxite/alumina, coal, base metals (copper, lead and zinc), diamonds, gold, heavy mineral sand products, iron ore, manganese ore, nickel, salt, tin/tantalum/lithium, basic raw materials (clay, silica sand, rock, aggregate, gravel, lime sand, limestone and gypsum), talc and petroleum.

Environmental impacts

Environmental impacts on the physical, biological and social environments are dependent on the type and extent of mining or petroleum activity undertaken and the nature of the environment in which these activities occur. Mineral exploration, essential for defining mineral resources, generally involves low impact activities such as reconnaissance in light vehicles, airborne surveys, satellite imaging, geochemical and geophysical work. The use of mechanised equipment (for example, dozers or graders), however, has the potential to cause environmental disturbance during excavation and vegetation clearing. Mining operations usually involve small areas of land, although impacts on these areas may be substantial.

Petroleum exploration and production activities usually involve seismic surveys, drilling and production. Properly managed, these activities are likely to cause limited environmental disturbance. Sound environmental management is assisted by the development of codes of practice and guidelines. Potentially significant impacts are screened and assessed through the environmental impact assessment process. If not adequately managed, the following impacts may result from mining and petroleum activities.

Physical impacts include erosion, soil damage, changes to surface water and groundwater, salinisation, acidification, changes to coastal processes, air emissions, dust and noise in the terrestrial environment, contamination, sedimentation and turbidity in the marine environment.

As of November 1997 there were approximately 37 petroleum production facilities and in excess of 300 large-scale mining operations with annual reporting requirements under the control of the Department of Environmental Protection and the Department of Minerals and Energy (DME); in excess of 100 State Agreement Acts under control of the Department of Resources Development; and numerous small scale (short-term) quarry operations that are either under control of the DME or a local government authority administered through the *Local Government Act 1995* (*WA*).

As of November 1997 there were approximately 415,000 square kilometres of land held under mineral exploration and mining titles and approximately 164,000 square kilometres held under petroleum exploration titles and production licences applicable to onshore areas. The area of disturbance associated with these activities varies depending on the nature of the operation being undertaken. Data on areas of disturbance are currently being collected by DME as part of environmental audit reports on exploration and production. This information will be provided in DME's 1998 annual report.

Biological impacts include loss of flora and fauna, habitats and food sources, and the introduction of pests and diseases.

Social impacts include impacts on local industry, public works, conservation values, agriculture, heritage and recreation sites and land-use conflict.

Waste and pollution impacts include soil and water contamination, groundwater contamination, air emissions, noise, localised marine pollution and the possibility of oil spills.

Challenges to Ecologically Sustainable Development

The mineral and petroleum industries are a major source of income for Western Australia. 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.

Intra-generational equity, or the degree to which economic benefits of mining and petroleum production are distributed to Western Australians, will be an increasingly important issue as the industry becomes even more capital intensive and less labour intensive. Another challenge to ecologically sustainable development is inter-generational equity, that is, the need to ensure mineral resources are not alienated through land use decisions so they are available for future generations, a factor that may require long-term planning. These considerations are in addition to the recognition that areas of the State which provide irreplaceable environmental, heritage and social values place restrictions on the area that is accessible to mining and petroleum production.

Current Responses

Steps already being taken towards sustainability include:

- environmental impact assessment of new proposals;
- rehabilitation that is compatible with future land use;
- environmental reporting, auditing and monitoring of operations (including requirements under State Agreement Acts) the *Mining Act 1978* (*WA*), the *Petroleum Act 1967* (*WA*), *Petroleum Pipelines Act 1969 (WA)*, *Petroleum* (*Submerged Lands*) *Act 1982* (*WA*) and the *Environmental Protection Act 1986* (*WA*);
- maintenance of an environmental performance bond system to ensure those mining companies whose operations are administered under the *Mining Act 1978 (WA)* comply with their environmental obligations;
- petroleum companies must have insurance funds to clean up the environment should they be unable to meet their environmental commitments in the event of an environmental accident;
- policy and guidelines have been developed to assist mining and petroleum companies to develop mineral and petroleum resources in an environmentally acceptable manner;
- guidelines for environmental management of mining and petroleum operations have been 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;
- programs to rehabilitate abandoned minesites identified as a public health risk are underway in the Eastern Goldfields, Galena area and at Wittenoom and Ravensthorpe. A management plan for the historic Galena area is being developed to cover the environmental, public safety and heritage aspects of the old mine workings in the area. An inventory of abandoned mines has commenced so that remedial work can be identified;
- flora and fauna surveys of areas where mining or petroleum operations are proposed; 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, they are unlikely to gain future access. Existing operations will be rehabilitated using bond or insurance funds if rehabilitation work is not completed. The community is unlikely to support mining and petroleum production if such safeguards are not in place, especially in environmentally sensitive areas. As such there is a recognised need for continual improvement by industry in management practices to be consistent with ISO 14000 (Standards Australia, 1996), or an equivalent environmental management system.

See Section 8 of the SoE Reference Group Draft Working Papers for more information on Mining and Petroleum Production.

Tourism

Natural Resource Use Sectors

Conclusion

The expected growth of tourism in Western Australia will bring increased pressure on the natural environments used by the tourism industry. In many cases tourism is expanding in environments that are already under significant pressure from a range of uses and degrading processes not necessarily caused through tourism.

Western Australia has yet to experience severe negative impacts from haphazard tourism developments and uncontrolled access to high value conservation areas. It can be expected that, with continued growth, an even greater need for environmental management will be required. 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. It is also essential that existing threats to natural environments be resolved to ensure the sustainability of nature-based tourism.

Objective

To conserve and preserve the natural environment while enabling nature-based tourism and other tourism activities to take place. The vision statement of the *Nature-based Tourism Strategy* aims to ensure that Western Australia maintains its natural advantage and establishes itself as the leading nature-based tourism destination in Australia.

Indicators

Monitoring or measuring the sustainability of nature-based tourism activities is not easy, particularly in the short-term. Current monitoring systems need to be improved and research programs developed to collect information on visitor numbers and visitor experiences, attitudes and impacts. Models that compare and evaluate the costs, benefits and sustainability of developments have yet to be developed. However, the approach to reducing impacts to sustainable levels has been achieved through management controls such as restricting access, charging and setting levels of entry fees, restricting licences, introducing management zoning, and providing alternative sites to visit.

Suggested Responses

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.

To guide the development of sustainable tourism practices, the Tourism Commission in conjunction with the Environmental Protection Authority published a code of ethics in the *Eco Ethics of Tourism Development* in 1989. This code guides tourism developers, operators and tourists to co-exist in harmony with the natural environment. The code of ethics covers the environment in general but also includes specific attention to micro environments, that is, beaches and ocean frontage, remote environments, forests and national parks, waterways and wetlands, and heritage or built environments.

The Department of Conservation and Land Management licenses operators entering the estate under its jurisdiction. Industry self-regulation is being promoted and consideration is being given to developing a code of practice for tourism operators based on the code of ethics. A quality assurance program is being implemented throughout Western Australia by the Tourism Council Australia and the National Eco-tourism Accreditation Program has been developed at the national level.

Description

The tourism industry consists of many sectors and uses a wide variety of the State's environments in many different ways. This generally passive use should not of itself cause a great impact on the environment except in the case of large-scale developments or a concentration of developments or uses 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 scale of development taking place and the volume of tourist numbers visiting an area or attraction. There is a need to limit tourist numbers to the carrying capacity of the environment, as well as retaining wilderness areas for future generations. In remote areas, access may depend on the capacity of environmental management to prevent environmental impacts.

Challenges to Ecologically Sustainable Development

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

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 visitors 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.

Property development has become an integrated part of tourism development. Good planning strategies and systems must be put in place to avoid any adverse impacts on the natural environment.

Current Responses

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 Nature-based Tourism Strategy to guide the sustainable development of the tourism industry in the future. A three-year Government funded implementation program is under way.

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 assisting Tourism Council Australia in implementing a quality assurance programme 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 Western Australia.

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

Water Supply

Natural Resource Use Sectors

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 addressed in the priority demand centres of Perth and Kalgoorlie; however, there is a need for continuous improvement in water efficiency across the State.

Strong actions are required to address land-use pressures on existing and potential water supplies. Salinity threats to the 'marginal' quality of 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 ecologically 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 and, where appropriate, water reuse.

Indicators

Percentage of resources with usage below the estimated ecologically sustainable limit. As the use of each groundwater or surface water resource grows, the estimated ecologically sustainable limit is progressively refined, the resource is subdivided as required and use is controlled through licensing to prevent over-use.

Percentage of public supply sources with effective water quality protection in place. Generally this will mean catchment protection plans developed in conjunction with landowners, compliance auditing and monitoring of raw water quality.

Percentage of scheme supply systems with average annual per capita consumption usage below efficient use limit. The Water and Rivers Commission (WRC) in consultation with water service providers will progressively set per capita consumption targets for each supply scheme and require regular compliance reporting.

Percentage of self supply users complying with industry standard best practice water use. Industry standard efficient water-use practices will be progressively established by the appropriate industry groups. Industry based benchmarking and auditing would determine compliance with best practice. The WRC would facilitate these processes.

Suggested Responses

- Continue to manage ongoing pressures for water source development to keep allocations within ecologically sustainable limits. Provide additional attention to the management of surface water allocation particularly the determination of environmental water provisions and flows.
- 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* and the recommendations of the Select Committee on Metropolitan Development and Groundwater Supplies (Legislative Assembly, 1994).
- Investigate 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.

- Encourage the investigation and trialing of greywater reuse and, if successful, prepare guidelines with Health WA and local authorities.
- Encourage the capping of uncapped artesian bores.
- Provide information on the benefits, costs and risks of the use of rainwater tanks.
- Establish the principle of restoration of degraded riverine systems to compensate for impacts on natural water resource values.
- Encourage the reuse of treated sewage and industrial effluent for irrigation purposes where appropriate.

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 that ecological functions and integrity are sustained in the long-term.

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 (including 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 to 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 per cent of groundwater management sub-areas have an over-allocation of water.

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

The mining industry in the Goldfields makes extensive use of hyper-saline groundwater from paleochannel aquifers to extract minerals from ore. Because the hyper-saline 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 hyper-saline 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 due to 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-western 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 7000 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. The Government has acted on these recommendations and Figure 26 shows a portion of the Metropolitan Region Scheme with the new water protection zone.

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. Over-allocation 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.

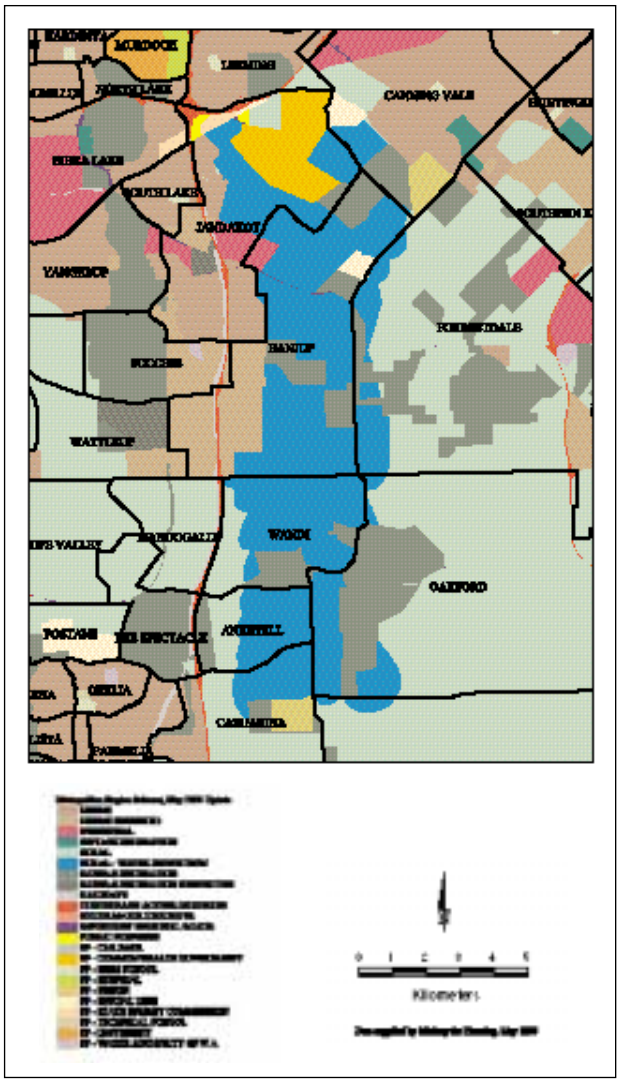


Figure 26. *The Metropolitan Region Scheme (updated May 1998) in the Jandakot area highlighting the new water protection zone (Source: Ministry for Planning).*

PROGRESS TOWARDS ECOLOGICALLY SUSTAINABLE DEVELOPMENT

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

GLOSSARY

Agenda 21: one of the outcomes of the 1992 United Nations Conference on Environment and Development which sets the agenda for achieving sustainable development in the 21st Century

agroforestry: planting trees and crops together usually in rows or bands (Miller, 1996)

agronomy: the study of rural economy and husbandry (Allaby, 1977)

airshed: a body of air bounded by topographical and/or meteorological features in which a contaminant, once emitted, is contained[1]

amenity: a concept expressing those natural or man-made qualities of the environment from which pleasure, enrichment and satisfaction is derived (Allaby, 1977)

anthropogenic: created by humans (Department of Environmental Protection, 1996c)

anti-fouling agents: paints applied to the hulls of vessels to prevent fouling by barnacles and other organisms (Australian and New Zealand Environment and Conservation Council, 1996)

aquaculture: growing and harvesting of fish and shellfish for human use in freshwater or saltwater ponds, irrigation ditches and lakes, or in cages or fenced-in areas of coastal lagoons and estuaries (Miller, 1996)

aquifer: porous soil or geological formation capable of being permeated by water, which holds and yields groundwater[2]

artesian bore: well bored into a confined aquifer which overflows the well-head (Allaby, 1977)

assemblage: Recognisable grouping or collection of individuals or organisms (Department of Environmental Protection, 1996c).

ballast water: water carried in tanks to maintain stability when a ship is lightly loaded; normally discharged to the sea when the ship is loaded with cargo[1]

benthos (benthic): All marine organisms living upon or in the sediment of the sea (Department of Environmental Protection, 1996).

best land management practices: the best practicable methods of meeting land resource management objectives (Environmental Protection Authority, *et al*. 1994)

biogenic: particles of a biological origin

biomass: the quantity of organic matter within an ecosystem (usually expressed as dry weight per unit area or volume)[1]

biota: the plants, animals and micro organisms of a region (Department of Environment Protection, 1996c)

brackish water: water that is saline, but less so than sea water; may be suitable for selective irrigation and watering of livestock[1]

carrying capacity: maximum stocking rate which an area of grazing land can support throughout greatest period of stress each year; ecologically, the maximum biomass which an area can maintain indefinitely. The notion has also been attempted to be applied to human populations.[2]

commensal species: a close association between organisms of different species during which only one partner receives benefits, but the other is not harmed. The association may be one in which the partners merely share a home or it may be much closer, where one species is transported, protected and gathers superfluous food from the partner (Allaby, 1977).

community: ecologically, any naturally occurring group of different organisms sharing a particular habitat (Department of Environmental Protection, 1996c)

conservation-tillage farming: crop cultivation in which the soil is disturbed a little (minimum-tillage farming) or not at all (no-till farming) to reduce soil erosion, lower labor costs and save energy (Miller, 1996)

degradation: any decline in the quality of natural resources commonly caused by human activities[2]

demersal: a term sometimes used as a synonym for 'benthic'; living in the lowest layer of a sea or lake (Allaby, 1977)

diffuse-source pollution: pollution from sources such as an eroding paddock, urban or suburban lands and forests; spread out, and often not easily identified or managed[1]

Dobson Unit (DU): unit of measure of total ozone in a vertical column of atmosphere. 100 DUs would equal 1 mm of ozone at sea level and $0^{o}C$.[2]

ecological footprint: the ecological impact of cities, including the direct local effects and the indirect regional and global effects due to the resources they use and the wastes they produce[1]

ecologically sustainable development (ESD): using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased[2]

ecosystem: unit including a community of organisms, the physical and chemical environment of that community, and all the interactions among those organisms and between the organisms and their environment (Department of Environmental Protection, 1996)

eco-tourism: nature-based tourism which involves education and interpretation of the natural environment and is managed to be ecologically sustainable[2]

El Nino: a warm water current which periodically flows southward along the coast of Ecuador and Peru in South America, replacing the usually cold northward flowing current; occurs once every five to seven years usually during the Christmas season (the name refers to the Christ child). Occasionally (eg. 1925, 1972-73, 1982-83 and 1990-94) the occurrence is major and prolonged; the opposite phase of an El Nino event is called a La Nina. *see* El Nino-Southern Oscillation[1]

El Nino-Southern Oscillation: a suite of events that occur at the time of an El Nino; at one extreme of the cycle, when the central Pacific Ocean is warm and the atmospheric pressure over Australia is relatively high, the El Nino-Southern Oscillation causes drought conditions over eastern Australia[1]

endangered species: those likely to become extinct unless action is taken to remove the factors that threaten their survival[2]

endemic: originating in a given area and confined to that area[2]

environmental indicator: physical, chemical, biological or socio-economic measures that can be used to assess natural resources and environmental quality[1]

eutrophic: applied to water bodies which are rich in plant nutrients and are therefore highly productive.

eutrophication: an increase in the rate of supply of organic matter to an ecosystem caused by unnaturally high loads of nutrients to that ecosystem (Department of Environmental Protection, 1996c)

extinct: species no longer in existence or not located in the wild during the past 50 years[2]

feral animal: wild exotic animal, usually a domesticated animal which has become wild[2]

food chain: series of organisms, each eating or decomposing the preceding one (Miller, 1996)

gully erosion: a form of erosion involving the formation of deep steep-sided channels or gullies which can not be removed by cultivation[1]

habitat: a geographic area or environment that can provide for the key activities of life[2]

heavy metal: metallic element with relatively high atomic mass (over 5.0 specific gravity), such as lead, cadmium, arsenic and mercury; generally toxic in relatively low concentrations to plant and animal life[1]

hydrologic cycle: biogeochemical cycle that collects, purifies and distributes the Earth's fixed supply of water from the environment to living organisms, and then back to the environment (Miller, 1996)

hypersaline: more salty than seawater[1]

indigenous species: species that are native to (that is, naturally occurring in) a region[1]

integrated pest management (IPM): combined use of biological, chemical and cultivation methods in proper sequence and timing to keep the size of a pest population below that which causes economically unacceptable loss of a crop or livestock animal (Miller, 1996)

ISO 14000: a series of standards representing a common global approach to environmental management (Standards Australia, 1996)

Landcare: a voluntary and cooperative movement that brings together rural people, government agencies and others with an interest in the long term health of the land; the term was first used in Victoria in 1986 but spread nationally after 1988 when the Australian Conservation Foundation and the National Farmers Federation persuaded the Commonwealth Government to provide significant financial support[1]

land degradation: the decline in condition or quality of the land as a consequence of human activities[2]

landfill: solid or liquid material disposed of by burial in the ground[2]

leaching: the removal in solution of soluble minerals and salts by water seeping through soil or rock[2]

Leeuwin Current: tropical warm waters moving in a southerly direction from Indonesia-New Guinea down the coast of Western Australia (Whyte, 1997)

marginal water: water that is suitable for watering of livestock, irrigation, and other general uses[1]

metabolite: a substance involved in metabolism; an essential nutrient (Allaby, 1977)

minimum tillage farming: See *conservation-tillage farming*

National Pollutant Inventory (NPI): a database designed to provide the community, industry and government with information on the types and amounts of certain chemicals being emitted to the environment

nature-based tourism: See *eco-tourism*[2]

nitrogen dioxide (NO_2): a gas and air pollutant; motor vehicles are the main source in metropolitan areas[2]

nitrous oxide (N_2O): gas naturally produced though bacteriological decomposition of organic matter. Also produced anthropogenically, for example, by manufacturing and use of nitrogen based fertilisers[2]

non-renewable resource: resource that exists in a fixed amount (stock) in various places in the Earthís crust and has the potential for renewal only by geological, physical and chemical processes taking place over hundreds of millions to billions of years. Examples are copper, aluminium, coal and oil. We classify these resources as exhaustible because we are extracting and using them at a much faster rate than the geological time scale on which they were formed (Miller, 1996)

no-till farming: see *conservation-tillage farming*

NO_x: oxides of nitrogen; nitric acid (NO) and nitrogen dioxide (NO_2) are the most common[2]

old-growth forests: forests dominated by mature trees and with little or no evidence of any disturbance such as logging, road building or clearing[1]

open cut mining: the working of coal or an ore by removing the overburden to expose the ore-body which is removed and may be partly processed on site. The technique is used to obtain some coal and many other minerals, especially where the rock contains so little of the required substance that conventional techniques of tunnelling along the veins can not be used. The effect on the landscape is considerable; with some minerals the pollution may be high, and restoration of the land when work has finished may be difficult. (Allaby, 1977)

organochlorine: a hydrocarbon compound containing chlorine. Includes many pesticides and industrial chemicals[1]

ozone: a gas with molecules comprising three atoms of oxygen. In the stratosphere it occurs naturally and provides a protective layer shielding the Earth from ultraviolet radiation; in the troposphere, it is usually formed from anthropogenic emissions and is a major component of photochemical smog. Ozone is also a greenhouse gas[1]

ozone depleting substances: substances, such as chlorofluorocarbons, that destroy ozone in the stratospheric ozone layer[2]

ozone depletion: depletion of stratospheric ozone by substances such as chlorofluorocarbons and halons, allowing increased ultraviolet radiation to reach the earth[2]

particulate matter: solid particles or liquid droplets suspended or carried in the air (Miller, 1996)

pelagic: associated with the surface or middle depths of a body of water[1]

photochemical smog: smog forming in the lower atmosphere through the action of sunlight on the pollutants oxides of nitrogen and hydrocarbons[2]

photovoltaic: producing an electric force through sunlight falling on the junction of two dissimilar materials, such as a metal and a semi-conductor

phyla (phylum): a phylum is a major taxonomic division of living organisms thought to be evolutionarily related, for example, arthropods (spiders, insects and crustaceans)[2]

phthalates: esters of phthalic acid used to give plastic compounds their flexibility

PM10/PM2.5: See *Total Suspended Particles*[1]

point-source pollution: pollution from an easily discernible, single source such as a factory chimney[1]

polychlorinated biphenyls (PCBs): group of 209 different toxic, oily, synthetic chlorinated hydrocarbon compounds that can be biologically amplified in food chains and webs (Miller, 1996)

polycyclic aromatic hydrocarbons (PAH): a group of chemical compounds, including benzopyrene, dibenzopyrene, dibenzoacridine, which are carcinogenic to man (Allaby, 1977)

potable water: water suitable for drinking[1]

precautionary principle: where there are threats or serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, public and private decisions should be guided by:

a) careful evaluation to avoid, whatever practicable, serious or irreversible damage to the environment; and
b) an assessment of the risk-weighted consequences

prescribed fire: a fire deliberately lit and controlled by humans, usually as part of a land management programme; for example, to reduce the chance of uncontrollable bushfires or to control weeds[1]

protocol: a protocol that relates to the process to be followed in measuring environmental characteristics to determine:

a) whether a particular standard or goal is being met or achieved; or
b) the extent of the difference between the measured characteristic of the environment and a particular standard or a particular goal (*National Environment Protection Council Act 1996* (*WA*))

pulplogs: logs that are used to produce woodchips or woodbased products such as chipboard[1]

rangeland: areas of native grasslands, shrublands and woodlands that cover a large proportion of the arid and semi-arid regions, and also include tropical savanna woodlands. Regular cropping is not practiced and the predominant agricultural use, if any, is grazing of sheep and cattle on native vegetation.[1]

remediate: to clean up a contaminated area (land) to the level required for the intended use, often according to regulations[2]

riparian vegetation: vegetation situated on or belonging to a river or stream bank[2]

run-off: the portion of precipitation (rain, hail, snow) which flows across the ground surface as water; major agent of water erosion[2]

salinisation: the accumulation of salts in the soil to an extent which causes degradation of soils and vegetation[2]

salinity: the concentration of salts in water[2]

sawlogs: logs that can be sawn to produce sawn timber, sleeper, poles, etc.[2]

sedimentation: material of varying size, both mineral and organic, deposited away from its site of origin by the action of water, wind, gravity or ice[2]

Shelterwood cutting: removal of mature, marketable trees in an area in a series of partial cuttings to allow regeneration of a new stand under the partial shade of older trees, which later are removed. Typically, this is done by making two or three cuts over a decade (Miller, 1996)

silviculture: branch of forestry focusing on the cultivation of trees[2]

sink: places or processes which remove or absorb materials from a system[2]

sodic soils: soils with a high proportion of sodium that cause poor physical conditions. About 30 per cent of Australian soils are sodic[1]

soil acidification: a gradual increase in the acidity of a soil as a consequence of a variety of natural processes and management actions[1]

stocking rate: actual number of animals (or animal equivalents) carried per unit of grazing land at a specific time (Allaby, 1977)

stratosphere: the region of the atmosphere roughly 15 to 20 km above the Earth's surface where typically the temperature changes little or increases with height. Its thermal structure is determined by radiation balance and is generally very stable.[1]

stubble burning: burning of remnant material after agricultural harvesting[2]

surfactant: a material that facilitates and accentuates the emulsifying, wetting and other surface-modifying properties of substances[1]

tailings: waste material of little economic value separated from the economic material during processing; usually second grade or waste rock fragments derived from screening or processing of raw ores[2]

taxa (taxon): a defined unit (for example, species or genus) in the classification of plants or animals[2]

tillage: mechanical disturbance of the soil by using various implements to alter the soil structure; usually done to create seedbed, kill weeds or increase water entry[1]

threatened species: species facing threatening processes such as extensive destruction of habitat. These processes may threaten the survival, abundance or evolutionary development of the species.[2]

Total Suspended Particles (TSP): includes all particles from the smallest up to 50 µm in diameter; subcategories within the TSP range include those particles less than 10 µm in diameter known as PM10, and those smaller than 2.5 µm and known as PM2.5[1]

tributytin (TBT): an ingredient of anti-fouling paint applied to ships and coastal vessels above 25 m in length

turbidity: a measure of the amount of suspended solids (usually fine clay or silt particles) in water and thus the degree of scattering or absorption of light in the water[1]

2, 4, 5-T (2, 4, 5-trichlorophenoxyacetic acid): translocated hormone weed killer used to control woody weeds (Allaby, 1977)

ultraviolet (UV) radiation: shortwave radiation invisible to the human eye which is higher in energy than visible light. Too much exposure can cause human skin cancer.[2]

vulnerable species: those that soon may become endangered if causal factors (habitat destruction, over-exploitation, other environmental disturbances) continue[2]

water abstraction: the removal of water from a natural water body for human use[1]

[1] denotes State of the Environment Advisory Council (1996)

[2] denotes Environmental Protection Authority (1997)

Units

ppt	Parts per thousand
ppm	Parts per million
ppb	Parts per billion
µm	Micrometre
km	Kilometre
µg/m3	Micrograms per cubic metre
g/km	Grams per kilometre
g/L	Grams per litre
Pb	Lead
ha	Hectares
mm	Millimetres
t	Tonne
Gwh	Gigawatt hour
PJ	Petajoule
GSP	Gross State Product

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PHOTOGRAPHS

Captions for photographs

vi) Lake Tarblin near Narrogin was a fresh water wetland before land was cleared of its native vegetation for agriculture. This has led to saline groundwater rise and the death of the surrounding woodland and fringing vegetation. Photographer: Jiri Lochman

10) Crowds in Kings Park, Perth for Australia Day Celebrations. Photographer: Dennis Sarson

14) Recycling is now common in most urban areas of Perth and in some regional centres. Photograph Courtesy of Department of Environmental Protection

18) Biodiversity at a granite outcrop, Mt Lindsey, Western Australia. Photographer: Marie Lochman

30) Clouds over the wheatbelt, Western Australia. Photograph courtesy of Agriculture Western Australia

49) 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.

52) SPOT image of 2 March 1995 showing seriously degraded inland areas and the sediment plume from the flooding Gascoyne River. Satellite image courtesy of Department of Land Administration and SPOT Imaging

57) Mapping and monitoring of dryland salinity from Landsat TM and landform data. The area shown is approximately 120 km by 120 km of the Upper Blackwood catchment, WA. Areas mapped as saline using 1989/90 image data are shown in red; yellow shows increases in salt affected land from 1990 to 1994; remnant vegetation and waterbodies are shown in green. Satellite image courtesy of CSIRO, Perth

68) Toxic blue green algae blooms dominating a creek in Perth. Photographer: Dennis Sarson

88) Dusky Morwong at Mulluloo-Sorrento Reefs, north of Perth. Photographer: Dick Beilby

91) Western Australia has a wide range of habitat types which are crucial to the survival of marine animals. Photographer: A. Storrie

98) Food production is just one of the areas requiring the development of ecologically sustainable practices. Photograph courtesy of Agriculture Western Australia

103) Without careful management grazing in rangeland areas can lead to erosion, sedimentation and significant impacts on biodiversity. Photograph courtesy of Agriculture Western Australia