Environmental Research in Australia: A Review

1990

Australian Science and Technology Council

ENVIRONMENTAL RESEARCH IN AUSTRALIA

A REVIEW

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29 June 1990

The Hon R J L Hawke, AC MP
Prime Minister
Parliament House
CANBERRA ACT 2600

My dear Prime Minister

We have the honour to submit to you a report, *Environmental Research in Australia - A Review*, as the first phase of ASTEC's response to your reference of 7 August 1989. The Review describes the organisation and funding of environmental research in Australia and establishes a basis for the second phase which will consider the more complex policy related issues raised in the terms of reference.

The Review provides a comprehensive analysis of resources devoted to the support of environmental research and draws attention to deficiencies in our methods of data collection and management.

We believe that Australia must establish integrated coordination mechanisms which will enable policy makers and managers of environmental research to focus the nation's research efforts more efficiently. Such mechanisms would facilitate the task of integrating the results of environmental research into the Government's resolution of natural resource use issues and the assessment of the conservation consequences of its decisions.

The effectiveness of strategies for achieving this integration and for addressing present deficiencies in research and training will be the subject of the concluding report, *Environmental Research in Australia - The Issues*, associated with this study. This report will be presented to you at the end of 1990.

Yours sincerely

R L Martin
Chairman

For and on behalf of

D A Aitkin
G Clark
F M Davidson
A W Goldsworthy
R G Gregory
A Henderson-Sellers
R Johnston
P J Laver
J P Maynes
J G McLeod
D J Nicklin
A E-S Tay
L S Zampatti

TERMS OF REFERENCE

Consistent with the definitions, objectives and priorities outlined in the "National Conservation Strategy for Australia — Living Resource Conservation for Sustainable Development", ASTEC should:

1. review the organisation of, and effort expended in, environmental research in Australia; identify the principal users of that research and its application to the resolution of natural resource use issues where conservation and development are competing objectives;
2. assess the status of environmental research (including research training) in Australia and its effectiveness in contributing to information needs of national Government for the resolution of natural resource use issues of national significance;
3. advise on strategies for Government action to address deficiencies in research and necessary training effort required to provide authoritative advice to Government in its responsibility for environmental issues, specifically with respect to the assessment of conservation consequences of its natural resource use decisions.

FOREWORD

The field of 'environmental research' is itself very new, although environment related research has been conducted within the established and traditional fields of science for many years. The definitions and classifications which pertain to its description are evolving rapidly. For this reason, in presenting this Review, ASTEC wishes to make clear that it is aware that the data it contains are not definitive. However, the exercise of attempting to identify and classify the data available has been invaluable in itself.

It is hoped that this first attempt in a new area will lead to more useful definitions and classifications and new ways of collecting environmental research data which will build on and improve upon the work contained in this Review.

ASTEC welcomes comments on this Review, particularly where such comments will fill gaps or enlarge on particular areas. Organisations or individuals who have not so far submitted submissions to the Study may wish to do so in the light of this Review and are encouraged to do so. Those who have already made submissions may wish to make additional submissions on particular matters. Such submissions should reach ASTEC by the end of September 1990.

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LIST OF ACRONYMS

ABARE	Australian Bureau of Agricultural & Resource Economics
ABRS	Australian Biological Resources Study
ABS	Australian Bureau of Statistics
ADFA	Australian Defence Force Academy
AHC	Australian Heritage Commission
AIMS	Australian Institute of Marine Science
AMC	Australian Maritime College
AMIC	Australian Mining Industry Council
AMOS	Australian Meteorological and Oceanographic Society
AMSTAC	Australian Marine Sciences & Technologies Advisory Committee
ANBG	Australian National Botanical Gardens
ANPWS	Australian National Parks & Wildlife Service
ANSTO	Australian Nuclear Science & Technology Organisation
ANU	Australian National University
ANZEC	Australian & New Zealand Environment Council
ARC	Australian Research Council
ARGS	Australian Research Grants Scheme
ARR	Academically Related Research
ASBR	Academically Separated Budgeted Research
AUSLIG	The Australian Surveying and Land Information Group
AWRAC	Australian Water Resources Advisory Council
BMR	Bureau of Mineral Resources, Geology and Geophysics
BMRC	Bureau of Meteorology Research Centre
BRR	Bureau of Rural Resources
CHI	Computer Horizons Incorporated
COSSA	CSIRO Office of Space Science and Application
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTEC	Commonwealth Tertiary Education Commission
DAS	Department of Administrative Services
DASETT	Department of the Arts, Sport, the Environment, Tourism and Territories
DEET	Department of Employment, Education and Training
DITAC	Department of Industry, Technology and Commerce
DPIE	Department of Primary Industries and Energy
EIA	Environmental Impact Assessment
EIS	Environment Impact Statement
ERIN	Environmental Resources Information Network
FOS	Field of Science
GBRMPA	Great Barrier Reef Marine Park Authority
GIRD	Grants to Industry Research and Development
GIS	Geographic Information System
GUF	General University Funds
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
LTER	Long-term Ecological Research

MSTGS	Marine Sciences & Technologies Grants Scheme
NCSA	National Conservation Strategy for Australia
NERD&D	National Energy Research, Development & Demonstration
NERDDC	National Energy Research, Development & Demonstration Council
NFI	National Forestry Inventory
NRIC	National Resource Information Centre
OECD	Organisation for Economic Cooperation and Development
R&D	Research and Experimental Development
RAC	Resource Assessment Commission
SCI	Science Citation Index
SEO	Socioeconomic Objective (derived by ABS)
SPRU	Science Policy Research Unit, University of Sussex
TASC	Centre for Technology and Social Change
WCRP	World Climate Research Programme
WMO	World Meteorological Organisation

CHAPTER 1

INTRODUCTION

1.1 THE CONTEXT FOR AN EXAMINATION OF ENVIRONMENTAL RESEARCH

In the past decade, environmental awareness among Australians has increased to the point where land use conflicts have become election issues and the environment has become a well-publicised element of government policy at all levels.

Increased understanding of the Australian environment has caused scientists, land managers and governments to look more closely at the impact of our activities on the environment. The 1989 Statement on the Environment, *Our Country, Our Future* described the impact of the past 200 years since European settlement:

> "Soil erosion over much of the continent has risen to ten times the natural geological rate. Nearly two thirds of the continent requires treatment for land degradation. Forest cover, just 10 per cent when European settlement began, has been halved. More than 41 million hectares of forest have been destroyed, including 75 per cent of the nation's rainforests."[1]

The financial costs to Australia of environmental degradation are enormous. To lost productivity caused by land degradation can be added costs related to water treatment, land decontamination, river and harbour dredging, increased fertilizer use, air and water pollution and loss of visual attractiveness.[2]

The remedy for such problems need not imply a no-development scenario. Australia's clear commitment to environmental protection exists within the context of the economic and social aspirations of its citizens. Government recognises the fundamental links between economic growth, social well-being and environment protection and has embraced a policy of 'ecologically sustainable development', based on the principles of the National Conservation Strategy[3] and of the World Commission on Environment and Development.

Intelligent and informed decision-making about environmental management requires an understanding of the complex ecosystems upon which our productive capacity ultimately rests. Assessment of the likely long-term consequences of any particular short-term action requires accurate information on the nature and tolerance levels of environmental resources. Current knowledge about many of our ecosystems is either limited or fragmented. This situation has reduced our capacity to make informed natural resource management decisions, especially when assessing the relative impacts of different land use activity.[4]

1 The Hon R J L Hawke, AC MP, *Our Country, Our Future: Statement on the Environment*, AGPS, Canberra, July 1989.

2 Hawke, *Our Country, Our Future: Statement on the Environment.*

3 Department of Home Affairs and Environment, *A National Conservation Strategy for Australia*, 2nd edition, AGPS, Canberra, 1984.

4 Hawke, *Our Country, Our Future: Statement on the Environment.*

Australia's ability to resolve the spectrum of issues — economic, international trade, production efficiency, natural resources conservation, pollution control and quality of life — depends on our scientists, industrialists and policy makers having access not only to knowledge and technologies but to the skill and insight to apply them.

It was within this context that the Prime Minister commissioned ASTEC to undertake a comprehensive Study of Environmental Research in Australia.

1.2 DEFINING ENVIRONMENTAL RESEARCH

Research on the systems and resources which constitute the natural environment has been carried out in Australia for many years, but it has rarely been organised and classified as 'environmental research'. Rather, it has been classified according to a particular resource or within a scientific discipline reflecting the main motivations for such research; the development of natural resources and the advancement of basic science. Existing classifications also reflect the traditional discipline oriented organisation of the scientific workforce.

While segregation of 'environmental research' from other scientific and social research was essential to the present Study, arriving at a suitable definition of 'environmental research' proved difficult. Most users of the term 'environment' tend to define it very broadly, if at all. For example, the *Environment Protection (Impact of Proposals) Act 1974*[5] defines the environment as all aspects of the surroundings of mankind, whether affecting individuals or in social groupings.

For the purposes of the Study, ASTEC has defined environmental research as:

> *Scientific work undertaken to acquire and to organise knowledge of natural systems that sustain life in Australia. Such knowledge embraces characteristics of natural systems, any impacts of human actions upon them, and measures to mitigate adverse impacts.*

Such environmental research is undertaken with the aim of contributing to management to sustain our natural systems whereby the health of biological communities and their genetic diversity are maintained. Basic research in science underlying this aim is included.

Natural systems consist of natural resources, living and non-living, and their interactions. Natural resources are plants, animals, and micro-organisms, both terrestrial and aquatic, and the land, air and water on which they depend.

Environmental research thus includes the study of terrestrial and aquatic ecosystems; wildlife and habitat conservation; quality of the physical environment, such as clean air and waterways; and the sustainable use of our natural resources.

Australia includes the external territories, the Australian Fishing Zone, and the Australian Antarctic Territory.

5 *Environment Protection (Impact of Proposals) Act 1974* (Cwlth).

This 'all encompassing' definition does little to limit the field of inquiry to the natural environment as required by the Terms of Reference. However, the Commonwealth Government's 1989 Statement on the Environment was largely based on the objectives of the National Conservation Strategy for Australia (NCSA) which are "to maintain essential ecological processes and life-support systems, to preserve genetic diversity, and to ensure the sustainable utilisation of species and ecosystems".[6]

The NCSA is concerned with conservation of living resources and with the non-living elements of the environment on which they depend. It is generally agreed, however, that the environment is more than those individually, and more than their sum. Its essence is the interactions between living rganisms and the systems of which they are components. 'Environmental research' must also include that scientific research designed to provide information on which to base improved management and protection of the natural environment.

With the NCSA in mind ASTEC has chosen to construct distinct boundaries in its Study of Environmental Research in Australia. The focus is on scientific research related to the natural environment. Environmental research dealing with cultural and socioeconomic fields receives little attention in this Review. The decision to exclude such research was made to contain the field to be reviewed. It does not reflect upon the significance of such research, merely upon ASTEC's role as a primarily scientific body.

1.3 THE STRUCTURE OF THE STUDY

The first stage of the ASTEC Study is a Review of Environmental Research in Australia. This Review describes the organisation of environmental research, the sources of funding and research performance and provides some qualitative assessment of environment related research in Australia. The conclusions and recommendations in this Review relate only to these aspects of environmental research.

The second stage of the Study will address the more complex issues raised in the Terms of Reference such as the application of environmental research to resource use decision making and its effectiveness in contributing to the needs of national government policy development. The second stage will also examine strategies for government action to address deficiencies in research and the training effort needed to achieve this.

During the preparation of this Review, ASTEC constructed a database of environmental research projects in the form of a Compendium of Environmental Research in Progress in Australia in 1989. It is based largely on research- in-progress databases managed by CSIRO for a variety of client groups. The Compendium is not a comprehensive list of all environmental research. Rather, by reflecting the range of research both readily identifiable as 'environmental' and easily accessible to the researcher, the Compendium provides a useful cross-section of research activity from which ASTEC was able to draw some general conclusions.

6 *National Conservation Strategy for Australia.*

ASTEC recognises that the Compendium excludes work which is in fact environmental research either because it was overlooked by the survey process or because those carrying out the research saw it as being performed for another objective such as agricultural productivity and failed to include it.

The Compendium has been published, in a limited edition, as a companion volume to this Review.[7] The maintenance of the database which forms the basis of the Compendium is not an appropriate activity for ASTEC. Discussions between the Departments of Primary Industries and Energy and the Arts, Sport, the Environment, Tourism and Territories together with the CSIRO and the data owners will address the most effective future role of the database.

1.4 ORGANISATION OF THIS REVIEW

Because there is no single source of information on environmental research a range of approaches has been taken with the intention of compiling as complete a picture as possible.

Chapter 2 explains in more detail the approach taken and describes and comments on the various data sources used.

Chapter 3 identifies funding sources for Australian environmental research, based on the Australian Bureau of Statistics (ABS) research and experimental development data compiled for the Review. Chapter 4 describes in more detail the organisation and performance of that research. The information in Chapter 4 is based on a much broader range of sources than Chapter 3 and these are identified at the beginning of each section.

While ABS statistics provide information about expenditure and human resources they do not reflect qualitative performance in a field of science nor the perceptions of researchers about their area of interest. This aspect of environmental research has been addressed in Chapter 5.

Chapter 6 details the essential elements of environmental research in Australia and highlights issues of concern or importance. Recommendations have been made about methods of data collection, classification systems and integration of data.

Chapter 7 provides a link between this preparatory Review and the second stage of the Study which will address issues of significance for the use of environmental research information in decision making in Australia.

[7] The Australian Science and Technology Council, *Environmental Research in Australia — A Compendium*, AGPS, Canberra, 1990.

CHAPTER 2

METHODOLOGY AND DATA SOURCES

2.1 METHODOLOGY

One of the challenges in conducting the Review has been the diversity of definitions of 'environmental research' used by institutions and organisations and the consequent incompatibility of data. In most cases the objectives of the collecting body have been quite different from those of ASTEC. For instance, in some classifications a category called 'environmental science' may only include pollution control research while natural resource related research is included under a category of biological or life sciences. It is common to find that an institution or organisation conducting research with environmental implications does not necessarily describe it as 'environmental science'.

ASTEC decided that it should use the data which best reflect the existing state of environmental research while ensuring that problems arising from comparisons between different data sets are clearly identified. The major sources of data used in this Review are:

- a survey of a range of existing on-line research in progress databases using ASTEC's definition of environmental research;
- ASTEC's 1989 publication, *Profile of Australian Science;*[1]
- Australian Research Council and National Energy Research, Development and Demonstration Council statistics on research funding;
- Australian Bureau of Statistics data on human resource and financial expenditure on environmental research and development; and
- statistics collected by the Department of Employment, Education and Training on tertiary enrolments and staff numbers.

These data sources and their strengths and weaknesses are described in more detail below. Information gleaned from these sources has been augmented by discussions with a broad range of environmental research practitioners and users (Appendix II.A), and the opinions expressed by more than 80 submissions from tertiary institutions, government agencies and private individuals in response to an advertisement placed in the national daily newspapers.

The information thus generated has been used to assess the nature and organisation of environmental research in Australia, and to draw some preliminary conclusions about its strengths and weaknesses. ASTEC expects additional information and views to emerge through the consultation and analysis process of the second stage of the Study.

1 Australian Science and Technology Council, *Profile of Australian Science: a study of the current state and potential of basic scientific research*, AGPS, Canberra, 1989.

2.2 PROFILE OF AUSTRALIAN SCIENCE

To arrive at some quantitative and qualitative indication of the output of Australian environmental research, bibliometric data and conclusions from the 1989 ASTEC publication, *Profile of Australian Science*[2] were reviewed. *Profile of Australian Science* describes basic research in the major fields of science.

Bibliometric indicators of research performance measure quantitative output through an assessment of the number of papers a researcher has published. They also measure qualitative impact by citation, or the frequency with which other researchers refer to a particular piece of published research. Bibliometrics is based on the assumption that if research is published in internationally refereed journals then it is subject to peer review and to that extent is of world recognised quality.

One limitation to bibliometrics doing what it does best, that is, showing trends in well-defined areas of basic research, is the dated view it can give. This is most pronounced when attempting to show the impact of research through citation or co-citation. The journal set on which CHI (Computer Horizons Inc) bases its citation analysis remained constant over the years 1973–84. This includes research done as much as 17 years ago but does not include the emergence of new journals or journals generated by new areas of science. With the environment having a much higher profile in the recent years it would be reasonable to assume that new journals have emerged. These would not necessarily be included in the Science Citation Index (SCI) or, as a consequence, in CHI. (A diagrammatic explanation of relationships between SCI and CHI is at Appendix II.B).

Another limitation to bibliometrics, at least in the Australian context, is the very small numbers on which percentages are often based. A 50 per cent increase in citation rate means little when starting, as is sometimes the case, from a single digit number.

Environmental research tends to be a multi-disciplinary activity which draws on the traditional sciences across a range of disciplines for particular applications. High quality basic science is necessary for the applied environmental research that ultimately follows. It is this basic science which is most amenable to analysis by bibliometric methods.

The analysis done for *Profile of Australian Science* in 1989 adequately covers the fields of study that contain the basic science relevant to environmental research. Of the fields examined, those of Biology and the Earth component of the Earth and Space Science field contain a high percentage of environment related research. Chemistry is clearly an important area and it may have been useful to include this field. The difficulty here lies in the small percentage of the total that is relevant to environmental research and how use of the whole field could distort our analysis. On this basis ASTEC decided to exclude the Chemistry field.

Profile of Australian Science concerns itself only with basic research. While an assessment of basic research is fundamentally important to a review of environmental research it must be remembered that much of the research into the nature and protection of our environment is applied research.

2 Australian Science and Technology Council, *Profile of Australian Science*.

2.3 THE COMPENDIUM OF ENVIRONMENTAL RESEARCH IN PROGRESS IN AUSTRALIA

Since the nature and extent of environmental research in Australia was largely unknown at the beginning of this Review a survey of existing environmental research activity appeared to be an appropriate first step. Thus, a Compendium of Environmental Research in progress was produced, listing the readily identifiable and easily accessible environmental research projects currently being carried out in Australia.

CSIRO AUSTRALIS[3] provides access to a collection of on-line databases containing information on research in progress in a number of areas. The databases are Australian in focus and include the natural, physical and social sciences. The research projects included in these databases are undertaken by disparate bodies, for varying purposes, and range across many academic disciplines. However, most of the databases on AUSTRALIS do contain some information relating to environmental protection or management. Many are supported cooperatively by Commonwealth and State government agencies and industry bodies.

ASTEC, using its definition of environmental research, was able to identify 2017 environmental research Projects in the following databases:

Rural Research in Progress	515
Energy Research in Progress	112
Australian Road Research Board	8
Marine Research in Progress	723
STREAMLINE (Water research in progress)	524
Australian Antarctic Research in Progress	80
Australian National Parks and Wildlife Service	55

Detailed descriptions of these databases are provided at Appendix II.C. This listing of environmental research in progress comprised the first stage in preparing the Compendium.

A second stage of data collection involved collaboration with the Bureau of Rural Resources in a survey of over 90 organisations (see Appendix II.D). Together with project data from supplementary sources, the entries for these projects were combined into a database of environmental research in progress. This second stage survey elicited 146 additional projects not in existing databases.

Once located, the projects were classified into one of the following categories based largely on the State of the Environment Report 1986:[4]

1. Open ocean
2. Marine coastal region
3. Land coastal region
4. Forests and woodlands
5. Inland waters
6. Land in general
7. Flora and fauna
8. Atmosphere

3 CSIRO AUSTRALIS is an on-line information retrieval service offered by CSIRO.

4 Department of Arts, Heritage and Environment, *State of the Environment in Australia 1986*, AGPS, 1987.

9. Antarctica
10. Miscellaneous

Inclusion of projects in the ASTEC environmental research database was made subjectively by ASTEC and the organisations surveyed.

The current method used by database managers to collect data does not seek information about resource commitment, expenditure or source of funds. The data which can be generated from AUSTRALIS do not reflect the size or importance of individual projects and therefore creates a skewed profile of environmental research based only on weight of numbers. The Compendium only provides information on who is doing research and on what, not on funding or on effort expended in performance. A summary of projects contained in the Compendium and their sources is contained in Appendix II.E.

2.4 AUSTRALIAN BUREAU OF STATISTICS RESEARCH AND EXPERIMENTAL DEVELOPMENT STATISTICS

ASTEC sought the assistance of the Australian Bureau of Statistics (ABS) in collecting statistical data about environmental research funding and performance in Australia.

The Australian Bureau of Statistics regularly collects data on Australian research and experimental development (R&D) which has as its primary objective the acquisition of new knowledge, with or without a specific practical application or new or improved materials, products, devices, processes or services.[5] Research and experimental development expenditure includes capital expenditure on acquisition of fixed tangible assets and current expenditure on wages, materials, maintenance, data processing and an appropriate proportion of general overheads.

The human resources measured are those devoted directly to R&D activity — for example, researchers, technicians and other staff. Actual expenditure on research is derived by a survey of the time spent on research by staff.

The data are organised by sector of performance, funding sector and by socioeconomic objective for government, higher education and private non-profit groupings. The non-profit sector includes private or semi-public incorporated organisations which are established with the intention of not making a profit.[6] The ABS has included local government organisations in the funding data but excluded them from the expenditure data because their contribution to R&D activity is considered to be minimal. Business sector data are organised by industry of enterprise or product of research rather than by socioeconomic objective, which precludes any meaningful extraction of information on industry activity in environmental research.

Easily accessible data at this level were available only for the financial years 1984–85 and 1986–87, data before then being too difficult to retrieve to the new ABS computer system. The 1988–89 data were not available before the conclusion of this report.

5 Australian Bureau of Statistics, *1986–87 Research and Experimental Development: General Government and Private Non-Profit Organisations Australia*, Cat. No. 8109.0, 1988.

6 Australian Bureau of Statistics, Cat. No. 8109.0, 1988.

To facilitate comparative analyses, ABS data on environmental R&D for 1984–85 and 1986–87 are shown at average 1986–87 prices throughout this Review. Average 1986–87 dollars were calculated using implicit price deflators supplied by ABS.

Research and development statistics are classified by socioeconomic objective (SEO) and by field of science (FOS). Socioeconomic objectives refer to the principal areas of expected national benefit rather than to the immediate objectives of the researcher. Fields of science refer to the fields in which the R&D activity was performed rather than the fields used in the research program. It is possible to allocate research to several SEOs or FOSs at any one time and for the research to be classified according to the percentage splits.

The ABS collects R&D data by socioeconomic objective every two years. Respondents to ABS R&D surveys ascribe their activities to a hierarchical arrangement of categories or levels within specified socioeconomic objectives. Although normally collected down to the third level in this hierarchy, ABS data is published at the more aggregated first and second levels. The third level data are available from ABS on a commission basis.

For specific purposes ABS has developed fourth level categories for particular SEO areas. This has happened in response to government requirements related to policy development. For instance, the 1984–85 and 1986–87 ABS R&D surveys include fourth level categories for the Energy socioeconomic objective.

Although it is possible to extract data on research performance at the third level the fourth level would provide the most useful indication of R&D actually performed in Australia. This is particularly true of an area like environmental research. A diagrammatic explanation of the relationship between the levels of categories of ABS data collection is at Appendix II.F.

ASTEC used SEO statistics, in preference to FOS, because they give a more useful overview of scientific research likely to be done for the environment. In addition, SEOs can be broken down into sub-categories which enable more detailed identification of environmental research.

In consultation with ABS, ASTEC selected a set of SEOs which it considered to best reflect environmental research. These are described in some detail in Chapter 4. This SEO set is not exhaustive, does not always accord with reality, and did not reflect ASTEC's analytical requirements as a user of the data. SEOs could be improved in several ways to describe environmental research and development more accurately and to better meet user analytical needs. ABS, in consultation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and other interested agencies (including ASTEC itself), is currently undertaking a review of its statistical classification system, including SEOs, to present a more precise picture of, amongst other things, environmental research.

2.5 COMPETITIVE GRANTS FOR ENVIRONMENTAL RESEARCH

To supplement the ABS statistics, which give a general picture, ASTEC sought information from the Australia Research Council (ARC), the Department of Primary Industries and Energy and the Department of Industry, Technology and Commerce about the funding of environmental research through competitive grant schemes.

The Australian Research Council (ARC) is one of Australia's major sources of funding for academic research. The ARC's mission is to "devise, develop and help to implement an effective national research system, especially in the higher education sector, which will make the greatest possible contribution to the social, cultural and economic well-being of Australia." The ARC Grants Scheme supports high quality research by individuals or research teams throughout Australia. Grants have in the past gone predominantly to academic institutions. The four ARC panels, Biomedical, Biological and Veterinary Sciences; Engineering, Earth and Applied Sciences; Social Sciences and Humanities and Physical, Mathematical and Chemical Sciences are not focused on environmental research as a definitive area, but environmental research is funded and it is possible to gain an impression of the relative funding of such areas over a ten year period.

The analysis in this Review is restricted to grants provided by the Australian Research Council (ARC) through its Grants Scheme, which incorporated the Australian Research Grants Scheme (ARGS) and the Marine Sciences and Technologies Grants Scheme (MSTGS) in July 1988. The first formal year of ARC grants was 1989.

When interpreting the statistics derived from the ARGS it should be noted that State or Commonwealth research organisations (such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Institute of Marine Science (AIMS), the Australian Nuclear Science and Technology Organisation (ANSTO) and the Bureau of Mineral Resources, Geology and Geophysics (BMR) and the Australian National University's Institute of Advanced Studies, were not eligible to apply for grants. With the establishment of the ARC this situation has changed.

Effective from 1989, these research organisations, while still not eligible for a grant in their own right, can be a party to collaborative projects as joint chief investigators, one of whom must be from an eligible higher education institution which receives the grant. Such projects must be truly collaborative, with the publicly funded research organisation making an equivalent contribution of resources and lending equal weight to the common endeavour.

The ARC data used in this Review are approximate. They have been developed from the various subject categories used by the ARGS (and modified by the ARC) which most closely relate to environmental research. Grants disbursed through the MSTGS are all assumed to relate to environmental research. MSTGS grants before 1985 were expressed in financial years and have been averaged to conform with the calendar year format of the ARC grants.

The ARC, ARGS and MSTGS data on environmental R&D for 1980 to 1989 are shown at average 1989 prices. Average 1989 dollars were calculated using unpublished implicit price deflators supplied by ABS.

The National Energy Research, Development and Demonstration Council (NERDDC) aims to encourage increasingly efficient use of energy resources, to influence the level and direction of energy research, development and demonstration and to facilitate the efficient use of all energy forms in Australia.[7] It does this through the National Energy Research, Development and Demonstration (NERD&D) Program.

Grants are available to all sectors of the energy research and development community, including universities, industry and government research organisations such as the CSIRO.

The NERD&D Program is jointly funded by the Commonwealth Government and a levy on the coal industry. The allocation of projects to the environmental research category used in this Review is NERDDC's own and based on its perception of what constitutes environmental research. Environmental research makes up a small but significant proportion of the projects supported. Statistics are available from 1978 but for consistency with ARC data only those from 1980 onwards are used in this Review.

The NERD&D Program data on environmental R&D for 1980 to 1989 are shown at average 1989 prices. Average 1989 dollars were calculated using unpublished implicit price deflators supplied by ABS.

The Grants to Industry Research & Development (GIRD) Scheme, administered by the Department of Industry, Technology and Commerce (DITAC), provides discretionary funds of up to 50 per cent of expenditure on research and development projects. GIRD funds are available to those enterprises not able to take advantage of the 150 per cent tax concession introduced by the Commonwealth Government for industry research and development. The tax concession applies to expenditure on basic and applied research and experimental development from 1 July 1985 to 30 June 1993. More than 2500 companies registered for these concessions in 1986–87.[8]

Statistics which would make it possible to compare relative funding of environmental research are not collected in regard to either of these schemes although it must be assumed that some research related to the environment is funded in this way.

For the same reason it has not been possible to use statistics relating to the Rural Industries Research Funds. These Funds are made up of industry levies for 'commodity' research collected by the Department of Primary Industries and Energy and transferred to trust accounts for research and support purposes. The Commonwealth matches half the expenditure from a trust fund up to the level of industry contributions. There is an increasing trend toward the establishment of research and development corporations along the lines of the Wool Research and Development Corporation to undertake this type of research activity.

7 Department of Primary Industries and Energy, *Annual Report 1988–89*, AGPS, Canberra, 1989.

8 Ronanyne, J, Boag, C, *Science and Technology in Australia, Antarctica and the Pacific Islands*, Longman Guide to World Science and Technology Series, Longman, UK, 1989.

It should be noted, however, that while it is difficult to estimate funds specifically allocated to environmental research, many of the individual environmental research projects supported by both the energy and rural research programs will have been included in *Environmental Research in Australia — A Compendium* described at Section 2.3.

2.6 INDUSTRY SURVEY

Because ABS industry R&D statistics are not collected by socioeconomic objective they are not amenable to extraction of information on industry environmental research activity. Furthermore, it is difficult for industry to differentiate between research and experimental development, and product development in a way which would allow useful comparisons with public sector data. Another constraint on collection of truly representative statistics is the commercial-in-confidence nature of much industry R&D.

ASTEC used two different mechanisms to obtain data on environmental research in the private sector. A paper was commissioned by an expert in the area and a survey of industry was conducted.

Professor Ralf Buckley of Bond University was commissioned to prepare a paper on private sector environmental research and much of Section 4.5 is based on this. This paper did not attempt to identify actual research undertaken by industry.

In an attempt to supplement this paper the Working Party surveyed 90 major industries selected from *Scientific and Technical Research Centres in Australia*, compiled by the Information Services Unit of CSIRO,[9] seeking examples of identifiable environmental research (see Appendix II.G). The response rate was little more than 23 per cent, which is not unacceptable for broadcast surveys. It has been possible to use the returns from this survey to gain some idea of what industry considers environmental research.

2.7 DEPARTMENT OF EMPLOYMENT, EDUCATION AND TRAINING STATISTICS

Directories of Higher Education have been produced for some years. A comparison of such Directories over the last decade gives some impression of the development of 'environmental studies' as a field of tertiary study.

The Directories were used to identify appropriate tertiary institutions from which to seek student enrolment and staff employment data from the Department of Employment, Education and Training (DEET) statistical collection.

ASTEC was able to obtain 1987–89 data for each institution for the following:

- total number of postgraduate students enroled in courses leading to environmental and natural resources qualifications;

[9] Ermers, A., (ed), *Scientific and Technical Research Centres in Australia*, Information Services Unit, CSIRO, 9th edition, 1988.

- total number of research staff employed in environmental studies.

These statistics do not tell us whether graduates are finding employment in their field.

2.8 SOLICITED SUBMISSIONS

ASTEC advertised nationally for submissions to the Review of Environmental Research. In addition, ASTEC approached State and Territory Governments seeking advice on their role as performers of environmental research. In all 83 submissions (listed at Appendix II.H) were received from:

- Commonwealth Government Organisations (10)
- State Governments and Organisations (17)
- Higher Education Sector (30)
- Industry (5)
- Private Individuals (28)

These submissions contributed toward preparation of Chapter 5 of this Review. Where correspondents addressed themselves to the major issues which will be the focus of the second phase of the Study they will find their concerns considered more fully in *Environmental Research in Australia — The Issues.*

2.9 INTERNATIONAL COMPARISONS OF AUSTRALIAN GOVERNMENT FUNDING FOR ACADEMIC AND RELATED RESEARCH

An examination of international research funding would enable comparisons to be made about the relative funding for environmental research in Australia and other countries.

One possible source of statistics from which to make international comparisons of government funding of research is the R&D data collected by the Organisation for Economic Cooperation and Development (OECD) from its 21 member countries. There are, however, a number of problems with OECD data.

Definitions vary widely from country to country, making it difficult to compare performing sectors where the definition of a 'university' and the demarcation between the public and private sector are not consistent.

More importantly, from the point of view of this Review, are the limitations imposed by the highly aggregated nature of OECD data, which differentiate only between agriculture, natural sciences, engineering, medicine, social sciences and humanities. Unless it is assumed that all R&D performed in the natural sciences is environment related, and no research with such a focus is carried out in the other fields, the available data will do little to increase our understanding of the funding and performance of environmental research.

A recent study carried out by ASTEC[10] goes some way to addressing the inherent problems of OECD data. The study produced figures on Australian funding of academic and related research comparable with those of six other developed countries – the United Kingdom, West Germany, France, the Netherlands, USA and Japan – published by Irvine et al of the Science Policy Research Unit (SPRU), University of Sussex.[11]

Only academic and related research funding is considered in the Irvine study. Private-sector finance for academic research is excluded entirely. This makes it difficult to interpret the results of the Irvine study in a manner relevant to the broader purposes of this Review.

In addition, the Irvine study does not attempt to compare expenditure on research that is not of an academically related nature. For example, R&D in mission-oriented government laboratories like those operated in many countries by Ministries of Industry or Agriculture is not included. This means that much of CSIRO expenditure, a major component of Australian environmental research expenditure, is necessarily excluded from consideration.

The base level at which the Irvine data were collected prevent the construction of an environmental category which is consistent with the definition of environmental research developed for this Study. Use of the extant environmental category, based on a narrow definition of environmental research would be misleading.

ASTEC is also mindful of the constraints in interpreting statistics and making comparisons between Australia and other developed countries given their very different economic bases. A comparison with Canada would have been more appropriate, because of its similar economic and political structure. Unfortunately, the necessary statistics were not available at the time of preparation of this Review.

ASTEC decided therefore not to present or analyse data from either the OECD or Irvine's work in this Study.

10 Australian Science and Technology Council, *Government Funding of Academic and Related Research in Australia: An international comparison*, AGPS, Canberra, 1990.

11 Irvine, J, Martin, BR, and Isard, PA, *Investing in the Future: An International Comparison of Government Funding of Academic and Related Research*, Edward Elgar Publishing, Aldershot, 1990.

CHAPTER 3

FUNDING OF ENVIRONMENTAL RESEARCH

3.1 INTRODUCTION

The analysis of environmental research in this Chapter is based on detailed statistics supplied by the Australian Bureau of Statistics (ABS) for 1984–85 and 1986–87. However, these statistics are not comprehensive since they only provide a partial picture of private sector funding of environmental research.

Because ABS data for industry R&D are collected by industry of enterprise or for a particular product or process, it is not possible to directly extract information on environmental research. The data which are available are derived from figures on private sector funding of environmental research performed only by Commonwealth, State, higher education and private non-profit organisations.

In this Chapter, source of funds is defined as the original source of funds for environmental research, as opposed to the expenditure incurred by an organisation in performing that research. Expenditure on the performance of environmental research is addressed in Chapter 4.

3.2 NATIONAL OVERVIEW

3.2.1 Funding Sources

Funding sources for environmental research in Australia are varied. ABS data identify seven distinct funding sources as shown in Tables 3.1, 3.2 and Appendix IIIA, and Figures 3.1 and 3.2. These are:

i) Commonwealth government organisations;
ii) State and local government organisations;
iii) private business enterprises;
iv) public business enterprises;
v) higher education institutions;
vi) private non-profit and other Australian organisations; and
vii) overseas sources.

Tables 3.1 and 3.2 show that total funding for environmental R&D was $213.5 million (1985–86 dollars) in 1984–85 and $222.7 million in 1986–87. This is a 4.2 per cent increase from 1984–85 to 1986–87.

For 1986–87, the year for which the most recent data are available, the major funder was the Commonwealth Government, which accounted for $187.3 million or 84.1

Table 3.1 Environmental research by socioeconomic objective by source of funds for 1984–85 ($'000 1986–87 dollars).

Commonwealth	Local	State and Enterprises	Business	Other			Total	% of Total
				Higher Education	Private Non-Profit	Overseas		
ENVIRONMENT PROTECTION								
air pollution	2268	194	64	—	75	14	2614	1.22%
water pollution	9799	1509	193	46	169	10	11726	5.49%
other pollution	562	—	—	—	11	—	573	0.27%
other environment: natural	21866	10302	176	1	157	252	32754	15.34%
other environment: human	40	145	—	—	2	—	187	0.09%
other environment	6985	244	310	—	97	35	7671	3.59%
Total	**41519**	**12394**	**742**	**48**	**512**	**311**	**55526**	**26.01%**
ADVANCEMENT OF KNOWLEDGE								
earth	41858	3380	639	—	380	239	46496	21.78%
ocean	27008	239	161	—	54	58	27520	12.89%
atmosphere	23262	27	56	—	30	22	23397	10.96%
remote sensing	2075	91	25	—	12	16	2219	1.04%
soils	16451	13938	613	—	191	8	31202	14.62%
Total	**110654**	**17676**	**1495**	**—**	**666**	**344**	**130835**	**61.28%**
MINING AND ENERGY								
Production & utilisation of energy								
Environment protection								
oil & gas	937	5	8	—	3	—	953	0.45%
oil shale & tar sands	1127	5	2	—	3	—	1137	0.53%
coal	2924	56	50	—	21	—	3051	1.43%
Total	**4988**	**65**	**61**	**—**	**28**	**—**	**5142**	**2.41%**

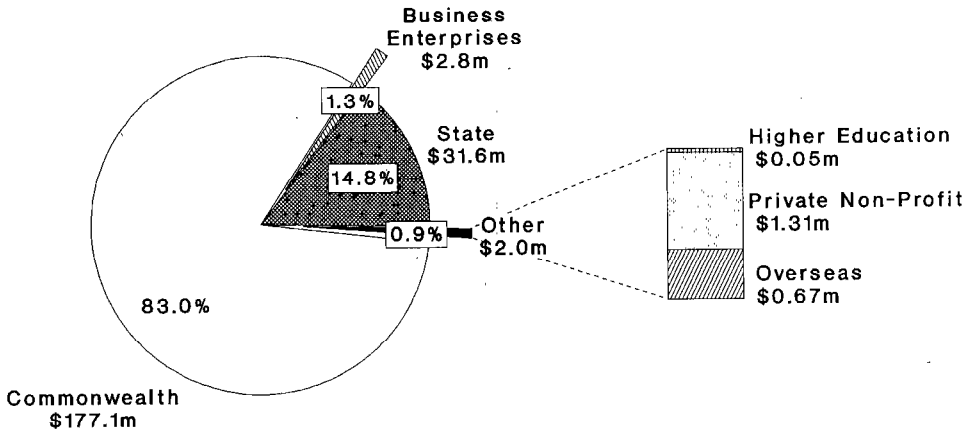
Conservation of energy								
industry	6452	50	67	—	54	1	6624	3.10%
residential & commercial	1135	1295	68	—	23	—	2521	1.18%
transportation	2468	25	142	—	10	10	2656	1.24%
other (eg waste recycling)	189	54	8	—	5	1	257	0.12%
Total	**10243**	**1424**	**285**	**—**	**93**	**13**	**12058**	**5.65%**
Mining of energy minerals								
Environment protection								
uranium	9181	2	—	—	2	—	9191	4.31%
coal	497	23	176	—	5	1	701	0.33%
oil & gas	30	—	1	—	5	—	36	0.02%
oil shale & tar sands	—	—	—	—	—	—	—	0.00%
Total	**9707**	**25**	**183**	**—**	**12**	**1**	**9928**	**4.65%**
Total	**24938**	**1515**	**529**	**—**	**132**	**14**	**27128**	**12.71%**
TOTAL	**177112**	**31584**	**2765**	**48**	**1310**	**669**	**213488**	**100.00%**

Table 3.2 Environmental research by socioeconomic objective by source of funds for 1986–87. ($'000 1986–87 dollars)

	Commonwealth	State and Local	Business Enterprises	Other			Total	% of Total
				Higher Education	Private Non-Profit	Overseas		
ENVIRONMENT PROTECTION								
air pollution	1964	92	74	—	14	9	2153	0.97%
water pollution	10823	2917	503	—	65	28	14336	6.44%
other pollution	4572	45	—	—	—	—	4617	2.07%
other environment: natural	20223	7418	408	—	335	79	28463	12.78%
other environment: human	10	187	—	—	—	—	197	0.09%
other environment	9955	298	191	—	133	26	10603	4.76%
Total	**47547**	**10957**	**1176**	**—**	**547**	**142**	**60369**	**27.10%**
ADVANCEMENT OF KNOWLEDGE								
earth	48873	1631	406	—	215	269	51394	23.07%
ocean	30727	591	175	—	125	61	31679	14.22%
atmosphere	18264	73	122	7	34	174	18674	8.38%
remote sensing	3714	491	64	5	37	22	4333	1.95%
soils	15124	15375	455	—	230	22	31206	14.01%
Total	**116702**	**18161**	**1222**	**12**	**641**	**548**	**137286**	**61.64%**
MINING AND ENERGY								
Production & utilisation of energy								
Environment Protection								
oil & gas	1502	16	33	—	11	2	1564	0.70%
oil shale & tar sands	692	8	10	—	—	—	710	0.32%
coal	3830	292	138	—	15	22	4297	1.93%
Total	**6024**	**316**	**181**	**—**	**26**	**24**	**6571**	**2.95%**

Conservation of energy								
industry	6135	113	139	—	62	28	6477	2.91%
residential & commercial	930	292	18	—	127	—	1367	0.61%
transportation	1091	72	84	—	12	1	1260	0.57%
other (eg waste recycling)	161	10	18	—	26	—	215	0.10%
Total	**8317**	**487**	**259**	**—**	**227**	**29**	**9319**	**4.18%**
Mining of energy minerals								
Environment Protection								
uranium	7894	—	2	—	3	—	7899	3.55%
coal	474	296	28	—	8	—	806	0.36%
oil & gas	265	1	86	—	1	—	353	0.16%
oil shale & tar sands	123	—	—	—	—	—	123	0.06%
Total	**8756**	**297**	**116**	**—**	**12**	**—**	**9181**	**4.12%**
Total	**23097**	**1100**	**556**	**—**	**265**	**53**	**25071**	**11.26%**
TOTAL	**187346**	**30218**	**2954**	**12**	**1453**	**743**	**222726**	**100.00%**

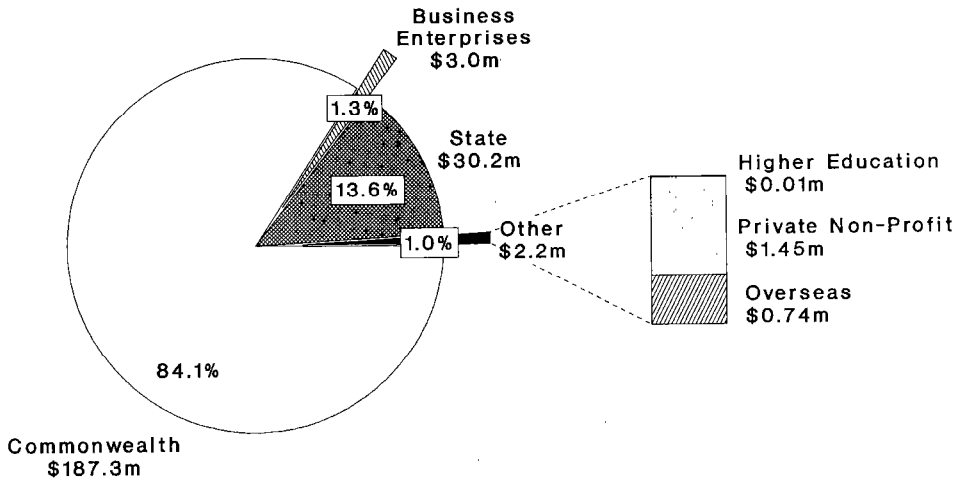
Figure 3.1 Environmental research by source of funds for 1984–85 $ million (1986–87 dollars)



Total environmental research: $213.5 million

Source: ABS data commissioned by ASTEC

Figure 3.2 Environmental research by source of funds for 1986–87 $ million (1986–87 dollars)



Total environmental research: $222.7 million

Source: ABS data commissioned by ASTEC

per cent of total funds ($222.7 million) for environmental research (Figure 3.2 and Table 3.2). State and local governments provided $30.2 million or 13.6 per cent of total funds. The remaining $5.2 million or 2.3 per cent of environmental research funds for 1986–87 were sourced from business enterprises, private non-profit organisations, overseas sources and higher education institutions.

It is important to point out that the $3.0 million sourced from business enterprises (Table 3.2) is a measure only of environmental research funded by business enterprises but undertaken by Commonwealth and State governments, higher education and private non-profit organisations. Environmental research funded by and undertaken by business enterprises themselves cannot be extracted from ABS data (see Chapter 2.6). The data on business enterprises can be divided into private and public for Commonwealth, State and private non-profit organisations. However, a complete breakdown into the private and public components is not possible because data supplied by the higher education sector is not available at this level of detail.

Funds from private non-profit and overseas sources are small, but readily identifiable: $1.45 million and $0.47 million respectively for 1986 and 1987 (Figure 3.2 and Table 3.2).

The higher education sector is also listed as a source of funds, $0.01 million in 1986–87. These funds are generally contributed by higher education institutions to joint projects with Commonwealth and private non-profit organisations.

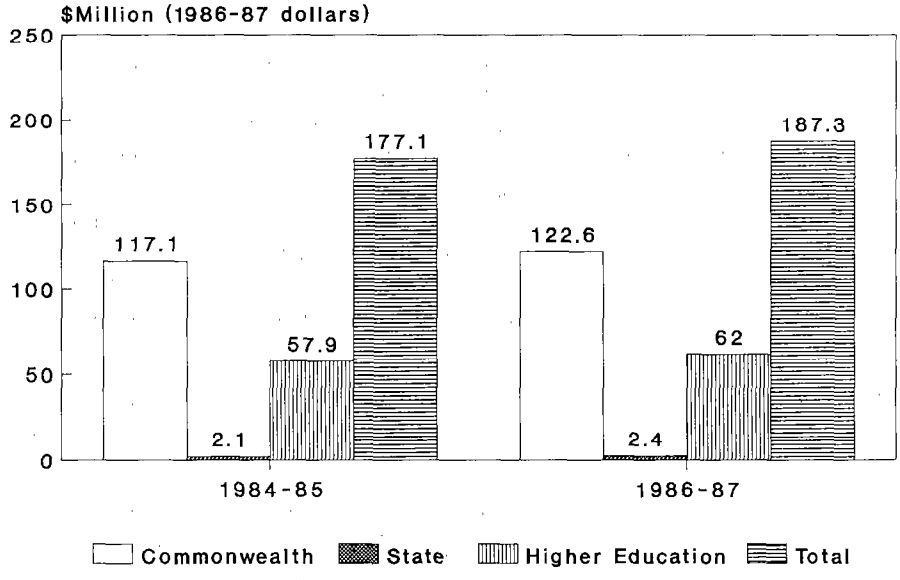
A comparison of total funds for environmental research between 1984–85 and 1986–87, using 1986–87 dollars, reveals minor changes to the proportions of funds derived from the various sources (Figures 3.1 and 3.2). As a percentage of total funds, the Commonwealth Government's share has increased by about 1 per cent from $177.1 million to $187.3 million. There has been a corresponding decrease in the State and local government's share from $31.6 million to $30.2 million. The ABS assumes that local government organisations provide funds for environmental research, but does not distinguish between their contribution and that of State government organisations. The proportion of the total funds for environmental research contributed by the other funding sources have remained virtually unchanged.

When the funding sources are compared with each other, it is clear that the greatest changes have occurred in the government sector (Figures 3.1 and 3.2). Since 1984–85, Commonwealth government funds have increased by 5.8 per cent ($10.2 million) and State and local government funds have fallen by 8.1 per cent ($1.4 million). Over the same time period, total funds from business enterprises, private non-profit and overseas sources have increased by about $0.4 million. Individual increases are 6.8 per cent for business enterprises, 10.9 per cent for private non-profit organisations and 11.2 per cent for overseas sources.

3.2.2 Distribution of funds

Figure 3.3 indicates the distribution of Commonwealth funding for environmental research in 1984–85 and 1986–87. The majority of the funds are provided directly to Commonwealth organisations (65 per cent of the total in 1986–87) followed by higher education institutions, which received 33 per cent of the total funds in 1986–87. Only

Figure 3.3 Distribution of Commonwealth environmental research funds 1984–85 and 1986–87



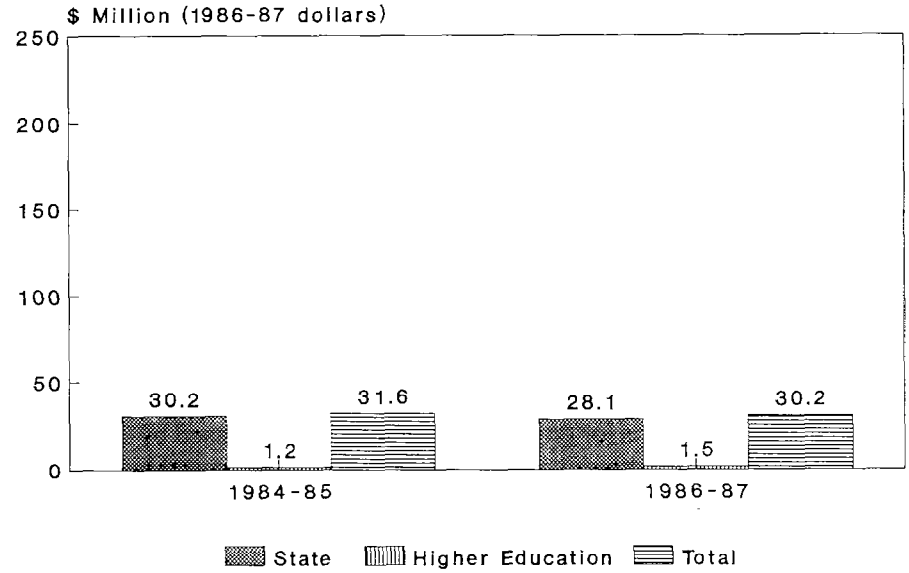
Source: ABS data commissioned by ASTEC

Private Non-Profit data too low to include

2 per cent of the Commonwealth funds were provided to State and private non-profit organisations. The relative distribution of funds amongst Commonwealth, State and higher education organisations for 1986–87 has not altered significantly since 1984–85. However, Commonwealth funds provided to private non- profit organisations have increased almost 80 fold to $0.319 million since 1984–85, but from an extremely low level.

State government organisations receive the bulk of State and local government funds dedicated to environmental research (Figure 3.4). In 1986–87, only 7 per cent of the total State and local government funds were allocated to Commonwealth, higher education and private non- profit organisations. Ninety-three per cent were received directly by State government organisations. Funds received by State government organisations fell from $30.2 million to $28.1 million between 1984–85 and 1986–87. The proportions of total funds allocated to Commonwealth, higher education and private non-profit organisations have increased slightly from very low levels since 1984–85.

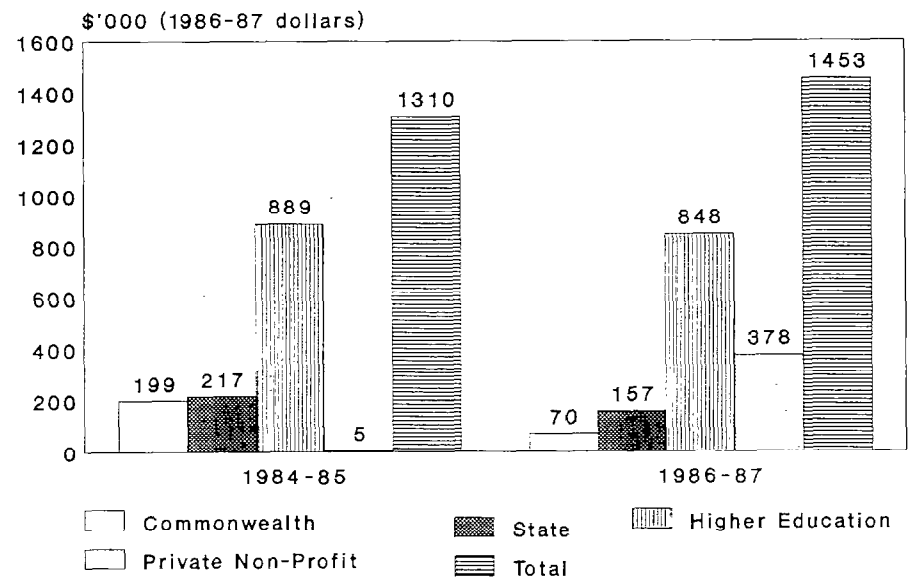
Figure 3.4 Distribution of State environmental research funds — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

Commonwealth and Private Non-Profit data too low to include

Figure 3.5 Distribution of Private Non-Profit environmental research funds — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

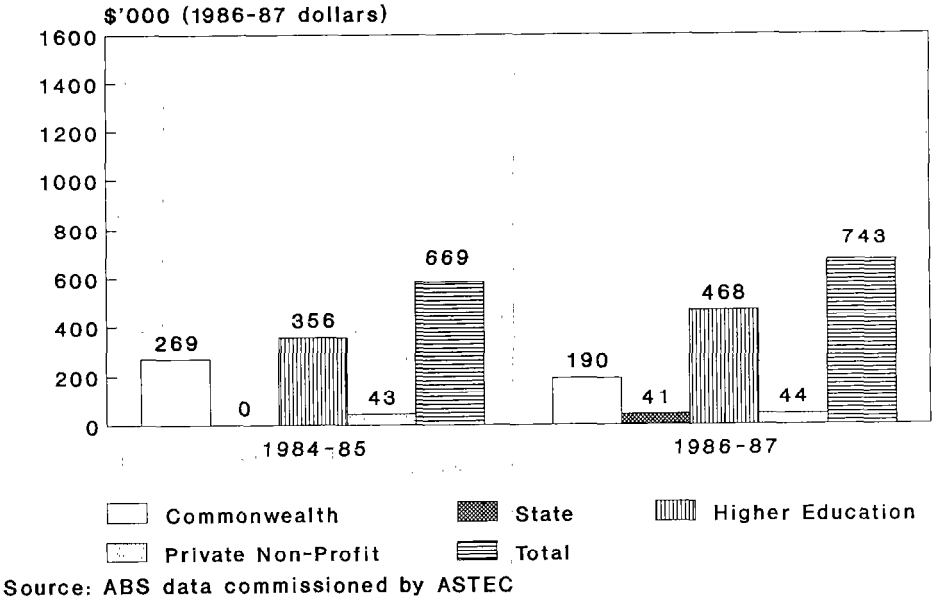
Tables 3.1 and 3.2 show the distribution of the very low level of higher education funding for environmental research for 1984–85 and 1986–87. It is difficult to attach any importance to the apparent changes in fund distribution between the two years because the funding is so low, $0.05 million in 1984-85 and $0.01 million in 1986–87. Furthermore, the changes may merely reflect the subjectivity of respondents to ABS R&D surveys in selecting a funding category to describe the higher education component of joint research projects.

Most of the private non-profit sector's funds for environmental research are received by higher education institutions (Figure 3.5). This is true for both 1984–85 and 1986–87. The private non-profit sector has increased the use of its own funds for environmental research substantially since 1984–85. Funds provided to Commonwealth and State government organisations have decreased.

Funds from overseas sources are distributed predominantly to higher education institutions, and to a lesser extent to Commonwealth government organisations (Figure 3.6). From 1984–85 to 1986–87, funds from overseas sources allocated to higher education institutions for environmental research increased by 30 per cent and funds for Commonwealth government organisations decreased by the same percentage. State government organisations, which reported no funds for environmental research in 1984–85, obtained funds in 1986–87.

An analysis of funds for environmental research sourced from private and public business enterprises would have been of interest, but is precluded by the lack of detail available fromhigher education institutions. A comparison of Figures 3.1 and 3.2 shows that overall funds from business enterprises (as defined in Section 3.2.1) for environmental research have increased marginally between 1984–85 and 1986–87.

Figure 3.6 Distribution of Overseas environmental research funds — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

3.2.3 Mechanisms for distributing funds

As mentioned above, 98 per cent of Commonwealth funds for environmental research is received by Commonwealth government organisations and higher education institutions. These funds are provided by direct budget appropriation to Commonwealth research agencies, by operating grants to higher education institutions, and through major R&D granting programs. Similar mechanisms exist for disbursement of State funds for environmental research.

Major R&D granting programs which provide some funds for environmental research are:

i) Australian Research Council Grants Scheme (formerly the Australian Research Grants Scheme and the Marine Sciences and Technologies Grants Scheme);

ii) Grants for Industrial Research and Development Scheme;

iii) Rural Industry Research Trust Funds;

iv) Primary Industry R&D Corporations;

v) Water Research Program; and

vi) National Energy Research, Development and Demonstration (NERD&D) Program.

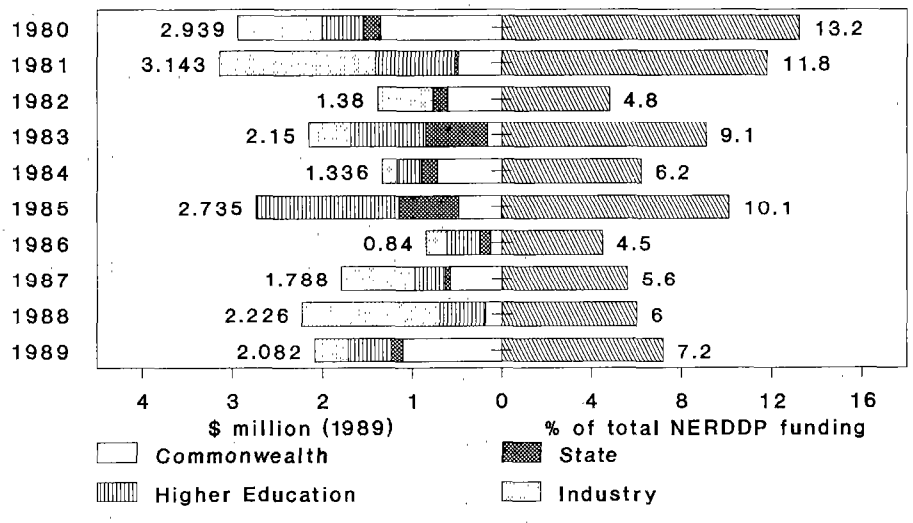
The R&D granting schemes indicated in i) to v) above are discussed in Chapter 4 in terms of expenditure of the funds on environmental research by the organisations performing the research.

Alone amongst the R&D granting programs, data were readily available from the NERD&D Program on grants disbursed for environmental research. The NERD&D Program Secretariat's definition of environmental research is not necessarily consistent with the ASTEC definition developed for this Study.

Figure 3.7 shows total funds for environmental research sourced from NERD&D Program for 1980–89 in 1989 dollars. It indicates in which institutional sector the funds are spent and expresses environmental research funds as a percentage of total NERD&D Program funds for each year.

Over the past decade there has been a considerable variation in year to year NERD&D Program funds for environmental research (Figure 3.7). To some extent this reflects the commencement and termination of various large projects which have been supported by the program. Nevertheless, there has been a fall of more than 25 per cent in NERD&D Program funds for environmental research since the early 1980s. This fall in funds is accompanied by a similar significant decrease in the percentage of total NERD&D Program grants dedicated to environmental research (from about 13 per cent in 1980 to about 7 per cent in 1989).

Figure 3.7 Distribution of NERD&D Program funds for environmental research — 1980 to 1989



Source: NERD&D Program Secretariat

There is no clear pattern for expenditure of NERD&D Program environmental research funds by institutional sector. This is not unexpected since NERD&D Program grants, although assessed against a set of priorities, are open to competition from research organisations from all institutional sectors.

CHAPTER 4

ORGANISATION AND PERFORMANCE OF ENVIRONMENTAL RESEARCH

4.1 INTRODUCTION

This Chapter reviews expenditure on the performance of environmental research in the public, private, higher education and private non-profit sectors.

The term 'expenditure' is used in this Chapter to differentiate between the costs associated with the performance of research and the original source of funds for that research. As an example, a tertiary institution may be carrying out a particular research project, providing staff salaries, equipment and other overheads but it is doing so with Commonwealth funds received under a particular granting program. In this instance, the research is 'funded' by the Commonwealth but 'performed' by the tertiary institution which is responsible for the 'expenditure' on the particular research.

4.2 NATIONAL OVERVIEW

The Australian Bureau of Statistics (ABS) data on research expenditure by socioeconomic objectives is the statistical basis for this Section. The data was collected from Commonwealth and State government, higher education and private non-profit organisations as part of the Survey of Research and Experimental Development for the financial years 1984–85 and 1986–87. At the time of writing, 1988–89 expenditure data were not available. Interpretation of the available data must be constrained by the possibility that the most recent information, when it becomes available, may not support trends discernable from the earlier years.

The ABS data provide information on:

- who is incurring expenditure in the conduct of research, and
- how human resources are expended.

Table 4.1 shows expenditure on environmental research undertaken by institutional sector in 1984–85 and 1986–87. Total expenditure on performance of environmental research for these two years is detailed in Table 4.2. Total expenditure for 1984–85 (1984–85 dollars) was $186.5 million. For 1986–87, total expenditure (1986–87 dollars) was $222.7 million.

Although the increase of $36.1 million over three years appears substantial, when the 1984–85 expenditure is converted to 1986–87 dollars to allow for inflationary effects, the total expenditure on environmental research for 1984–85 is $213.6 million (Table 4.2) and the increase is reduced to $9.1 million or 4.2 per cent.

Table 4.1 Environmental research expenditure according to sector and SEO — 1984–85 and 1986–87 ($'000).

	Commonwealth			*State*			*Higher Education*			*Private Non-profit*		
	1984–85		*1986–87*	*1984–85*		*1986–87*	*1984–85*		*1986–87*	*1984–85*		*1986–87*
	$84–85	*$86–87*		*$84–85*	*$86–87*		*$84–85*	*$86–87*		*$84–85*	*$86–87*	
ENVIRONMENT PROTECTION												
air pollution	213	243	476	243	275	132	1811	2096	1545	—	—	—
water pollution	4661	5321	6434	1419	1607	2862	4147	4800	5039	—	—	—
other pollution	492	562	4572	10	11	45	—	—	—	—	—	—
other environment: natural	19026	21719	20098	9740	11031	7801	—	—	—	4	4	564
other environment: human	—	—	—	165	187	197	—	—	—	—	—	—
other environment	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6626	7669	10604	n.a.	n.a.	n.a.
Total	**24392**	**27845**	**31580**	**11577**	**13111**	**11037**	**12584**	**14565**	**17188**	**4**	**4**	**564**
ADVANCEMENT OF KNOWLEDGE												
earth	16103	18382	25251	2964	3357	1115	21391	24758	25029	—	—	—
ocean	19307	22040	25396	329	373	629	4368	5056	5606	45	49	48
atmosphere	16776	19151	14399	—	—	—	3668	4245	4275	—	—	—
remote sensing	747	853	1761	53	60	481	1130	1308	2092	—	—	—
soils	9743	11122	8347	13111	14848	16754	4520	5231	6104	—	—	—
Total	**62676**	**71548**	**75154**	**16457**	**18638**	**18979**	**35077**	**40598**	**43106**	**45**	**49**	**48**
MINING AND ENERGY												
Production & utilisation of energy												
Environment protection												
oil & gas	538	614	1008	—	—	—	293	339	557	—	—	—
oil shale & tar sands	776	886	620	—	—	—	217	251	91	—	—	—
coal	1657	1892	3101	42	48	237	960	1111	959	—	—	—
Total	**2971**	**3392**	**4729**	**42**	**48**	**237**	**1470**	**1701**	**1607**	**—**	**—**	**—**

Conservation of energy												
industry	3719	4245	4835	5	6	69	2050	2373	1574	—	—	—
residential & commercial	371	424	0	1154	1307	271	683	791	834	n.p.	n.p.	261
transportation	1334	1523	50	—	—	176	979	1133	991	102	110	42
other (eg waste recycling)	—	—	—	—	—	47	222	257	169	—	—	—
Total	**5424**	**6192**	**4885**	**1159**	**1313**	**563**	**3934**	**4553**	**3568**	**102**	**110**	**303**
Mining of energy minerals												
Environment protection												
uranium	7869	8983	7792	—	—	—	181	209	106	—	—	—
coal	—	—	—	7	8	294	599	693	513	—	—	—
oil & gas	—	—	—	—	—	—	30	35	353	—	—	—
oil shale & tar sands	—	—	—	—	—	—	—	—	124	—	—	—
Total	**7869**	**8983**	**7792**	**7**	**8**	**294**	**810**	**938**	**1096**	**—**	**—**	**—**
Total	**16264**	**18566**	**17406**	**1208**	**1368**	**1094**	**6214**	**7192**	**6271**	**102**	**110**	**303**
TOTAL	**103332**	**117959**	**124140**	**29242**	**33117**	**31110**	**53875**	**62355**	**66565**	**151**	**163**	**915**

n.a = not applicable n.p = not for publication

Table 4.2 Environmental research expenditure by socioeconomic objective ($'000)

	1984–85			1986–87	
	Total $1984–85	Total $1986–87	% of Total	Total	% of Total
ENVIRONMENT PROTECTION					
air pollution	2267	2614	1.22	2153	0.97
water pollution	10227	11728	5.49	14335	6.44
other pollution	502	573	0.27	4617	2.07
other environment: natural	28770	32754	15.33	28463	12.78
other environment: human	165	187	0.09	197	0.09
other environment	6626	7669	3.59	10604	4.76
Total	**48557**	**55525**	**26.00**	**60369**	**27.10**
ADVANCEMENT OF KNOWLEDGE					
earth	40458	46497	21.77	51395	23.08
ocean	24049	27517	12.88	31679	14.22
atmosphere	20444	23396	10.95	18674	8.38
remote sensing	1930	2221	1.04	4334	1.95
soils	27374	31202	14.61	31205	14.01
Total	**114255**	**130833**	**61.25**	**137287**	**61.64**
MINING AND ENERGY					
Production & utilisation of energy					
Environment protection					
oil & gas	831	953	0.45	1565	0.70
oil shale & tar sands	993	1137	0.53	711	0.32
coal	2659	3050	1.43	4297	1.93
Total	**4483**	**5141**	**2.41**	**6573**	**2.95**
Conservation of energy					
industry	5774	6624	3.10	6478	2.91
residential & commercial	2208	2521	1.18	1366	0.61
transportation	2415	2766	1.30	1259	0.57
other (eg waste recycling)	222	257	0.12	216	0.10
Total	**10619**	**12168**	**5.70**	**9319**	**4.18**
Mining of energy minerals					
Environment protection					
uranium	8050	9192	4.30	7898	3.55
coal	606	701	0.33	807	0.36
oil & gas	30	35	0.02	353	0.16
oil shale & tar sands	—	—	—	124	0.06
Total	**8686**	**9928**	**4.65**	**9182**	**4.12**
Total	**23788**	**27237**	**12.75**	**25074**	**11.26**
TOTAL	**186600**	**213594**	**100.00**	**222730**	**100.00**

Table 4.3 Human resources by socioeconomic objective (person years) — 1984–85 and 1986–87

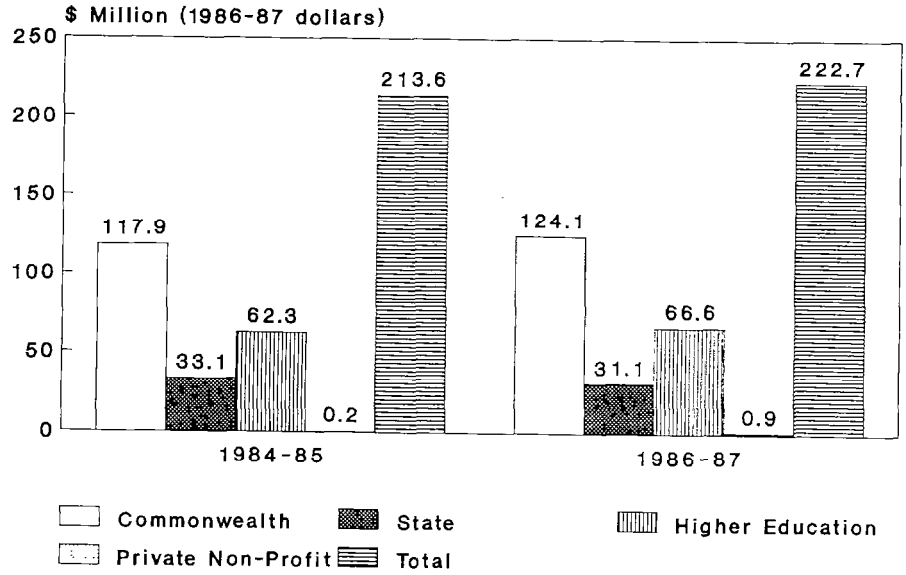
	Commonwealth		*State*		*Higher Education*		*Private Non-profit*		*1984–85*	*1986–87*
	1984–85	*1986–87*	*1984–85*	*1986–87*	*1984–85*	*1986–87*	*1984–85*	*1986–87*	*Total*	*Total*
ENVIRONMENT PROTECTION										
air pollution	3	6	7	5	57	35	—	—	67	46
water pollution	77	91	34	52	167	160	—	—	278	303
other pollution	11	7	1	1	—	—	—	—	12	8
other environment: natural	322	307	230	166	—	—	—	16	552	489
other environment: human	—	—	7	5	—	—	—	—	7	5
other environment	n.a.	n.a.	n.a.	n.a.	198	295	n.a.	n.a.	198	295
Total	**413**	**411**	**279**	**229**	**422**	**490**	**—**	**16**	**1114**	**1146**
ADVANCEMENT OF KNOWLEDGE										
earth	147	271	73	30	608	632	—	—	828	933
ocean	91	107	9	15	138	167	1	2	239	291
atmosphere	213	215	—	—	119	118	—	—	332	333
remote sensing	14	28	2	13	35	62	—	—	51	103
soils	161	131	357	348	141	163	—	—	659	642
Total	**626**	**752**	**441**	**406**	**1041**	**1142**	**1**	**2**	**2109**	**2302**
MINING AND ENERGY										
Production & utilisation of energy										
Environment protection										
oil and gas	10	11	—	—	9	17	—	—	19	28
oil shale and tar sands	12	7	—	—	8	4	—	—	20	11
coal	21	34	1	7	33	29	—	—	55	70
Total	**43**	**52**	**1**	**7**	**50**	**50**	**—**	**—**	**94**	**109**

Table 4.3 Human resources by socioeconomic objective (person years) — 1984–85 and 1986–87

	Commonwealth		*State*		*Higher Education*		*Private Non-profit*		*1984–85*	*1986–87*
	1984–85	*1986–87*	*1984–85*	*1986–87*	*1984–85*	*1986–87*	*1984–85*	*1986–87*	*Total*	*Total*
Conservation of energy										
industry	59	77	—	3	74	50	—	—	133	130
residential and commercial	7	—	5	3	22	25	n.p.	3	34	31
transportation	23	1	0	2	31	27	3	1	57	31
other (eg waste recycling)	—	—	—	1	11	4	—	—	11	5
Total	**89**	**78**	**5**	**9**	**138**	**106**	**3**	**4**	**235**	**197**
Mining of energy minerals										
Environment protection										
uranium	96	75	—	—	6	2	—	—	102	77
coal	—	—	—	1	17	17	—	—	17	18
oil and gas	—	—	—	—	1	13	—	—	1	13
oil shale and tar sands	—	—	—	—	—	5	—	—	—	5
Total	**96**	**75**	**—**	**1**	**24**	**37**	**—**	**—**	**120**	**113**
Total	**228**	**205**	**6**	**17**	**212**	**193**	**3**	**4**	**449**	**419**
TOTAL	**1267**	**1368**	**726**	**652**	**1675**	**1825**	**4**	**22**	**3672**	**3867**

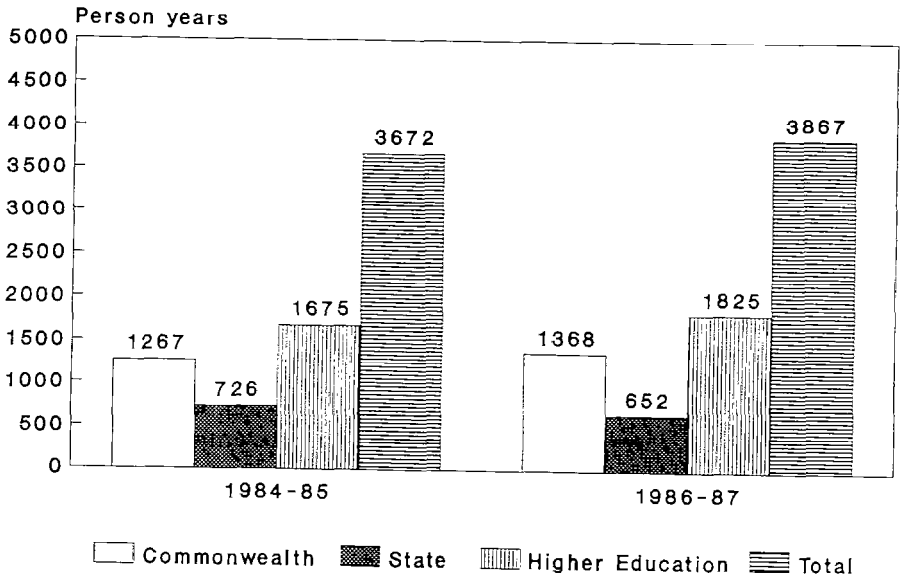
n.a = not applicable n.p. = not for publication

Figure 4.1 Expenditure on environmental R&D by sector undertaking the research — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

Figure 4.2 Environmental R&D by performance by human resource — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC Private Non-Profit data too low to inc

Any increases in expenditure apparent in the higher education and Commonwealth government sectors are largely offset by a decrease in the State government sector (Figure 4.1).

Consistent with the overall expenditure, person years committed to the performance of environmental research in Australia have increased by 5.6 per cent from 3622 in 1984–85 to 3825 in 1986–87 (Figure 4.2 and Table 4.3).

4.2.1 Expenditure by Socioeconomic Objectives

The ABS statistics are grouped according to socioeconomic objectives (SEOs) and subdivided into categories. In consultation with ABS and in keeping with its own definition of environmental research, ASTEC selected socioeconomic objectives which could be identified as environment related. The socioeconomic objectives (SEO) selected are set out in Box 4.1.

There are certain concerns with the detail of the selected SEOs. In the SEO *Environment,* the bulk of the contents are classified as *Other Environment: Natural.* This title provides little information about the contents of the classification. For example, it is impossible to pinpoint research performance in inland waterways or research related to vegetation as opposed to flora and fauna. *Other Environment* consists of data provided by higher education institutions relating to pollution other than air and water pollution and to a range of natural environment research and is even less decriptive because it is more aggregated.

In the SEO *Mining of Energy Minerals,* only *Other (eg safety, environmental protection),* related to environmental protection in the energy mineral industry has been broken down into sub-categories. There is no breakdown into sub-categories for other mineral industries such as bauxite, gold or mineral sands, or for the manufacturing industry.

SEO *Remote sensing* is, strictly speaking, a technique, not research. The expenditure and human resources indicated here would be more meaningful if they were included, where appropriate, in the other *Advancement of Knowledge of the Physical Environment* categories.

For the purposes of discussion ASTEC has grouped like categories. ASTEC has added *Agriculture: Soils (Conservation, Science, etc)* from SEO *Agriculture, Forestry and Fisheries* to the SEO *Advancement of Knowledge of the Physical Environment* to form a category: Advancement of Knowledge. ASTEC has also grouped the SEO *Production and Utilisation of Energy* with the SEO *Mining of Energy Minerals* and the SEO *Conservation of Energy* to form a category: Mining and Energy. Box 4.2 shows the ASTEC grouping.

Thus, discussion of environmental research performance in this Section is based on data derived from the following groupings of ABS socioeconomic data:

Box 4.1 ABS socioeconomic objectives related to the environment

ENVIRONMENT (including Protection and Rehabilitation)

- Air Pollution
- Water Pollution
- Other Pollution
- Other Environment: Natural
- Other Environment: Human
- Other Environment

ADVANCEMENT OF KNOWLEDGE OF THE PHYSICAL ENVIRONMENT (excluding aspects covered under the category Environment)

- Earth (except mineral aspects)
- Ocean (except fisheries aspects)
- Atmosphere (including Meteorology)
- Remote Sensing

AGRICULTURE, FORESTRY AND FISHERIES

- Agriculture: Soils (conservation, science etc)

PRODUCTION AND UTILISATION OF ENERGY

From Oil and Gas (excluding Oil Shale and Tar Sands)
Other (eg Safety, environmental protection)

From Oil Shale and Tar Sands
Other (eg Safety, environmental protection)

From Coal
Other (eg Safety, environmental protection)

CONSERVATION OF ENERGY

- In Industry
- Residential and Commercial
- Transportation (e.g. fuel savings, public transport)
- Other (eg heat pumps, waste recycling)

MINING OF ENERGY MINERALS

- Other (eg safety, environmental protection)
  - uranium
  - coal
  - oil and gas (excluding oil shale and tar sands)
  - oil shale and tar sands

Box 4.2 ASTEC Groupings based on ABS socioeconomic objectives related to the environment

ENVIRONMENT PROTECTION

- Air pollution
- Water pollution
- Other pollution
- Other environment: natural
- Other environment: human
- Other environment

ADVANCEMENT OF KNOWLEDGE

- Earth
- Ocean
- Atmosphere
- Remote Sensing
- Soils

MINING AND ENERGY

Production and utilisation of energy

- Environment protection
  - oil and gas
  - oil shale and tar sands
  - coal

Conservation of energy

- industry
- residential and commercial
- transportation
- other (eg waste recycling)

Mining of energy minerals

- uranium
  - uranium
  - coal
  - oil and gas
  - oil shale and tar sands

In 1986–87, the majority of environmental R&D expenditure in Australia (61.7 per cent) was devoted to Advancement of Knowledge (Table 4.2). A further 27.0 per cent was devoted to Environment Protection and 11.3 per cent was allocated to Mining and Energy (Figure 4.3).

Between 1984–85 and 1986–87 there were few major changes in funding characteristics within these groupings(Figures 4.4, 4.5 and 4.6).

The ratio of expenditure between the three major performance sectors — Commonwealth Government and State Governments and higher education — remained relatively unchanged. The Commonwealth had the highest expenditure, followed by the higher education sector.

4.2.1.1 Environment Protection (Table 4.2)

Expenditure: 1984–85 — $55.5 million (1986–87 dollars);
1986–87 — $60.4 million

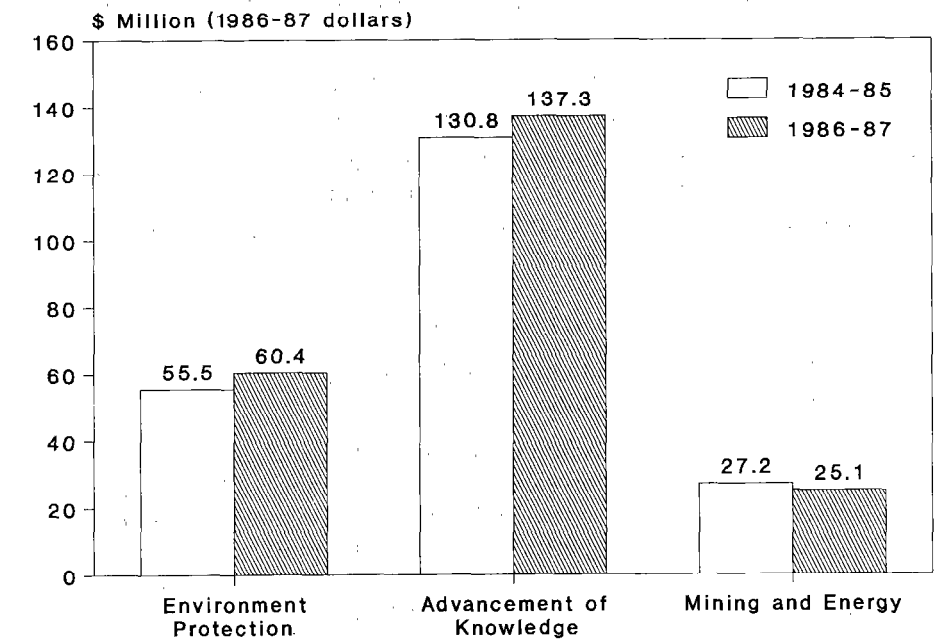
Expenditure on environment protection increased slightly (8.8 per cent) between 1984–85 and 1986–87. The Commonwealth sector's dominance of the category is evident and increased from 50 per cent to 52.3 per cent. The higher education sector improved its percentage of overall performance slightly from 26.2 per cent to 28.5 per cent but it is not possible to tell if the focus was on research related to pollution control or on that related to the natural environment. State sector percentage of expenditure, which was focused on the natural environment, declined from 23.6 per cent to 18.3 per cent. A comparison between 1984–85 and 1986–87 of the component parts of Environmental Protection is shown at Figure 4.7.

4.2.1.2 Advancement of Knowledge (Table 4.2)

Expenditure: 1984–85 — $130.8 million (1986–87 dollars);
1986–87 — $137.3 million

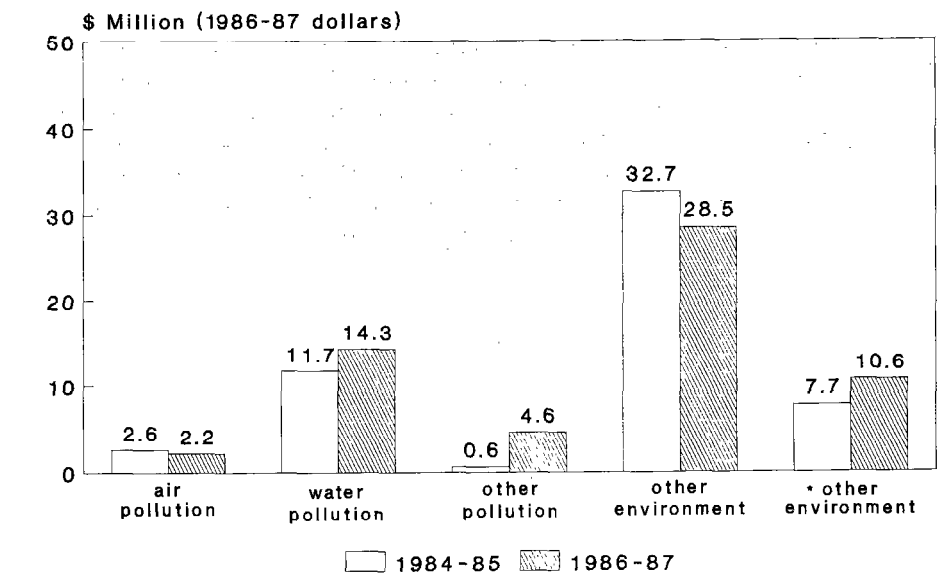
Expenditure on Advancement of Knowledge relates to the major elements of earth, air and water. There was a slight increase in overall funding during the period (4.9 per cent). Generally, the percentage share of expenditure by the three major sectors changed little. The Commonwealth from 54.6 per cent to 54.7 per cent, the State sector from 14.2 per cent to 13.8 per cent and the higher education sector from 31 per cent to 31.4 per cent. A comparison between 1984–85 and 1986–87 of the component parts of Advancement of Knowledge is shown at Figure 4.8.

Figure 4.3 Environmental R&D expenditure — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

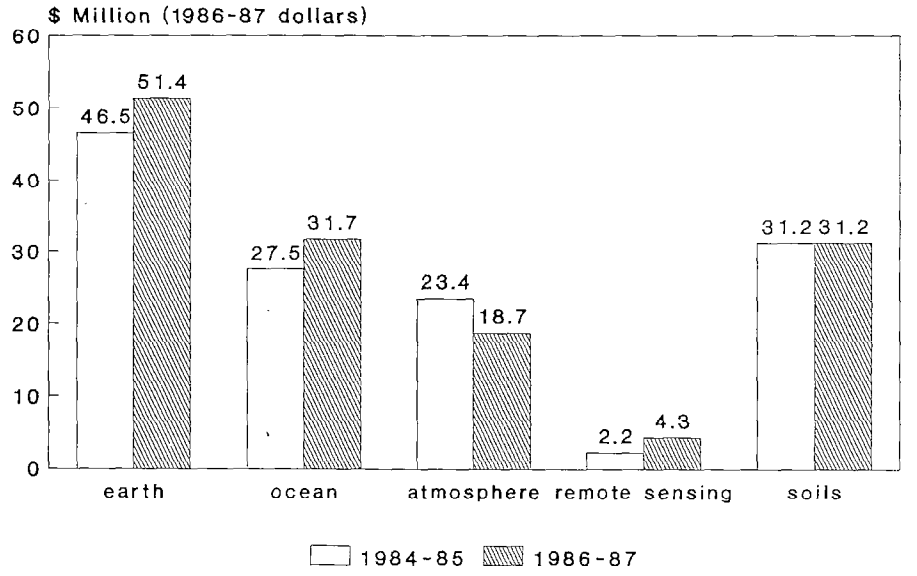
Figure 4.4 Environmental research by expenditure — Environment Protection 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

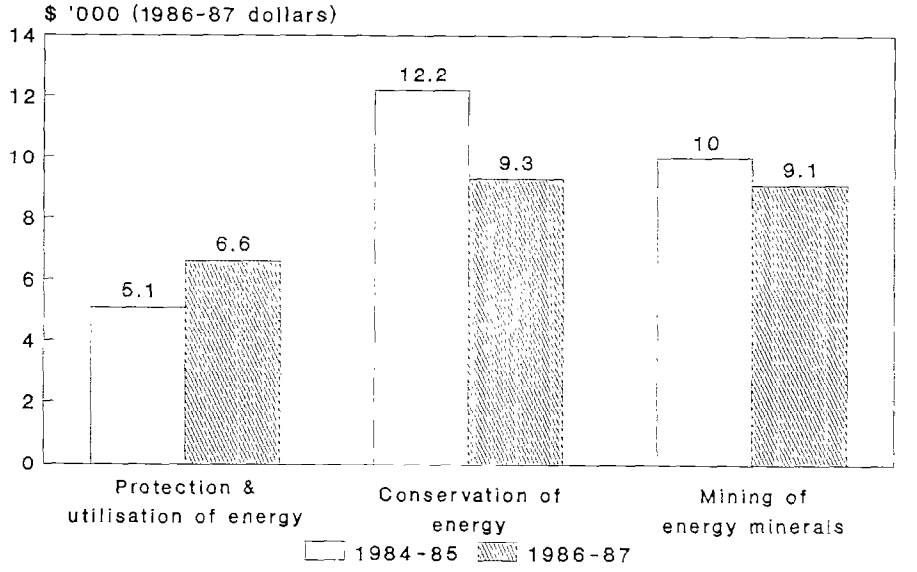
* derived from Higher Education data

Figure 4.5 Environmental research by expenditure — Advancement of Knowledge 1984–85 and 1986–87



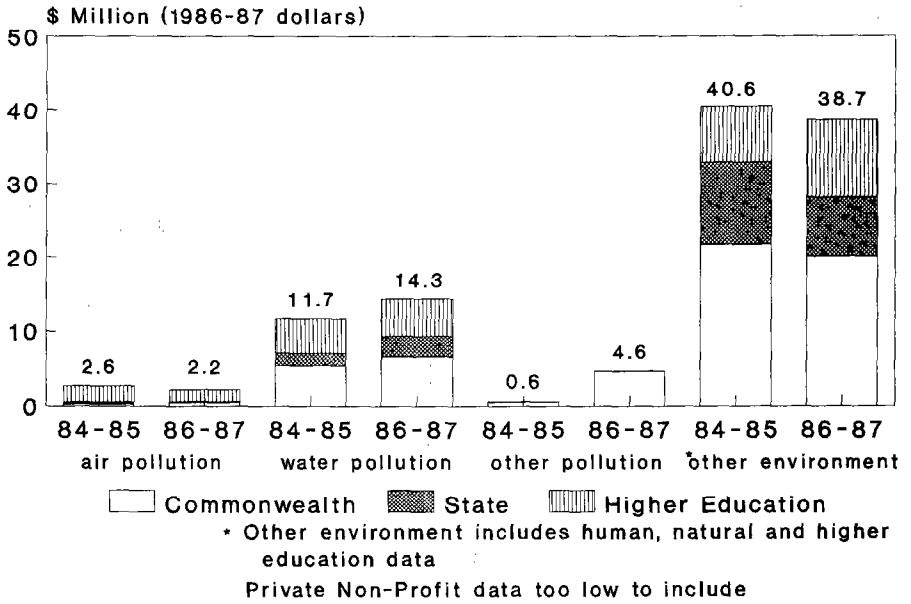
Source: ABS data commissioned by ASTEC

Figure 4.6 Environmental research expenditure — Mining and Energy 1984–85 and 1986–87



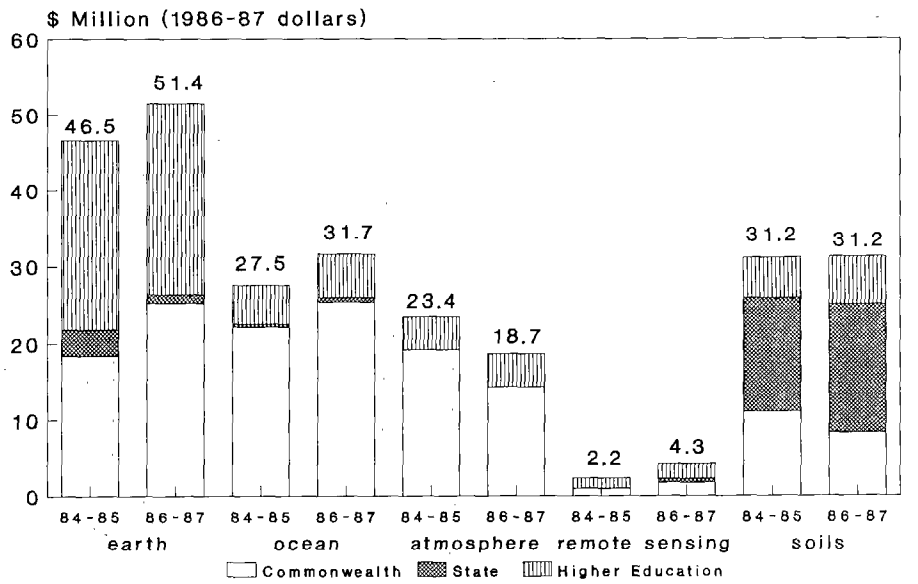
Source: ABS data commissioned by ASTEC

Figure 4.7 Environmental research by expenditure and sector performing the research — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

Figure 4.8 Environmental research by expenditure and sector performing the research — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

4.2.1.3 *Mining and Energy (Table 4.2)*

Expenditure: 1984–85 — $27.2 million (1986–87 dollars)
1986–87 — $25.1 million

Expenditure on energy conservation fell although that for the mining related research was maintained. Overall there has been a fall of 7.9 per cent in expenditure in this category. By far the biggest performer is the Commonwealth with 69.4 per cent of expenditure (increased from 68.2 per cent). The State (from 5 per cent to 4.4 per cent) and higher education sectors (from 26.4 per cent to 25 per cent) remained steady. A comparison between 1984–85 and 1986–87 of the component parts of Mining and Energy is shown at Figure 4.9.

4.2.2 Type of research activity

Environmental research activity, using OECD and ABS definitions, is broken up into:

- pure basic research;
- strategic basic research;
- applied research; and
- experimental development.

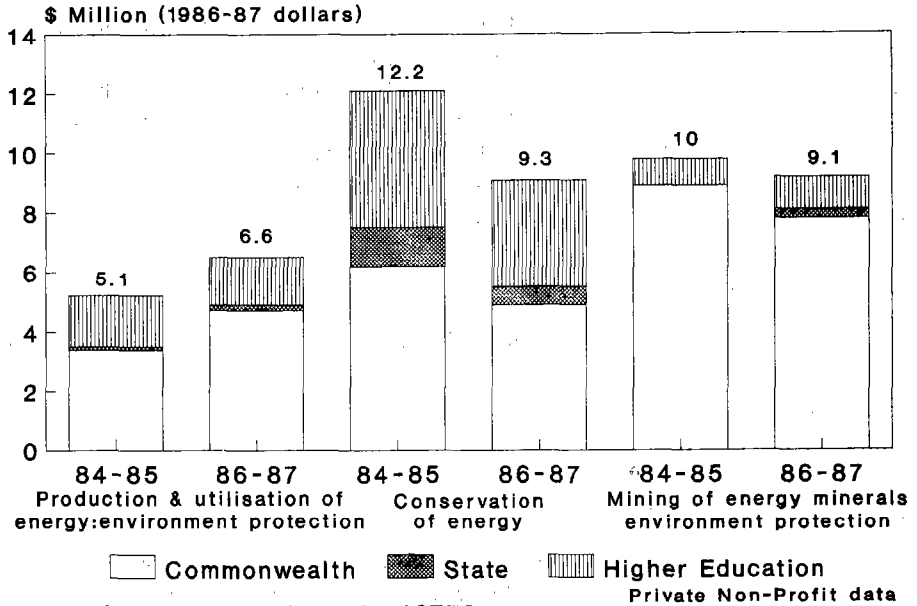
Respondents to ABS R&D surveys use their own judgement when assigning a research type to their activities. The ABS definition of each of these types of research is at Appendix IV.A.

The overall pattern for expenditure on environmental research by type of research activity is consistent for 1984–85 and 1986–87 (Figure 4.10 and the Tables at Appendix IV.B). Applied research is dominant while experimental development lags well behind the other components of environmental research. The 1986–87 figures show that since 1984–85 expenditure on pure basic environmental research has increased by 10 per cent, as has experimental development of environmental research, but from a very low level. Strategic basic environmental research expenditure has not changed and applied environmental research expenditure has increased marginally.

The pattern of research expenditure by Commonwealth government organisations contrasts with that for total expenditure which has slightly increased between 1984–85 and 1986–87 (Figure 4.10). Levels of expenditure on strategic basic, applied and experimental development have all declined between 1 and 5 per cent in the Commonwealth sector since 1984–85 (Figure 4.11), while expenditure on pure basic environmental research has increased by almost 30 per cent.

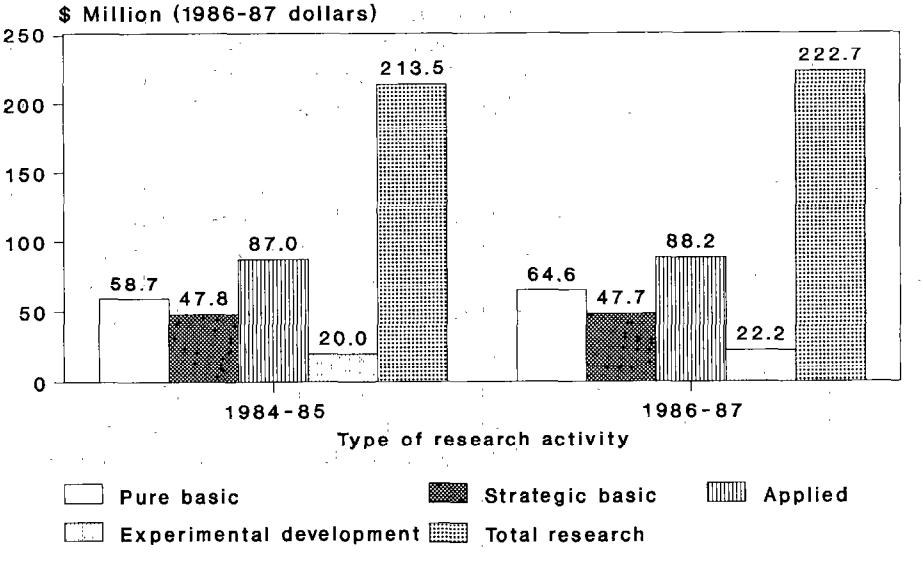
Figure 4.12 shows clearly that State government organisations direct the majority of their environmental research funds into applied research. This is consistent with their constitutional responsibility for managing and protecting natural resources.

Figure 4.9 Environmental research by expenditure and sector performing the research — 1984–85 and 1986–87



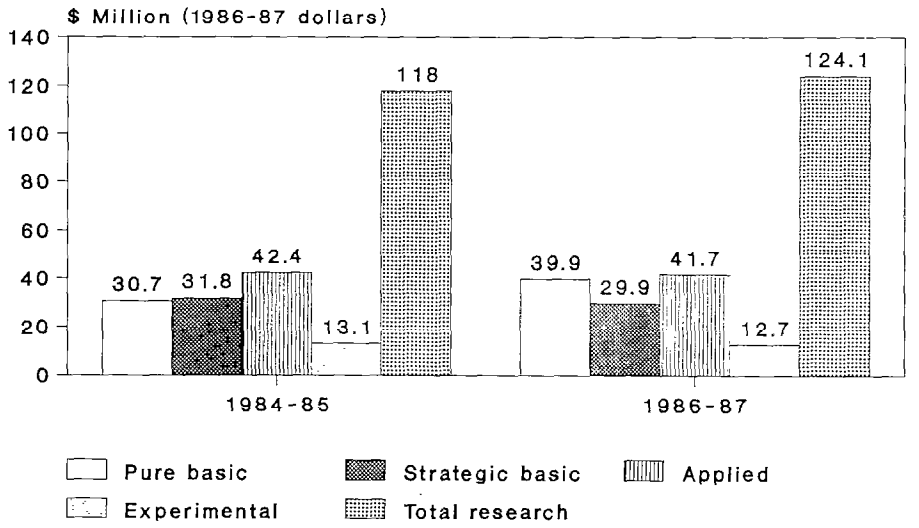
Source: ABS data commissioned by ASTEC

Figure 4.10 Total Expenditure on environmental research by type of research activity — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

Figure 4.11 Expenditure on environmental research by type of research activity — Commonwealth — 1984–85 and 1986–87

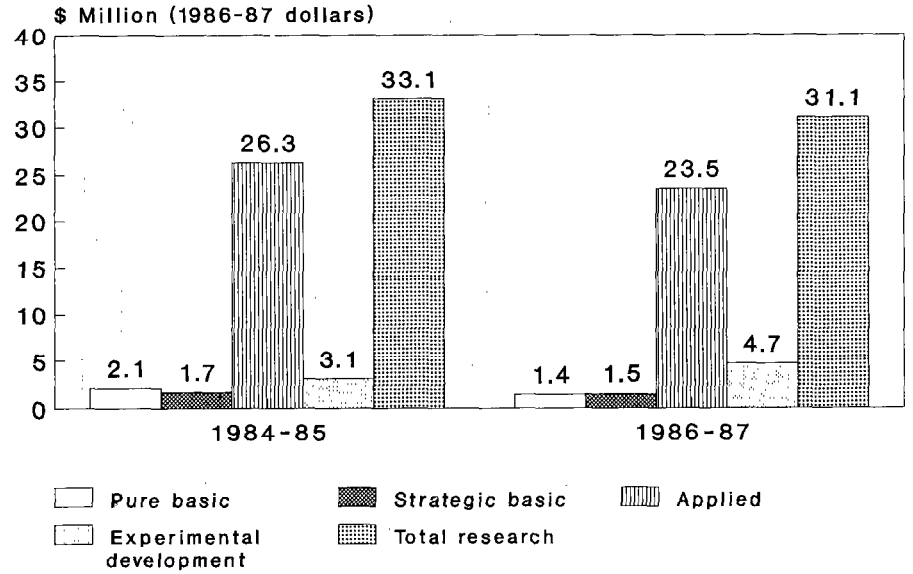


Source: ABS data commissioned by ASTEC

The decline in total expenditure by State government organisations on environmental research between 1984–85 and 1986–87 (about 6 per cent) is closely reflected in the 1986–87 figures for applied and strategic basic research. However, pure basic environmental research fell by almost 35 per cent. In contrast, experimental development of environmental research increased by more than 50 per cent.

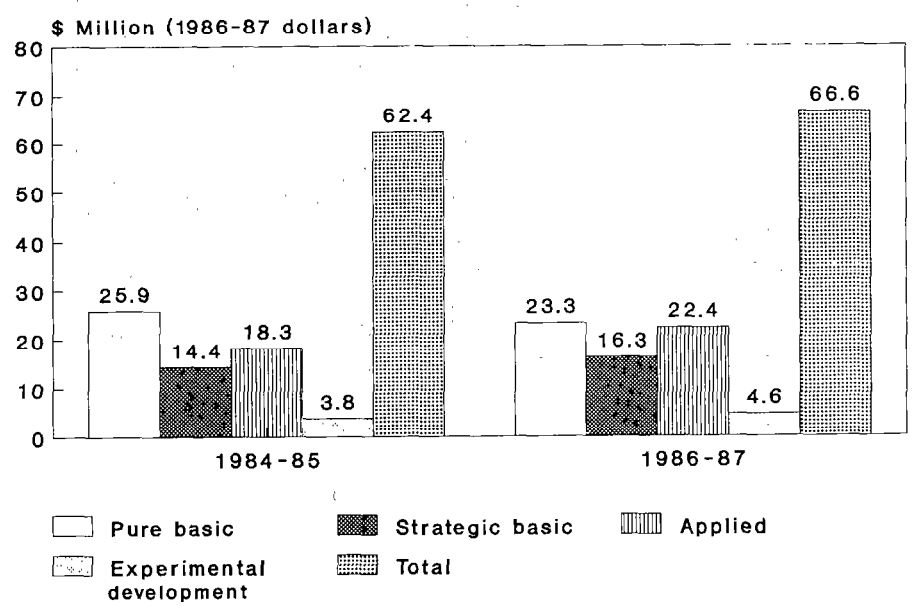
The higher education data (Figure 4.13) show that expenditure on experimental development of environmental research is less than 7 per cent of the total environmental research expenditure for both 1984–85 and 1986–87. There is a fairly even distribution of expenditure on pure basic, strategic basic and applied environmental research. This trend is more pronounced in 1986–87, where expenditure on strategic basic and applied environmental research increased (13 per cent and 22 per cent respectively) while that on pure basic research fell by 10 per cent. Expenditure on experimental development increased by 20 per cent, although from a low level.

Figure 4.12 Expenditure on environmental research by type of research activity — State — 1984–85 and 1986–87



ABS data commissioned by ASTEC

Figure 4.13 Expenditure on environmental research by type of research activity — Higher Education — 1984–85 and 1986–87



Source: ABS data commissioned by ASTEC

A comparison of 1984–85 and 1986–87 data for business enterprises and private non–profit organisations has not been attempted. The figures available are extremely small and in the case of business enterprises undoubtedly not representative of that sector's investment in environmental research. The data that are available are contained in Table 4.4 at Appendix IV.B.

4.3 THE GOVERNMENT SECTOR

Because the Australian Constitution does not explicitly address the environment, direct power in environment matters rests with State Governments. The State public sector is predominantly responsible for installing facilities to provide water, electricity, transport and communication, and for land management. Environmental matters of national significance fall to the Commonwealth Government.

Australian Bureau of Statistics (ABS) data on State government expenditure on R&D used in this Review are aggregated for all States. Consequently, data do not make allowance for the fact that not all States and Territories will exhibit the same trends in expenditure on environmental research.

Total expenditure on R&D performed by the Commonwealth government in 1984–85 was $669.4 million (1984–85 dollars) and its expenditure on environmental research was $103.3 million, representing 15.4 per cent of total expenditure[1] (Table 4.1). Total expenditure on R&D performed by the Commonwealth Government in 1986–87 was $782.3 million (1986–87 dollars) and its expenditure on environmental research was $124.1 million, representing 15.9 per cent of total expenditure (Table 4.1).

State environmental R&D[2] is falling as a percentage of total State R&D expenditure. In 1984–85, environment R&D was 10.2 per cent of total State R&D expenditure ($285.9 million) In 1986–87, environment R&D was 8.8 per cent of total State expenditure ($353.4 million).

Expenditure on environmental research performed by the Commonwealth increased by $6.2 million (1986–87 dollars) from 1984–85 to 1986–87. State government expenditure fell by $2 million (1986–87 dollars) from 1984–85 to 1986–87.

In 1984–85, State government expenditure on the performance of environment related research was $29.2 million (Table 4.1). In 1986–87, expenditure was $31.1 million. However, when 1984–85 figures are converted to 1986–87 dollar values to account for inflation (and become $33.1 million), it is clear that in real terms there has been a $2 million or 6 per cent fall in expenditure.

In 1986–87, the Commonwealth performed 56 per cent of all environmental research in Australia. The States performed 14 per cent. Since 1984–85 this represents an increase of 0.5 per cent in the Commonwealth Government's share of expenditure and a decline of 2 per cent in State governments' share of expenditure.

1 Australian Bureau of Statistics, *1986–87 Research and Experimental Development: General Government and Private Non-Profit Organisations Australia*, Cat. No. 8109.0, 1988.

2 Australian Bureau of Statistics, Cat. No. 8109.0.

4.4 THE COMMONWEALTH GOVERNMENT

Commonwealth government activities in environmental research generally stem from the exercise of those Commonwealth responsibilities established in the Constitution. Consequently, several Commonwealth agencies have developed a substantial environmental research capability.

Within the constraints of federalism the Commonwealth Government organises environmental research for the following:

- control of activities in its territories and offshore areas;
- activities of its own agencies which affect the environment; and
- functions incidental to using its more general powers, such as those over external trade, foreign investment, defence, nationhood (which provides CSIRO with its remit) and the power to meet obligations of international treaties.

In addition, the Commonwealth Government funds a substantial amount of basic research through a range of granting mechanisms. For example, the Australian Research Council (ARC) administers a competitive grants program aimed at supporting excellence in research rather than any particular socioeconomic objective. ARC competitive grant funds are discussed in Section 4.4.2.

Most Commonwealth government departments and agencies would claim to conduct, sponsor or use some environmental research. It is relatively easy to identify research done for the specific purpose of describing, managing or protecting the environment. This identification task becomes more complex when the research is initiated for other purposes but contains within it implications for some aspect of the environment.

The Ministerial portfolios where most environmental research is done or commissioned are:

- *Administrative Services*
  - The Australian Surveying and Land Information Group (AUSLIG)
  - The Bureau of Meteorology

- *Arts, Sport, the Environment, Tourism and Territories*
  - The Antarctic Division
  - The Australian Heritage Commission (AHC)
  - The Australian Biological Resources Study (ABRS)
  - The Australian National Botanic Gardens (ANBG)
  - The Australian National Parks and Wildlife Service (ANPWS)
  - The Great Barrier Reef Marine Park Authority (GBRMPA)
  - The Alligator Rivers Region Research Institute

- *Industry, Technology and Commerce*
  - The Commonwealth Scientific and Industrial Research Organisation (CSIRO)
  - The Australian Nuclear Science and Technology Organisation (ANSTO)
  - The Australian Institute of Marine Science (AIMS)
  - The Grants to Industry Research & Development (GIRD) Scheme

- *Primary Industries and Energy*
  - The Bureau of Rural Resources (BRR)
  - The Australian Bureau of Agricultural and Resource Economics (ABARE)
  - The Murray–Darling Basin Commission
  - National Energy Research, Development and Demonstration Council (NERDDC)
  - The Bureau of Mineral Resources, Geology and Geophysics (BMR)

There are numerous programs at the Commonwealth level supporting research to improve environmental knowledge. This research is funded through direct grants to organisations or individuals to enable the pursuit of specific lines of research, or, as part of an organisation's annual budget allocation to support stated corporate objectives. Also, research may be conducted through consultancies for very specific tasks designed to provide direct input into the decision making process.

A high proportion of Commonwealth research is performed by the CSIRO. Other major agencies are the Office of the Supervising Scientist for the Alligator Rivers Region, the Bureau of Meteorology, Australian Institute of Marine Science and the Australian Nuclear Science and Technology Organisation. The balance of environmental research at the Commonwealth level is the responsibility of the Ministries of the Arts, Sport, the Environment, Tourism and Territories and of Primary Industries and Energy. For a more detailed description of the Commonwealth's environmental research responsibilities see Appendix IV.C.

4.4.1 Commonwealth Scientific and Industrial Research Organisation

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is the largest single performer of environmental research in Australia. It has responsibility for the performance of approximately one third (29 per cent) of environmental research.

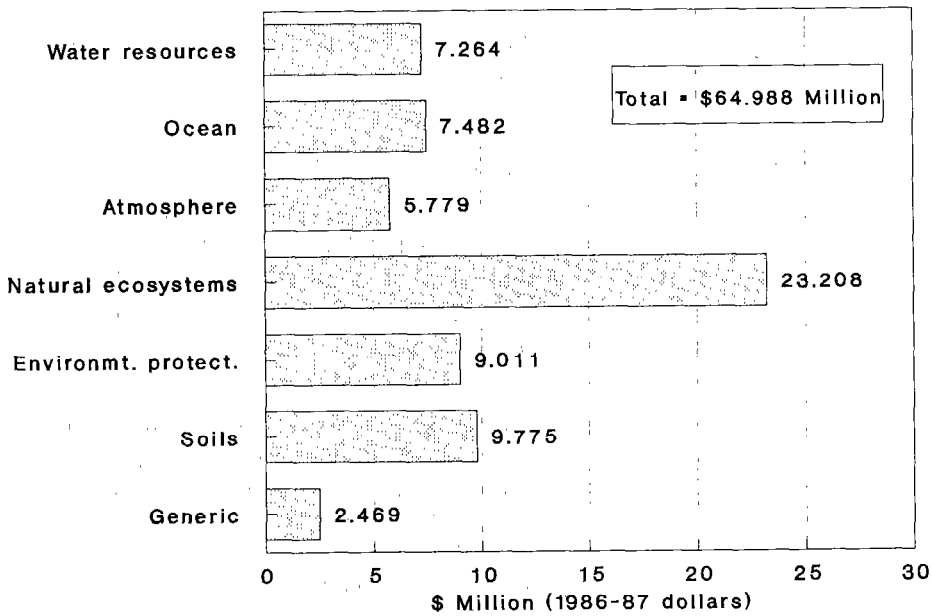
In 1986–87, CSIRO committed $65 million, or 14.6 per cent of its total expenditure ($446 million), to environment related research.[3] This 14.6 per cent includes environmental research conducted outside its two environmentally focussed Institutes. Within CSIRO's environmental research effort a further breakdown (Figure 4.14) indicates that the majority of expenditure in 1986–87 (35.7 per cent) went to natural ecosystems, 11.5 per cent to oceans, 15 per cent to soil research and 13.8 per cent to environment protection. The remainder was devoted to water resources, atmosphere and generic research.[4]

The available ABS statistics only provide data for 1984–85 and 1986–87. However, CSIRO's own research data provide more recent information and make a projection for 1989–90. CSIRO's environmental research data for 1988–89 were collected using different classification system to that used for the 1986–87 data. The more recent data indicates that environmental research remains a constant percentage of the CSIRO's total R&D expenditure. Figure 4.15 shows a comparison over several years.

3 CSIRO Australia, Research Data Office.

4 CSIRO Australia, Research Data Office.

Figure 4.14 CSIRO distribution of Research effort — 1986–87



Source: CSIRO Research Data Office

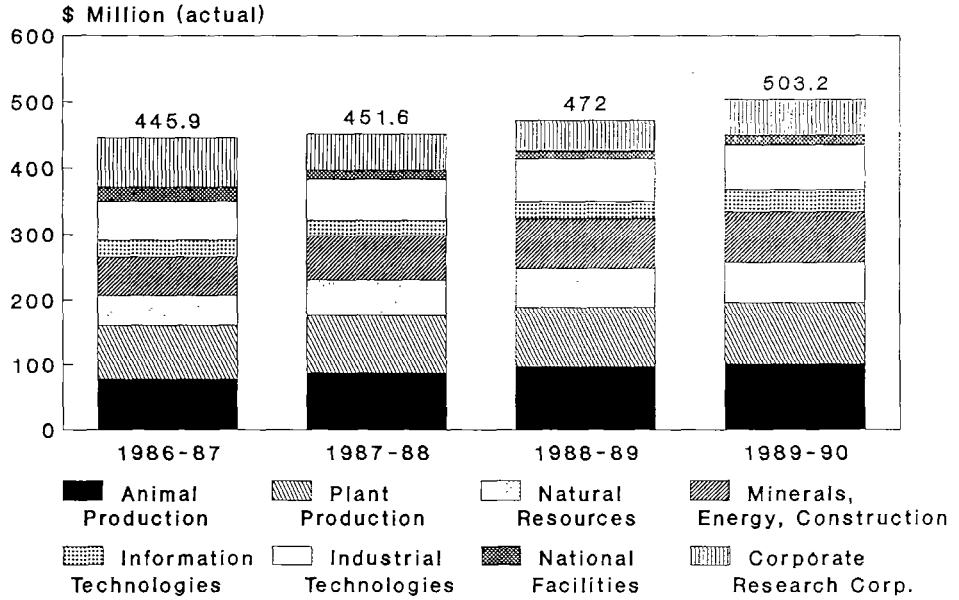
Of CSIRO's six Institutes, two conduct the majority of environment related research. These are the Institute of Natural Resources and Environment and the Institute of Plant Production and Processing.

The Institute of Natural Resources and Environment contains the following Divisions:

- Atmospheric Research
- Fisheries
- Oceanography
- Water Resources
- Wildlife and Ecology
- Centre for Environmental Mechanics.

This Institute aims to provide the scientific knowledge required for the effective management and conservation of Australia's natural resources and environment. Particular emphasis is placed on the conservation and protection of natural heritage and the sustainable use of natural resources by dependent industries. Attention is also given to interactions and changes in natural systems including the atmosphere, soils, terrestrial waters and oceans, and the plants, animals and micro-organisms which inhabit them.

Figure 4.15 CSIRO expenditure 1986–87 to 1989–90(Est)—expenditure by institution (actual dollars)



Source: CSIRO Research Data Office

The Institute of Plant Production and Processing contains the following Divisions:

- Entomology
- Forestry and Forest Products
- Horticulture
- Plant Industry
- Soils
- Tropical Pastures

While this Institute has as its objective the sustained productivity and profitability of industries based on field crops, pastures, horticulture and forests, these industries are inevitably based on improved knowledge of Australia's soils, plants and insects.

Most of CSIRO's remaining Institutes claim to do some environmental research in association with their work program. CSIRO's own calculations put this at an additional $2 million, or 3 per cent of the budget in 1988–89. An example is the CSIRO Office of Space Science and Applications (COSSA) which is a part of the Institute of Information and Communications Technologies.

COSSA's role is to identify opportunities for space related R&D in CSIRO and capture the benefit of this activity for the nation. Increasingly, space science and its applications are seen as making a major contribution to environmental research through remote sensing from both aircraft and space.

CSIRO has recently begun two long-term multi-disciplinary programs of environmental research — one on climate change and the other on land and water care. Although it is too soon to assess the success of these programs they are a significant first step in breaking down the traditional barriers between scientific disciplines in the interests of integrated research.

4.4.2 Coordination Mechanisms

Recognising the diversity of environmental issues and the need for an integrated approach to the conduct of research and the compilation of data, the Commonwealth Government has instituted a number of mechanisms designed to coordinate information about environment related research.

4.4.2.1 National Resource Information Centre

The Commonwealth Government established the National Resource Information Centre (NRIC) within the Department of Primary Industries and Energy (DPIE) in May 1988. The aim of NRIC is to improve the information base for Commonwealth decision making processes relating to natural resource management issues. To date, most of its work has been to meet the needs of DPIE where it is jointly staffed and operated by the Bureaux of Mineral Resources, Geology and Geophysics and of Rural Resources.

The core of NRIC is a computer based Directory of sources of resource information – what data is available, who is responsible for the data, where it is located and how it may be accessed. It has not been NRIC's intention to make a practice of collecting and storing data or to duplicate other holdings. Thus, negotiating access to data held by other parties, particularly State authorities, has led to the development of an extensive consultative mechanism which underpins NRIC.

NRIC aims to be able to utilize all major geographical information system (GIS) packages currently in use for resource data management within Australia. NRIC will also develop GIS techniques to interrogate the information by area and type of data and to carry out the preparation and display of integrated resource information. The Centre also has an image-processing capacity for handling remote sensing data.

The initial stages of the Directory development have been completed and a pilot version of the interrogation software FINDAR (Facility for the Interrogation of the NRIC Directory of Australian Resources) is being tested.[5]

4.4.2.2 Environmental Resources Information Network

The Commonwealth Government's 1989 Environmental Statement announced the establishment of an Environmental Resources Information Network (ERIN) within the Department of the Arts, Sport, the Environment, Tourism and Territories (DASETT).

ERIN aims 'to provide geographically related environmental information of an extent, quality and availability required for planning and decision making to provide an information system allowing ready access to key information on the Australian

[5] Department of Primary Industries and Energy, *National Resource Information Centre (NRIC)*, an undated pamphlet and Johnson, D, *The National Resource Information Centre (NRIC) – Its Role in Geoscience Mapping and Data Development*, paper presented at the 1989 BMR Research Symposium, Canberra.

environment for use in decision making on environmental issues. It further aims to draw together, upgrade and supplement information on the distribution of endangered species, vegetation types and heritage sites.'[6]

ERIN has been developed to:

- create a database facility and computer analysis tools within the Bureau of Flora & Fauna for use by the Portfolio;
- connect with NRIC;
- ensure availability of relevant data sets and to integrate and supplement information about the natural environment;
- coordinate a national effort in cooperation with other Commonwealth, State and research agencies;
- provide effective systems for the prediction of species and ecosystems distributions;
- establish a framework within which to assess implications of environmental change or modification.

ERIN is still in the development stage. It, like NRIC, will have an initial responsibility to satisfy the needs of its home department. Interaction already exists between ERIN and NRIC at this early phase of development.

4.4.2.3 Resource Assessment Commission

The Resource Assessment Commission (RAC) was established by the Commonwealth Government in 1989 to provide advice to government in regard to Australia's natural resources. An incentive for the establishment of the RAC was a concern that all aspects of contentious conservation and development issues were not being considered in the political decision making process. The Commission will investigate environmental, economic, financial, cultural, and social implications of major resource use proposals and provide the Government with advice about options available in relation to those resources and their future utilizations. As part of this process, the RAC will identify the extent of the resource in question and the various uses that could be made of it.

The RAC's first inquiry is into options for the use of Australia's forest and timber resources. The RAC will also hold inquiries into the future use of the Kakadu Exploration Zone and into major coastal zone development issues.

As part of the RAC Forest and Timber Resources Inquiry, the current information base on the extent and composition of Australia's forest resource has been identified as incomplete. A National Forest Inventory (NFI) is being developed by DPIE and DASETT to extend this information base. The RAC will cooperate with the NFI and expects to include this information as part of its present Inquiry.

[6] Kestel Research, CSIRO Australia and Computer Power, *User Requirements of the Arts, Sport, the Environment, Tourism and Territories Portfolio for the Environmental Resource Information Network, Final Report, February 1990.*

The following areas are under investigation for inclusion in the information base created by the RAC:

- the extent of the forest resource;
- tenure designations and associated restrictions;
- an assessment of the timber resources in each of the States and in specific regions; and
- the composition and classification of the forest resource.

Also, the RAC will be collecting data on the adequacy of protection of plant and animal communities associated with forest areas and on conservation management practices in forested areas.[7]

4.4.3 National Inventories

A number of inventories established for specific purposes are maintained at the Commonwealth level.

The Bureau of Rural Resources (BRR) is responsible for several which are relevant to environmental research:

- *Fisheries Resources Atlas of Australia* — in conjunction with the Australian Surveying and Land Information Group and the CSIRO Division of Oceanography, this is to be completed by 1991.[8]
- *The National Forest Inventory* — initiated in cooperation with DASETT and DPIE, this involves the agreement on a national vegetation classification standard for forests in consultation with State agencies and development of a forest resource statistical database.[9]

Under the aegis of the Australian Heritage Commission, the Department of the Arts, Sport, the Environment, Tourism and Territories (DASETT) is developing:

- *A National Wilderness Inventory* — which applies established and consistent criteria to the natural environment to assess its wilderness value. The Inventory has been completed in Tasmania and Victoria.

Also within DASETT, the Bureau of Flora and Fauna is developing:

- *The Australian Biological Resources Study* (ABRS), in collaboration with Commonwealth, State and Territory agencies. The ABRS coordinates studies on the description, classification and distribution of Australian plants and animals, as a record of the natural heritage and to provide a scientific basis for conservation and resource management.

7 Resource Assessment Commission, *Forest and Timber Resources Inquiry Background*, Paper 1, 1990.

8 Department of Primary Industries and Energy, *Annual Report 1988–89*, AGPS, Canberra, 1989.

9 Department of Primary Industries and Energy, *Annual Report 1988–89*.

In addition, there are several databases of research in progress maintained by the CSIRO which contain information about environmental research:

- *Rural Research in Progress* (for the Department of Primary Industries and Energy)
- *Enerlinks:* Australian Energy Research, Development and Demonstration Projects (for the Department of Primary Industries and Energy)
- *Australian Marine Research in Progress* (for the Australian Institute of Marine Science, CSIRO, Great Barrier Reef Marine Park Authority and the Victorian Institute of Marine Sciences)
- *STREAMLINE:* Australian Water Research (for the Department of Primary Industries and Energy)

Details of these CSIRO databases are at Chapter 2.3 and Appendix II.C.

4.4.4 Commonwealth Biological Collections

In addition to the museum and herbaria supported by State Governments, the Commonwealth has, either for reference purposes or as a consequence of research activities, developed a number of 'national' biological collections administered and curated separately from each other. These are:

- Australian National Wildlife Collection
- Australian National Insect Collection
- Australian National Herbarium
- Australian National Fish Collection
- Australian National Botanic Gardens Herbarium
- Antarctic Division Collections
- National Museum of Australia

An expanded description of these collections can be found at Appendix IV.D.

4.5 THE STATE AND TERRITORY GOVERNMENTS

State Governments are constitutionally responsible for protection and management of a large part of Australia's natural resources. In practice, they have primary responsibility for resource development and the provision of public utilities and services. Such environment related matters include water management, soil conservation, forestry management, fisheries management, regulation of mining and urban development including transportation, the use of energy and the development of standards for emissions into the environment.

State Governments have established a range of public authorities to meet their environmental management and regulation needs. ABS statistics assume that local government, which takes an even more focused view of environment related concerns, does not undertake research.

While State Governments of necessity take a regional perspective, they are able to undertake cooperative activities with each other and the Commonwealth through a

range of joint Ministerial Councils. Commonwealth and State Ministerial Councils which have environment matters on their agenda include:

- The Australian Environment Council
- The Council of Nature Conservation Ministers
- The Australian Agriculture Council
- The Soil Conservation Standing Committee
- The Australian Water Resources Council
- The Australian Minerals and Energy Council

Although not all of these Councils administer research funds, they do set priorities and directions for research within their spheres of influence.

4.5.1 Summary of State Government Areas of Environment Research

Each State has different Departments, Commissions or Authorities responsible for research related to environment protection, resource development and the provision of public utilities and services. In some States, these responsibilities are subject to separate administrative arrangements while in others they are amalgamated into large Ministeries such as the Victorian Department of Conservation, Forests and Lands. The following summary of State environment R&D is based on more detailed information provided to the Review by State Governments which is contained in Appendix IV.E.

4.5.1.1 Water and Related Resources

States have separate Departments or Commissions responsible for water management. These government bodies undertake a range of functions involving some environmental research including:

- water resource inventory studies;
- environmental assessments associated with water distribution developments;
- integrated management of natural resources within catchment areas;
- management of the quality of water resources;
- sewage and waste management; and
- research related to impacts of development on wetlands; salinity studies, stream habitats, and catchment management.

Frequently, Departments of Environment or Conservation exist within States which include water quality studies within their research responsibilities. Additionally, other Departments within States have a role in water research — for example, power station research of surface and ground water quality and chemistry.

4.5.1.2 Agriculture and Conservation

Some States have Departments of Agriculture or Primary Industry which are concerned with environmental research for land, soil and water conservation, animal and plant control, monitoring and minimising use of agricultural chemicals

and monitoring their effects on production. In others, some or all of these responsibilities are undertaken by a Department of Conservation or an Environment Protection Authority.

Several States have established specialised Mining, Minerals and/or Energy Departments to undertake regional geological mapping, data compilation and resource assessment, floristic studies, topsoil handling and comparisons of the patterns of plant succession in pre-mining and post-mining efforts.

Some States have Departments or Commissions of Fisheries responsible for conducting research for the acquisition of knowledge about the freshwater environment, the impact of other activities on fisheries, and the management of the fisheries resources.

Forestry Departments or Commissions have been established in some States to carry out research related to the management of forest resources while in others, such as Victoria, this role has been assumed by large departments responsible for a range of natural resource-related functions.

4.5.1.3 Museums and Biological Collections

A great deal of Australia's basic taxonomic information has been collected through the activities of State Libraries and Museums. This includes systematic research into Australian plants with information on their distribution and, for rare or endangered species, their conservation status.

Research and conservation studies are conducted at zoological parks and are aimed at improving breeding and management of the collections, and application of skills gained to wildlife conservation issues.

4.7.1.4 Town Planning, National Parks and Tourism

Some States have established Commissions or Authorities responsible for environmental and social planning. This is required as a basis for assessment of land-use and development proposals, and for future tourist development.

Environment research, monitoring and assessment is also undertaken for National Parks and Reserves.

4.6 HIGHER EDUCATION

Australia has 29 State universities, the Australian National University and one private university (which enrolled its first students in 1989). This number is likely to increase as proposals by a number of colleges of advanced education that they be upgraded to university status take effect. Higher education in the context of this Review has been taken to mean universities, principally because other tertiary institutions although they can claim to do some research, tend to be primarily teaching and training institutions.

Since 1974, the Commonwealth Government has accepted full responsibility for the funding of universities. The rapid growth and increased research role of universities have coincided with the entry of the Commonwealth Government into the area.

The higher education sector makes a substantial contribution to environmental research in Australia, accounting for 29 per cent of research expenditure in 1984–85 and 30 per cent in 1986–87. Higher education research expenditure increased from $53.9 million in 1984–85 to $66.6 million in 1986–87. When the 1984–85 figure is adjusted to 1986–87 dollars to account for inflation, the increase in expenditure is $4.2 million or 6.7 per cent (see Figure 4.1).

Since 1984–85, higher education expenditure has increased in all the environment related ABS socio-economic objective categories except for Air Pollution and Conservation of Energy (Table 4.1). The data indicate that the largest single focus of higher education environmental research activity was earth science (Figure 4.8). Human resources devoted to the environmental research effort have reflected expenditure patterns. (Tables 4.1 and 4.3).

4.6.1 Special Funding Arrangements for Higher Education

4.6.1.1 Australian Research Council Funding

Through the Australian Research Council (ARC) granting schemes, the Commonwealth funds high level research and development on the basis of merit as judged by assessors from Australia and overseas. See Section 2.5 for a more detailed explanation of the ARC funding program. ARC funding of environment related research has been maintained at about one-third of the total program for the past decade (Figure 4.16) including the funding for Key Centres for Teaching and Research and Special Research Centres. Details of ARC environmental research funding are at Appendix IV.F.

4.6.1.2 Key Centres for Teaching and Research

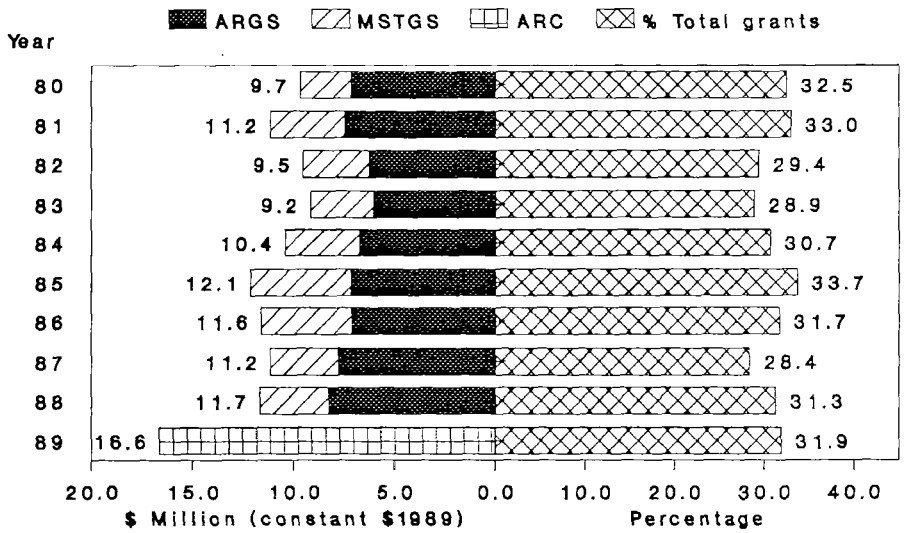
In 1984, the Government announced the establishment of Key Centres for Teaching and Research to build on existing teaching and research capabilities in higher education institutions. These Centres (32 in May 1990) were designed to increase coordination and concentration of the national teaching and research effort to focus on national priorities. The Centres are subjected to a review on a three year cycle at which time funding levels are reassessed. Of the Centres, three conduct research related to the environment:

- Centre for Antarctic and Southern Ocean Studies
  University of Tasmania
  (funding commenced in 1988)
- Centre in Dryland Agriculture & Land Use System
  Roseworthy Agricultural College
  (funding commenced in 1988)
- Centre for Land Information Studies
  University of Queensland
  (funding commenced in 1985)[10]

The Centres each received $176 000 in 1989. Funding for the Centres in 1990 will be a similar figure indexed to account for inflation.

10 Department of Employment, Education and Training

Figure 4.16 Major sources of competitive grants for environmental research in higher education institutions



Source: ARGS, MSTGS & ARC Annual Reports

4.6.1.3 Special Research Centres

The Special Research Centres Program was established to support very high standards of research in fields that will contribute substantially to Australia's development. These are centres of excellence in research of particular importance to Australia and where Australia gives a lead to the world. There were 15 such Centres in May 1990. The Centres are subjected to a review of operations including extent to which goals have been achieved every three years. Of the Special Research Centres only one conducts research related to the environment:

- Environmental Fluid Dynamics Centre
  University of Western Australia
  (funding commenced in 1982)[11]

Funding for this Centre was $647 000 in 1989. Funding in 1990 will be based on this figure indexed for inflation.

Table 4.4. Students Enrolled in courses leading to environment qualifications 1987–89

Year	*Undergraduate*	*PostGraduate*	*Total*
1987	1613	636	2249
1988	1923	705	2628
1989	2085	649	2734

Data Source: DEET Statistics

[11] Department of Employment, Education and Training

4.6.2 Students Enrolled in Schools or Courses Leading to Qualifications in Environmental Science and Natural Resource Management

The Commonwealth Department of Employment, Education and Training collects data on the number of students in the Australian tertiary sector. It is possible to distinguish between postgraduate and undergraduate students over the period 1987–89 enrolled in environmental science, environmental studies, natural resources management, land use management and related courses. While it is difficult to extrapolate from these figures to the number of students who eventually graduate, the enrolments do reflect the interest in such courses.

Postgraduate students are more likely to continue to do research in their chosen field of environmental science. Their numbers give some indication of the potential new researchers available in the environmental research field (Table 4.4). A full list of Universities, the degree courses they offer and the student enrolments is at Appendix IV.G.

4.6.3 Environmental Science and Natural Resource Management Research Staff in Tertiary Institutions

The Commonwealth Department of Employment, Education and Training collects data on staff employed in the Australian tertiary sector. These data distinguish between term and contract staff as well as between those who are employed in teaching or research or in a combination of both.

From these figures it is possible to ascertain the number of academic staff engaged on either full-time research or research in conjunction with teaching duties in environment related areas. It is possible over a three year period to discern trends in term and contract staff and between staff employed solely on research and those combining some research with their teaching duties. Table 4.5 summarises the data which is included in full at Appendix IV.H.

Table 4.5 Higher Education staff engaged in environment related research by type of appointment (1988–89)

	Research						*Research and Teaching*					
	1988			*1989*			*1988*			*1989*		
	L	*T*	*O*	*L*	*T*	*O*	*L*	*T*	*O*	*L*	*T*	*O*
	305	79	24	324	61	17	135	439	30	146	463	34
Total			**408**			**402**			**604**			**643**

Key: L limited term; T tenurable; O other
Source: DEET statistics

4.7 THE PRIVATE SECTOR

Although the majority of environmental research in Australia is undertaken in public institutions, an important component is conducted or commissioned by the private sector. ABS collects private sector R&D data by industry of enterprise or for a particular product or process, not by SEO. This method of data collection precludes meaningful analyses of private sector environmental research.

Very little substantiated information is available about expenditure by private corporations on environmental research. Some companies and industry associations do release estimates, but not the basis on which they are made. Despite this difficulty some comments on the state of environmental research by the private sector and the direction of future development can be made.

Environmental research financed by the private sector is performed by:

- 'in-house' laboratories in development, chemical, manufacturing and processing industries;
- equipment manufacturers;
- universities and government laboratories under contract;
- private sector research and training institutions; and
- private consultants.

In general, only the largest resource development industrial corporations have their own environmental staff, few of whom would devote the major part of their time to what could be termed research. Most companies either rely entirely on consultants or employ a small number of staff for day-to-day environmental management and occasionally sponsor external bodies for specific research assignments.

Where corporations do carry out their own research 'inhouse', it is generally specific to their own projects and processes, though it may have wider application. Frequently, environmental implications are ancillary to the main research objective, making it difficult to assess the extent of private industry research effort.

Most major industry sectors have industry associations of various types (for example the National Association of Forest Industries). Some have an interest in or sponsor environmental research either directly or through research committees.

4.7.1 The Incentives for Private Enterprise Environmental Research

Industry sponsored research tends to be short-term, tactical research focussed on solving problems. Even long-term, more strategic work is directed towards understanding specific impacts rather than total systems. Often the driving force is the need to comply with existing or anticipated legislation.

Short-term, tactical environmental research by private corporations makes only a limited contribution to an integrated approach to environmental research. However, where private environmental research is longer term it tends to be driven by company business requirements.

For example, improved energy efficiency to reduce operating costs is a strong motivating factor in industry research and development and likely to have positive environmental consequences as is improved recycling of waste materials.

4.7.2 Legislation and Regulation

Environmental legislation having most impact on private enterprise is generally concerned with land and resources planning, pollution control, and environmental impact assessment (EIA). Each of these can involve local, State and Commonwealth Government, but for major resource developments State Governments have the primary responsibility. Local government is also strongly involved in planning, and the Commonwealth in EIA.

4.7.2.1 Land and Resources Planning

Building, engineering construction or localised resource exploitation generally requires specific approval. Depending on the location, scale and type of development, such approvals may be granted by local government agencies or may be referred to state planning agencies. For example, tourist developments, even if quite large, are generally handled by local government, whilst mineral developments are more likely to be referred to State agencies. The amount of environmental information needed to support a development application varies enormously from little or none to full environmental impact statements (EIS) or even public inquiries.

Some States have legislation requiring approval for the use of particular resources. There are, for example, ordinances in relation to the use of water and harvesting of particular plant and animal species. In some areas, regulations control vegetation clearance, use of fire, stocking rates, weed control, and use of pesticides.

4.7.2.2 Pollution Control

Pollution control legislation is largely the responsibility of State government agencies. There are local government ordinances in relation to municipal and domestic refuse, odours from particular industries such as abattoirs and tanneries, discharge of wastes from moored boats, and so on. Commonwealth agencies (for example, National Health and Medical Research Council) produce guidelines, codes of practice, and, occasionally, model legislation, but have little direct power other than in regard to marine pollution in Australian territorial waters.

State Governments are rapidly consolidating their own environmental protection instruments and standards, often previously covered by a range of single Acts, under one piece of environment protection legislation.

This move is echoed at the national level in recent decisions by the Australian and New Zealand Environment Council (ANZEC) to develop agreed national guidelines for air and water quality. A Background Statement and Criteria for National Water Quality Guidelines is to be released for public comment, academic review and consideration by relevant Ministerial Councils this year. A similar process is anticipated for air quality guidelines. In addition, ANZEC has agreed to publish a discussion paper on common penalties, fees and standards for environmental quality. The New South Wales government is chairing a national working party to investigate the issues and develop a long-term framework for uniform or co-ordinated national legislation in the area.

4.7.2.3 *Environmental Impact Assessment*

EIA legislation in most States is embedded in or coupled with planning legislation, and, under the administration of the same agency. However, environmental requirements differ between States.

The main Commonwealth EIA legislation is the *Environment Protection (Impact of Proposals) Act 1974* and associated regulations. These contain some relatively far-reaching provisions which (notably in Clauses 4 and 10 of the current Administrative Procedures under that Act) could be used to promote environmental research and improve environmental management, if they were generally applied. However, the Commonwealth Minister for Environment has no power to invoke the provisions of this Act, and the particular responsible Minister only has such powers in regard to a development if a Commonwealth decision is required under one of the various Constitutional heads of power.

4.7.3 Economic Priorities

Economic priorities are obviously another major influence on the performance of environmental research by or for the private sector. Research which adds to knowledge of, or protection of, the environment is generally undertaken as an adjunct to an industry's primary objective. Even where research may be directed more to developing than protecting resources the outcome may well be positive. Natural systems in a particular area may be studied intensively, as was the case with the Alligator Rivers Region of the Northern Territory or an environment may benefit from improved technology.

4.7.4 The Major Types of Research

4.7.4.1 *Research Associated with Development of New Technologies*

Industry typically develops new technologies to increase its own efficiency and productivity, to enable it more easily to meet environmental regulations or for commercial exploitation. Industry has, for example, developed more sophisticated technologies for re-incorporating its own waste products into manufacturing processes with recycling and recovery processes such as:

- sulphur recovery in coal gasification
- re-refining of waste oil
- reprocessing mineral tailings

In some cases, tougher anti-pollution regulations have been the catalyst for industry to investigate the economic advantages ofdeveloping more energy-efficient technologies. Competition within industries are also an incentive to minimise the high costs associated with waste disposal.

Customer preference for environmentally friendly products is increasingly an incentive for industries producing consumables such as packaging, household products and processed foods. The economic incentive to increase the marketability of products has lead to higher standards in food preservation, less environmentally damaging packaging, bio-degradable detergents and plastics and high hygiene standards for food handling. All of these advances have been dependent on the development of appropriate technologies.

Because of the competitive element in industry much of the research on which such developments are based tend to remain commercial- in-confidence unless it becomes a product in itself.

4.7.4.2 *Research Associated With EIA*

Much industry-sponsored environmental research is associated in some way with EIA legislation and procedures. Typically, corporations planning major new development projects will go through a number of successively more formal steps, each requiring more detailed environmental information.

Environmental Impact Assessment (EIA) documents include at least the first three of the following stages:

- description of existing environment: baseline surveys
- description of proposed development
- prediction of expected impacts
- proposals for minimising and mitigating impacts
- proposals for ongoing management and monitoring

Typically, baseline surveys involve research and some impact predictions. Some components of the baseline description are commonly derived from published literature; others require project-specific research. The particular components requiring field surveys in any given project depend on the type, scale and location of the project, and in particular, on expected emissions to air and water, groundwater seepages, soil contamination, and waste disposal.

Impact prediction in EIA generally involves comparison with other similar projects, relatively simple calculation (eg of noise attenuation), or, straightforward application of existing models (eg dispersion models). Rarely is research involved. However, in some cases predictive models are developed specifically for a particular project. These include atmospheric, oceanographic and groundwater dispersion models, and population models for particular plant and animal species.

EISs and associated supporting documents are used by government and the public during the EIA process. They may also contain original data which can be valuable in a wider sense to governments, the public and the scientific community. Original data are commonly collected for:

- flora and fauna: species inventories, occasionally population estimates
- meteorology: wind velocity, atmospheric stability classes
- air quality: parameters depending on type of development
- hydrology: stream gauging, watertable
- water quality: including pH, and salt content

Impact predictions made in EIA documents are effectively hypotheses about the responses of particular ecosystems to given human disturbances. Environmental monitoring data provide the means to test these hypotheses. Testing the accuracy of such predictions provides a measure of the scientific understanding of ecosystem processes, and also provides information needed to refine predictive models.

4.7.4.3 *Research Associated with Environmental Monitoring Programs*

Environmental monitoring programs are set up to measure performance or to test compliance to ensure:

- equipment is functioning efficiently;
- standards set in pollution control legislation are being met;
- environmental protection commitments made by the proponent; or requirements imposed by regulatory agencies during the EIA and planning approval process, are honoured.

The parameters most commonly monitored include:

- concentrations and dispersions of individual pollutants in emissions to air and water;
- ambient concentrations of individual pollutants in air and water on site, at the site boundary, and at predetermined monitoring points, typically up to 10km from the emission source, but occasionally further (eg downstream of a major mining operation or offshore from a major marine discharge);
- noise levels at site boundary.

Parameters less commonly monitored include:

- abundance of particular plant and animal species;
- pollutant concentrations in biological tissues and soils;
- chemical properties of groundwaters

Benefits of such research include development of better monitoring, measuring and analysis techniques and the introduction of new or better abatement measures covering environmental aspects such as air and water quality, flora and fauna protection and soil and groundwater contamination. Environmental monitoring data are currently collected by two main groups:

- the company concerned, to test compliance with standards for use in ongoing environmental management and to allow management for improved efficiency;
- government regulatory agencies, to test compliance.

If more generally available, corporate environmental monitoring data would also assist:

- in checking that developers are meeting environmental protection commitments and that government agencies are acting effectively and without negligence;
- researchers in many related fields – engineering, health, town planning etc;
- environmental scientists to:
  - refine predictive models;
  - examine patterns of variation of particular environmental parameters through time.

4.7.4.4 *Research Associated with Rehabilitation and Revegetation Research*

A common condition attached to development approvals under the planning and EIA processes for land use industries such as mining or forestry, is a requirement to rehabilitate all or part of the site. Such conditions rarely stipulate scientifically verifiable standards or performance criteria for such rehabilitation. They sometimes

do specify a particular end use or capability. Private sector rehabilitation research may therefore be used by scientists in government agencies and research institutions and by personnel responsible for rehabilitation in other operating corporations, both public and private sector.

Requirements for successful revegetation strategies generally require at least a minimum programme of research including:

- germination requirements of native species;
- trials of seeding, planting and establishment techniques, including:
  - soil preparation (eg. topsoil replacement);
  - fertilisation and watering regimes;
  - dust abatement and site beautification;

The results of revegetation research, though relatively site-specific, are often applicable in comparable operations elsewhere.

4.7.5 Dissemination of the Results of Privately Conducted Environmental Research?

Not all of the environmental research conducted by the private sector reaches the public domain, and much that does is not easy to locate. Environmental impact statements and associated supporting documents are generally made available for public comment for six to eight weeks. During this period they are commonly sold from a small number of outlets and may be deposited in local libraries. When the period for public comment ends, EISs — though still public documents — become hard to obtain in practice. The only copies may be those held by the relevant State planning agency, and these are only available for inspection in that agency's offices and at its discretion. This is particularly true for supporting documents, which generally contain far more detailed data than the EIS itself.

In contrast to EIA documents, which are public even though unpublished, data collected during environmental monitoring programs — even those specified as part of the EIA and planning approval process — are not always available to the public for commercial-in-confidence reasons. The proceedings of the annual AMIC Environmental Workshops do provide some mining industry data.

The Australian Mining Industry Council (AMIC) commissioned The Centre for Technology and Social Change to construct and maintain a database of R&D related to the metallic minerals and other non-metallic minerals industries in Australia. The database was initiated at the beginning of 1989 and covers private enterprise sponsored R&D, including joint projects with government organisations. The database is not comprehensive — data collection is continuing. Various categories have been selected to sort the database, including an environment category. As of November 1989, total industry support for environmental projects in the AMIC database was $685 000.

The results of private sector rehabilitation research, however, are somewhat more widely disseminated — through publication in journals such as *Reclamation and Revegetation Research;* in newsletters such as *Landline;* and in conference proceedings, such as those of the North Australia Rehabilitation Workshops.

Relatively few papers in scientific journals are written by specialist consultants. Management techniques and prescriptions are more commonly written by specialist consultants. Impact statements and associated documents are the main documentary output. Monitoring programs provide the potential to produce valuable databases, but this rarely happens because monitoring programmes are usually purpose designed and not necessarily developed with research requirements in mind; and because monitoring data are normally considered to be confidential.

4.8 THE PRIVATE NON-PROFIT SECTOR

There is a small amount of environmental research conducted by private organisations, principally environmental groups, which are either conducting research to support their position or have a research program as one of their corporate objectives. It is of some interest that the percentage of private non-profit investment in environmental research has, while remaining a very small percentage of the whole, increased from 0.08 per cent of research expenditure in 1984–85 to 0.48 per cent in 1986–87 — a six fold increase (Table 4.1).

Private non-profit activity accounted for less than 0.5 per cent of environment related research in 1986–87. This situation contrasts markedly with countries such as the United States of America where philanthropic funding of environmental research has a long tradition.

Non-profit organisations performing environmental research include the World Wide Fund for Nature. This organisation had a research budget of approximately $700 000 in 1989–90. It funds research into specific species or habitats and is becoming more involved in research relating to sustainable ecosystems. Earthwatch contributes to environmental research mostly through the donations of paying volunteers.

Organisations like the Australian Conservation Foundation, The Wilderness Society, Greenpeace, and Friends of the Earth are lobby groups and tend to perform little scientific research of their own.

In addition, there are numerous zoological and ornithological societies which conduct site or species specific surveys. Many of these organisations receive assistance towards their administrative overheads from the Commonwealth Government under the Grants to Voluntary Conservation Organisations. They do not receive research grants under this scheme.

CHAPTER 5

QUALITATIVE ASSESSMENT OF ENVIRONMENTAL RESEARCH

5.1 INTRODUCTION

This Chapter examines the status of environmentally related research in two broad ways. Firstly, specific fields of environmentally related research are discussed. Field selection was predicated on major strengths and weaknesses in particular fields and the need to clearly document them. The discussion is based on ASTEC's recent report *Profile of Australian Science* and submissions received, supplemented by consultation. Secondly, basic research in the key fields of science which underpin environmental research are discussed. This latter discussion is based totally on *Profile of Australian Science*, where an indicator based evaluation is central to the material presented and the conclusions that are made.

5.2 DISCUSSION OF SPECIFIC AREAS OF ENVIRONMENTAL RESEARCH

The following discussion focuses on fields of science where there is significant environmentally related research activity. The major source for this Section is *Profile of Australian Science* supplemented by submissions to the Review and consultations.

The discussion incorporates some comment on the organisation and the strengths and weaknesses of environmental research in soil, water, atmosphere and biodiversity.

5.2.1 Taxonomy

While the description and classification of our often unique living organisms would seem to be a self-determining priority in the management of the Australian natural environment, research in taxonomy is regarded as being in decline.[1] Biology and zoology departments of universities are placing less emphasis on systematic taxonomy and museums (such as the Australian Museum) which are active in systematic taxonomy are having difficulty funding long-term projects.[2]

The Australian Biological Resources Study (ABRS) is developing the descriptive tools which are the necessary pre-requisites to the task of conservation. The ABRS is administered by the Department of the Arts, Sport, the Environment, Tourism and Territories (DASETT) through the Bureau of Flora and Fauna. While some research is done 'in house' the majority is funded through grants or contracts. The ABRS has

1 Dr Marilynn Fox, Royal Botanic Gardens Sydney, submission to ASTEC.

2 Australian Museum submission to ASTEC.

estimated that at its current rate of funding it will take until the year 2030 to complete the inventory of our flora and fauna.[3] Recently announced additional funding may accelerate that program.[4]

Taxonomy in Australia is active in conventional morphological, classical and nomenclatural work as well as experimental and cladistic work.[5] While the level of expertise in animal and plant taxonomy in Australia is high, these skills are widely dispersed both geographically and organisationally. Individual researchers have had considerable freedom to choose study topics simply because of the vast breadth of our flora and fauna.

Taxonomic work has been actively carried out by State museums and herbaria for many years (see Appendix IV.E). Continuation of this work requires assurance of long-term funding. Since much of the active taxonomic research is carried out by these institutions as a secondary function, its conduct and funding is likely to suffer unless some public support can be engendered. It is important that an active body of researchers is maintained at the State level. It has been suggested that consideration should be given to the development of regional emphases which could more effectively use existing resources.

CSIRO recognises the importance of systematics but open ended, long-term research coupled with the high overheads involved in maintaining reference collections may place the future of such activities in CSIRO in doubt, given the pressure on that organisation to change its role. However, in ASTEC's view this would be unfortunate and not in line with the Government's emphasis on biological diversity.

Amalgamation of national biological collections where there is duplication or potential for duplication of activities would assist in the development of priorities. Such priorities should ensure more emphasis is given to taxa which are highly significant from a conservation or land management point of view or which may be rare and/or endangered.

Closer ties between organisations involved in *ex situ* and *in situ* conservation of our natural resources would be beneficial in developing a more coordinated approach to this work. In this respect, we can look to examples such as cooperative work between NSW National Parks and Wildlife Service, Taronga Park Zoological Gardens and the Royal Botanic Gardens, at the State level, and the Australian National Parks and Wildlife Service and the Australian National Botanic Gardens at the Commonwealth level.

Systematic taxonomy is a basic tool for the maintenance of biological diversity. Its significance is emphasised in the Government's July 1989 Statement on the Environment.[6] It must, in turn, be supported by active research on species biology.

3 Australian Biological Resources Study Annual Report.

4 Speech by the Prime Minister, Opening of Atmospheric Research Building, CSIRO Division of Atmospheric Research, Aspendale, Victoria – 19 March 1990.

5 Cladisitics proposes a formal process for determining evolutionary relationships based on the view that taxonomic groups should consist only of members of discreet evolutionary branches or clades.

6 The Hon R J L Hawke, AC, MP, *Our Country Our Future: Statement on the Environment*, AGPS, Canberra, 1989, pp. 18–19

5.2.2 Ecology and Biogeography

Ecological research makes an active contribution to the development of effective conservation strategies. Interest in land use and management, and the uniqueness of the Australian flora, gave an early impetus to plant ecology both in CSIRO and in universities.

Ecologists are divided as to whether the focus of the discipline should be in seeking to understand the patterns, processes and short-term dynamics of the remaining relatively pristine ecosystems, or, to understand the processes of change. Research into both areas is needed.

Current ecological research concentrates on the microscale. The Ecological Society of Australia considers that ' . . . Australia is relatively weak in ecological theoreticians, understanding processes and systems research. We have a poor grasp of the long-term implications of land management practices or the processes of restoration ecology'.[7]

Biogeographers have the opportunity to examine further the macroscale to reveal basic patterns and their relationship with the environment. Also, greater emphasis needs to be placed on reaction to environmental change and its influence on population levels.

Australian biogeographers and ecologists have expanded their research output at least twofold in the past 15 years, with a substantial proportion of papers appearing in internationally refereed journals *(eg Journal of Biogeography, Journal of Ecology, Vegetation)* and the recently established *Australian Journal of Ecology*.

Australian ecological research is regarded as part of the common vocabulary of ecologists throughout the world[8] and the impact Australian ecologists have had in the international sphere was highlighted in 1984 when Herbert Andrewartha and Charles Birch jointly received the Eminent Ecologist Award of the Ecological Society of America.[9] The international reputation of Australian ecology rests with experimental and quantitative ecology but with less emphasis on the application of this work to conservation and management purposes.

While descriptive work such as biological surveys is important to nature conservation programs, more research needs to be done into the ecology, biology and genetics of introduced as well as indigenous species. Primary industry and our native flora and fauna have both felt the impact of feral animals. While the full effect of feral animals on our native fauna may never be known, it is clear that extinctions have occurred and that many small mammals and birds have been brought close to a similar fate. Introduced plants such Mimosa and Bitou Bush are destroying habitats.

Any reduction of research in the biological control of animal and plant pests and the vectors of disease would be viewed with concern by both primary producers and environmentalists.

7 Ecological Society of Australia submission to ASTEC.

8 Westoby, M., 'Comparing Australian Ecosystems to Those Elsewhere', *BioScience* Vol.38 No.8, 1988, pp. 549–556.

9 *Bulletin of the Ecological Society of America*, Vol.70, 1989, pp. 28–29.

In a submission to this Review, The Ecological Society of Australia[10] suggested the following priority areas for research in ecology:

1. *The structure and function of natural ecosystems*, including arid lands, wetlands, tropical forests and temperate woodlands. Aspects of particular concern include the roles of invertebrates and micro-organisms, nutrient cycling, and the effects of fire.

2. *The magnitude, rate and arrest of land degradation*, including soil erosion, salination, the degradation of water quality resulting from catchment alteration, and desertification.

3. *Rehabilitation after disturbance*, including research to address the techniques needed to ensure the rehabilitation of landscape, plant cover and ecosystems in degraded pastoral areas, in areas disturbed by mining and mining exploration, and in areas subjected to wind and water erosion.

4. *Planning for people*, including research addressing the capacities of ecosystems to cope with recreation and tourism (for example,in national parks and forest reserves), habitat planning in and around cities, inventories of urban wildlife and ecology of the urban environment, maintenance of patchy distributions, and urban land management.

5. *The implications of climatic change*, including ecological research to examine effects of changes in rainfall and water levels on managed lands and natural ecosystems. This includes the development, and progressive refinement, of predictions for changes of different magnitudes, to enable defensible decisions to be made at a time of considerable uncertainty. Long-term databases and details of environmental history will be needed to disentangle long-term trends from year-to-year variability and transient, local human impacts.

6. *The study of species of Australian animals and plants*, particularly those which are commercially-exploited, vulnerable, which may be indicative of ecosystem change or which have a dominant role in ecosystem function. These were highlighted as a research recommendation in the Australian Conservation Strategy.

7. *The effects of feral animals, invasive species and weeds* on natural and managed ecosystems as a basis for the sound management of natural and artificial ecosystems.

Australia is moving to conserve areas of environmental significance in many ways both at State and Commonwealth level through National Parks, World Heritage and National Estate listing. Declaration of areas will not in itself guarantee permanent conservation unless there is sufficient knowledge of the plant and animal communities contained within them to provide a basis for management. A wide range of use pressures, such as tourism, development and agriculture, demand a greater commitment of resources to plant and animal ecology. The users of these areas, whose impact can threaten the integrity of the resource, may be called on to make a greater contribution to funding of research activity in the future.

[10] Ecological Society of Australia submission to ASTEC.

It has been suggested that there is a need to establish long-term ecological research (LTER) sites in Australia such as those that exist in North America and elsewhere. Such sites could be important to the monitoring of the impact of global climate change and its effects on Australia. Remote sensing can be utilised to monitor LTER sites and information gained can then be used to validate and calibrate Imaging Spectrometer (IS) data to ultimately provide high resolution imaging. Developments in remote sensing in the 1990s show signs revolutionising such environmental monitoring.[11]

5.2.3 Marine Science Research

Based on the bibliometric work of ASTEC and the Centre for Technology and Social Change (TASC), marine science appears to be performing well. Strategic weaknesses such as the lack of a national coastal zone management plan impair our ability to apply much of the scientific knowledge Australia has. A lack of skills in areas such as marine environmental chemistry[12] was highlighted in the recent Wesley Vale pulp mill debate and further referred to in *Oceans of Wealth:*[13]

> "There are major gaps in Australia's knowledge of marine pollution . . . The absence of baseline and continuing monitoring studies for heavy metals is even more critical for organic contaminants, particularly polychlorinated biphenyls (PCBs,) . . . chlorinated hydrocarbons such as dioxins . . . and pesticides.
>
> The absence of data and the limited scientific capability which Australia has in this area is viewed with concern by the review committee."

Universities tend to cover nearshore marine biology very well, but there is less emphasis on open ocean biology. The Australian Institute of Marine Science (AIMS) is a very strong centre for reef biology, ecology and mangrove studies. The greatest strength in fish-related biology lies with the CSIRO Division of Fisheries. This Division has a predominantly practical orientation, but also conducts work on ecology, plankton and invertebrate biology. The Antarctic Division of the Commonwealth Department of the Arts, Sport, the Environment, Tourism and Territories has selective interests in Southern Ocean biology and ecology with a research funding capability through the Antarctic Science Advisory Committee.

The taxonomy of marine organisms is less well-known than that of terrestrial or freshwater organisms. Less than half the macro-faunal species of inshore habitats have been described and named. This has implications for environmental studies in the tropics or areas of special biogeographic status such as Bass Strait. Many poorly described species, particularly invertebrates, may be key indicators of environmental change.[14]

Australia offers opportunities for study of algal taxonomy and the University of Adelaide has a centre of world renown. More recently, the University of Melbourne and the University of Sydney have built up research groups in the area of algal

11 CSIRO Division of Space Research (COSSA) submission to ASTEC.

12 Australian Marine Science Association submission to ASTEC.

13 Department of Industry Technology and Commerce, *Oceans of Wealth,* a report by the Review Committee on Marine Industries, Science and Technology, 1989, pp.103-104.

14 Australian Marine Science Association submission to ASTEC.

development and physiology. Recent commercial development of algal culture for beta-carotene production arose out of basic research at the University of Wollongong and in CSIRO.

To some extent the strength of marine research in Australia lies in the latitudinal range of our coastline which provides opportunities for research in marine environments from the polar to the tropical in three oceans and seven seas. Marine resources and environments are of considerable economic and social importance to our near neighbours. The potential for Australia to export knowledge, training and scientific services to our Pacific and Asian neighbours is significant.

The application of much marine science has not in the past been defined by industrial, economic or social pressure. Recent concern to direct research efforts toward economically viable outcomes may alter the contributions of organisations like CSIRO and AIMS.

5.2.4 Atmospheric Science

Worldwide public concern about the possible impacts of the greenhouse effect on global climate has highlighted the paucity of our knowledge of our environment. It is clear that atmospheric science will assume an increasing importance in the future. The Australian Meteorological and Oceanographic Society (AMOS) has identified climate as a priority area for research in Australia.

A base for predictions of climate fluctuations on time scales of years and decades requires much more research. Such research must be based on long-term, stable and consistent observations of the global climate. Australia has an obligation, globally and in our own self-interest, to contribute to this international effort because of its relative isolation in the southern hemisphere and because any climate change is unlikely to be globally uniform.

Global climate research is big science and requires an international effort. It is currently directed through the World Climate Research Programme (WCRP), sponsored jointly by the International Council of Scientific Unions (ICSU), and the World Meteorological Organisation (WMO), and the International Geosphere–Biosphere Programme (IGBP), sponsored by ICSU. These complementary programs aim to determine the extent to which the overall climate system, extending from the physics and chemistry of the atmosphere and oceans to the biological response of terrestrial ecosystems, can be predicted. In the USA, the Committee for Earth Sciences is directing significant funding into projects of WCRP and IGBP supporting the national program on global change research.

Atmospheric research in Australia is carried out in the Bureau of Meteorology, CSIRO and the universities. There are increasingly active links between the government agencies and universities who provide higher degree training and research experience. University scientists also participate very actively in national and international research projects including the Australian Monsoon Experiment, the International Satellite Land Surface Climatology Project and the Tropical Ocean/ Global Atmosphere Experiment.

In 1989, the National Committee for Atmospheric Sciences of the Academy of Science recommended that at least one university department concerned with

atmospheric science should be built up to a level such that it is viable in the long term. The recent decision of Government to establish Cooperative Research Centres to strengthen the links between research and research training should assist in achieving this objective.

The Bureau of Meteorology Centre (BMRC) was established to support the Bureau's basic mission of advancing atmospheric science and to support the Bureau's operations and services. The research groups in BMRC cover short-range and medium-range weather prediction, climate studies including long-range forecasting, greenhouse modelling, remote sensing particularly from meteorological satellites, and tropical meteorology. Extensive field projects are carried out at a tropical climate monitoring and research station in Darwin, operated in collaboration with the Northern Territory Regional Office of the Bureau. Numerical modelling of weather and climate is a major activity of all the research groups.

The Bureau operates a Baseline Air Pollution Monitoring Station at Cape Grim. The scientific program is managed in cooperation with CSIRO, and the long-term observations at Cape Grim of atmospheric constituents are internationally recognised for their contribution to climate change research.

Meteorological research in CSIRO is concentrated in the Division of Atmospheric Research, with additional activity in the Division of Oceanography and the Centre for Environmental Mechanics.

CSIRO's atmospheric research work has been of a high calibre for a long period and is currently maintaining its international reputation. It covers the composition and chemistry of the atmosphere on a global, regional and local scale, with particular reference to climatic change and atmospheric pollution; satellite and ground-based systems and techniques for remote sensing of the atmosphere; understanding the processes occurring within or close to the boundary layer of the atmosphere (1 to 3km high); mechanisms that determine global atmospheric circulation and climate; and micrometeorology including air–sea interactions.

There are several higher education institutions which deal with some aspects of atmospheric research. Four universities offer first degrees in atmospheric science which are approved by the Bureau of Meteorology for entry into their Training School. These are the University of Melbourne (the Department of Meteorology), Monash University (Geophysical Fluid Dynamics Laboratory, Department of Mathematics), Flinders University (Institute of Atmospheric and Marine Sciences) and Macquarie University (School of Earth Science). Each of these groups focus primarily on specialist fields. The Flinders University group includes specialists in meteorology and physical oceanography, the Monash University group includes specialists in meteorology and fluid dynamics, Melbourne University's Meteorology Department emphasizes atmospheric dynamics, meteorological and oceanographic modelling and glacial studies and Macquarie University's Earth Science School includes specialists in climatic modelling, satellite data analysis and climatic impacts.

The Australian Marine Sciences and Technologies Advisory Committee (AMSTAC), subsumed by the Australian Research Council (ARC), provided stable funding for air–sea interaction studies for the best part of the past decade.

Australian Research Grant Scheme funding for atmospheric research in universities has concentrated on atmospheric physics with some grants to air–sea interaction,

atmospheric chemistry, geophysical fluid dynamics, mesoscale and tropical meteorology. The nature of funded research has varied from analytical studies and numerical modelling to laboratory and large-scale field experiments.

5.2.5 Oceanography

Australia has one of the largest ocean territories — 7 million square kilometres — and probably the lowest population density of marine scientists of any maritime nation. There are few identified gaps in research work, but the coverage is extremely thin.

Australia is traditionally very strong in geophysical fluid dynamics, and several of the world leaders in basic oceanography are Australian. This tradition has continued with the present generation of active oceanographers, enabling adequate training to be available in several universities. The CSIRO Division of Oceanography has a high international standing in aspects of basic physical and chemical oceanography.

Due to the lack of motivating economic interest, marine science research has been largely carried by scientists themselves. This has possibly led to a concentration on basic research. In the mid 1970s, as a result of increased political awareness, the Marine Sciences and Technologies Grants Scheme (MSTGS) provided very cost-effective enhancement of academic programs.

Australian performance in Oceanography has never been higher than at present. This is largely due to the stimulus of the MSTGS, the creation of several new university groups, the Australian Institute of Marine Science (AIMS), the Marine Geology Division of the Bureau of Mineral Resources, Geology and Geophysics, and the reorganisation and expansion of the CSIRO Divisions of Oceanography and Fisheries. Although Australian research remains quantitatively small in output, Australians are well represented internationally.

Major capital resources for marine research are of a relatively high standard but limited in numbers. CSIRO, the Australian Defence Force Academy (ADFA), AIMS the Australian Maritime College (AMC), and the Antarctic Division are all capable of expanding their research in oceanography. The accessibility of research vessels is reasonably well-matched to current demand although more geared to deep than shallow water research.

The field provides a stimulus for basic work in areas such as atmospheric physics, biology and geology and influences developments in climate prediction, environmental and fisheries management and mineral exploration. However, disciplinary advances are generally imported rather than exported.

5.2.6 Geomorphology

There has been a general shift to applied research in geomorphology and physical geography to meet the legislative requirements associated with development proposals.

There exists great potential for growth in the conduct of pure and strategic basic research to answer significant questions resulting from our use of resources and the consequent environmental changes.

Areas of strength in geomorphology are:

- coastal geomorphology;
- research on the Great Barrier Reef;
- global understanding of climate and sea level changes during the past 2 million years;
- arid zone geomorphology in Australia and Africa;
- understanding the environments of Antarctica and Papua New Guinea; and
- vegetational and climatic history of the tropics in Queensland, Papua New Guinea, and South East Africa.

There is also a growing link between pure and applied research related to questions of environmental stability. The problems to be resolved in land use and water supply point to the need for more focused basic research. However, collecting the base data on past climates, soils, ecology, biota and environmental processes is a major and expensive task.

While the traditional base for geomorphology lies in land use planning and hazard mitigation, the discipline has moved beyond this and can now be seen to encompass environmental issues such as salinity and erosion as well as the global issue of climate change.[15]

The Bureau of Mineral Resources is expected, under its new charter, to help improve the knowledge base needed to resolve environmental issues. New program areas in BMR's recently created Environmental Geosciences Unit will include compilation of high resolution records to provide answers to questions on the way the Australian continent has responded to climatic changes in relatively recent geological times; a coastal zone program to work on determining the geoscientific framework of the Australian coastal zone, enhancement of existing work on an inventory of the geological features of the Antarctic continent.

5.2.7 Soil Science

For a long time the environment has been regarded as an inexhaustible resource. It has been assumed that with proper farming techniques the earth will continue to be productive. It is now apparent that the long-term environmental and economic consequences of decisions about use of Australia soil resources are as serious as they are in any other industry.

The combination of fertile soils and moderate to high rainfall is not common in Australia. Most Australian soils have low fertility, are easily degraded with use and prone to erosion and salt movement. The problems of erosion, soil compaction, salination and pollution by synthetic chemicals are worsening.

There is a national responsibility to develop appropriate strategies to deal with these problems if our land resources are to continue to provide optimum productivity consistent with a stable soil base for the future. Research in this area can only be done in Australia. Work done elsewhere will not provide adequate solutions to our specific problems. In the Murray–Darling Basin, research is needed to investigate

15 Bureau of Mineral Resources submission to ASTEC.

the time scales of salination and groundwater movement as well as the mechanisms controlling recharge to aquifers. However, this is only part of the work required to address adequately the problems in the area.[16]

Australian universities are currently producing about 30 trained soil scientists per year. This is regarded by CSIRO, currently the major performer of soil research in Australia, as insufficient to maintain the profession.[17]

Particular areas of strength in Australia include soil mapping analysis, soil mechanics and soil mineralogy. Opportunities for further work, are soil erosion, secondary salination, and soil acidification.

Areas of weakness tend to relate to the interface between the physical structure and development processes of soil, and human activities. More emphasis needs to be placed on the interactions amongst soil organism chemicals especially under cultivated conditions.

In 1984, the Australian Society of Soil Science released a report, *Future Research Needs in Soil Science in Australia*. The report noted that both fundamental and applied research were relevant to Australia's problems. The report concluded that to maintain and improve Australia's soil resource as a productive base and to make the most effective use of Australia's limited water resources, a greater priority needs to be given to research into soil and landscape processes and the development of conservative soil management systems.

Eight areas of research were identified as continuing to require priority attention:

- Field pedological studies of natural soil landscape systems of national significance, to discover the principles of soil distribution and genesis, to provide a framework of understanding for other soil research.
- Revision and updating of existing soil classification schemes, development of special purpose land suitability classifications, and upgrading of soil survey procedures and standards.
- Research into all aspects of soil profile hydrology for spatially heterogeneous field situations and for major kinds of soils, under various management regimes.
- Research into the chemistry of fertilizer and pollutant interactions with soils and methods of determining economic and optimal fertilizer rates.
- Research into the basic process of land degradation, including loss of organic matter, deterioration of structure, erosion, salinisation, acidification and pollution.
- Research into the effects of management processes aimed at arresting degradation and increasing the efficiency of water use and crop production, including tillage, crop rotations, use of fertilizers and soil amendments and grazing practices.
- Research into mechanical and physical-chemical properties of soils concerned with foundation stability, water and waste product storage, sporting fields and rehabilitation of mining areas.

16 Bureau of Mineral Resources, *Murray Basin 88*, Conference Summary Report, 1988, pp.5-6.

17 CSIRO Division of Soils submission to ASTEC.

Soil degradation due to vegetation loss is a now recognised problem in Australia. Measures to mitigate such effects should include considerably more effort to develop plants as a major tool in rehabilitation.

Soil science has tended to concentrate on geological and biological aspects but is now being augmented by researchers from the fields of applied mathematics, mechanics, physics, colloid and surface chemistry, and computer science.

Considerable opportunities exist for research in areas of land degradation associated with mining. CSIRO regards the following as critical:[18]

- mineral weathering and environmental pollution;
- rehabilitation and revegetation of mine wastes;
- dewatering and stabilisation of tailings;
- land disposal of toxic effluents and process waters;
- pollution from industrial fallout, including organic compounds, acids and heavy metals.

These areas of research are often poorly funded and are accorded low priority by universities and mining companies. Cooperative work done by CSIRO Division of Soils and Ranger Uranium Mines suggests the possibility of more effective approaches to these problems.

5.2.8 Limnology

It is impossible to ignore the influence that land management practices have on the quality of our fresh water. The quality of 90 per cent of fresh water is determined by its passage through and over the soil.[19] The central issue is how water, solids and solutes react with land, and the extent to which that reaction renders toxic materials innocuous.

CSIRO Division of Soils suggests that resolution of such problems depends on greater knowledge of:

- soil surface energy and water balance;
- hydrodynamic dispersion and chemical reaction;
- soil biological activity and "control" of organics;
- chemistry of heavy metals in soils;
- chemistry and mobility of virus, organics and bacteria;
- reaction chemistry in anaerobic and intermittently anaerobic soils;
- chemistry of phosphate; and
- changes to the water balance due to deforestation which is producing salinity in many areas.

The study of fresh water systems has developed strengths in Australia due to its importance in management of unreliable water resources. Limnology draws on extensive knowledge of biology of fresh water organisms, on chemistry of water and sediments and on general hydrology of rivers and lakes.

18 CSIRO Division of Soils submission to ASTEC.

19 CSIRO Division of Soils submission to ASTEC.

The Australian Water Resources Advisory Council (AWRAC) provides research funds for limnology and there is some confidence this will continue. Recent achievements include, *Water Purification by Electro- oagulation* a project carried out by CSIRO in conjunction with *Clearwater Australia Pty Ltd* and a study of the *Ecological Processes in Saline Ecosystems* by the University of Adelaide. This work has been a catalyst in the recent formation of an International Consortium for Salt Lake Research.

5.3 AN INDICATOR BASED ASSESSMENT

The ASTEC report *Profile of Australian Science*[20] dealt comprehensively with the state and potential of basic research in Australia. The information derived from it is essentially quantitative. In addition, information arising from consultations with active researchers, submissions to the Study and published reports, form the basis of comment on discipline based research as it relates to environmental research.

An indicator based evaluation is a quantitative and qualitative assessment of the output and quality of scientific research based on papers published in internationally refereed journals. This is commonly referred to as bibliometrics. Bibliometric or literature based assessment examines at Science in categories defined by Science Citation Index[21] (SCI) and Computer Horizons Inc.[22](CHI) (Appendix V.A)

While bibliometrics has the advantage of providing a numerical basis for discussion, it is important to bear in mind both the age and the size of the data set. Published output should not be regarded as the only measure of performance as some sub-fields of science are not highly productive in that regard. Bibliometrics is therefore only a guide to performance and as such should be used advisedly. Difficulties with bibliometrics as an analytical tool are discussed in Ch 2.2.

The science fields of Biology and Earth and Space Science contain the research most relevant to environmental research. The breakdown of the fields into subfields only provides a very general view of scientific performance. For example, Taxonomy is an important area of environmental research but is not included as either a field or a sub-field in *Profile of Australian Science*. The Space Science component of the Earth and Space Science field was not considered to be relevant to this Review.

Chemistry is a discipline that would have been useful to consider as an acknowledgement of its value as an analytical tool. A difficulty here lies in the small percentage of the total chemistry that is specific to environmental research and how inclusion of the discipline as a whole could distort our impressions. Although Chemistry was not included in this study it is clearly an important feature of much environmental research.

20 Australian Science and Technology Council, *Profile of Australian Science*, AGPS, 1989.

21 *Science Citation Index* (SCI) is produced in the USA by the Institute for Scientific Information. It is accessed in Australia through DIALOGUE.

22 *Computer Horizons Inc* (CHI) produces the Science Literature Data Bank using as raw material publication data from SCI.

5.3.1 Summary of the Biological Sciences

In summarising the Biology literature contained within the international journal sets of SCI and CHI, *Profile of Australian Science*[23] found that:

> "While Australia's total share of world publications fell by 3.5% between 1980 and 1984, its total share of publications in Biology grew by 8.2%. In comparison, Japan's share of Biology publications grew by 7%, Canada by 4%, the UK and US both by 1%. The shares of France and Germany fell by 5% and 9% respectively.
>
> In terms of the number of citations received for Biology papers, Australia's share increased by 9% between 1976 and 1980 and 24% between 1980 and 1984. The only major country to show an increase in citation share between 1980 and 1984 was the US which improved by 3%. So Australia's share of world publication output in Biology has been increasing steadily between 1975 and 1984, and the share of citations these papers have received is growing at a faster rate, indicating an increasing impact or influence."

Between 1975 and 1984, Australian researchers contributed between 860 and 980 papers on Biology each year to international journals -- a 14 per cent growth in output. Australia produced approximately 4 per cent of the world's papers on Biology, roughly double that for all other Australian fields of science. Leading areas of research by publication count, share of international output, share of international citations and above average citations for 1984 are shown in Appendix V.B.

These data indicate that Australia has significant strength in **Botany, Marine Biology and Hydrobiology** also shows a strong citation performance. **General Zoology** has a small output of papers but a creditable citation performance.

5.3.1.1 Summary of Biological Science Disciplines

The areas of Biology summarised here include General Biology, General Zoology, Miscellaneous Zoology, Marine Biology and Hydrobiology, Botany, Ecology, Entomology and Miscellaneous Biology.

In international terms, **Botany** is one of the strongest performers in Australian science. Output increased by 53 per cent between 1975 and 1984. Research in Botany produced 23 per cent of Australian Biology papers in 1975. This increased to 31 per cent by 1984. In absolute terms, the growth was from 195 to 299 papers. This represented 3.25 per cent of the Botany papers in internationally refereed journals in 1975 and 4.17 per cent in 1984.

Marine Biology and Hydrobiology has doubled output from 48 papers in 1975 to 100 in 1984. It now contributes 10 per cent of Australia's output in biology and 5.5 per cent of the world's papers in Marine Biology and Hydrobiology.

General Biology accounts for 60 per cent of the papers published in the Australian Journal of Science Series, 20 per cent of those in Search and 15 per cent of those in Science. Australian papers in the sub-field have increased from 74 papers (5.12 per cent of the total) in 1975 to 101 papers (6.97 per cent) in 1980, and 54 papers or 4.26

[23] *Profile of Australian Science*, 1989.

per cent in 1984. The Australian share of citations is declining faster than the publication share indicating that less significant Australian work is being published in General Biology journals.

Publication data in journals such as *Annuals of Applied Biology, Cryobiology, American Anthropology and Journal of Experimental Zoology* indicate that the Australian contribution to **Miscellaneous Biology & General Zoology** is insignificant.

Miscellaneous Zoology includes a high proportion of the Australian work in comparative physiology, an area where Australian researchers are performing well. While the output is only around 50 papers per year it is above the Australian average for all fields of science and growing. The work that is being done is achieving a good citation share suggesting a greater influence.

Australian papers published in **Ecology** over the decade have grown from 25 to 45 and our share of the total from 2.33 per cent to 3.06 per cent indicating that this is becoming a strong area of research. However, citation performance is lagging. A cursory examination of the US publications, *Ecological Monographs and Ecology*, and the British publications, the *Journals of Applied Ecology, Animal Ecology and Ecology*, show publication levels around 5 per cent.[24] With Australian ecologists preferring to publish in Australia, journals these figures probably understate the overall position of Australian ecology and are inevitable in an indigenous science.

Australian output in **Entomology** dropped by half between 1975 and 1980 and then recovered to the 1975 level of 50 papers in 1984. The total is not significant and the citation share is declining so Australian entomological research would appear to be losing its international influence. Cutbacks in CSIRO Division of Entomology could hasten this decline.

Figure 5.1 Summary of Publication Share — Biology

Above world average share of input	**Fast Relative Growth**	**Fast Absolute**
Marine Biology	Marine Biology	Marine Biology
	Ecology	Ecology
	Botany	Botany
Below average share of world output	**Relative Decline**	**Absolute**
General Zoology	General Zoology	—
Misc. Zoology	Misc. Zoology	—
Entomology	Entomology	Entomology
	Misc. Biology	Misc. Biology
	General Biology	General Biology

[24] Pers. Comm. 1990, Mark Westoby, Associate Professor, School of Biological Sciences, Macquarie University.

5.3.2 Summary of Earth & Space Science

As explained in Section 2.2, ASTEC identified the Earth component of the Earth and Space Science field as containing a high percentage of environment related research.

Australian research performance in the field of Earth and Space Science has been strong in the decade ending 1984. The field is displaying a higher general level of activity with a 30 per cent increase in national output. The growth in output has clearly had an impact on citation performance with the Australian share increasing by 27 per cent from 1975 to 1984 compared with a 12 per cent increase for Germany, 4 per cent France and 3 per cent for Japan.

In 1984, this increase translated to 0.3 per cent of the world's papers in the field. Within this field, Earth Science produced 2.79 per cent of national research output compared with the strongest other field in Australia, General and Internal Medicine at 6.8 per cent (See Appendix V.B).

5.3.2.1 Summary of Earth Science Disciplines

Meteorology & Atmospheric Science output was unchanged between 1975 and 1980 but has shown some acceleration towards the end of the decade. A 74 per cent increase in output of this area over this period makes it, marginally, the fastest growing area within Earth Science with a strong citation performance.

Oceanography & Hydrobiology has been doubling its output every five years or so but from a very low base. As a result of this growing output the Australian percentage of publication share has grown from 0.46 per cent in 1975 to 1.85 per cent in 1984. Citation share is lagging behind the output share but this is regarded as normal in such a fast growing area.

Geology would appear to be performing well. In the period 1975 to 1984 papers produced increased from 77 to 94, an increase of 22 per cent against an international increase of 12 per cent. A measure of the growing influence of Australian geology is reflected in the fact that a 5.24 per cent of publication share has achieved 5.67 per cent of the citations.

Soil science could be considered a subset of Earth Science but is not sufficiently defined to allow any useful observations about its performance. Strengths and weaknesses in soil science are considered in Section 5.2.7.

5.3.4 Summary of Marine Science

In 1988, the Department of Industry, Technology and Commerce (DITAC) commissioned the Centre for Technology and Social Change (TASC) to provide some background information for the review of Marine Industry, Science and Technology in Australia. The resulting report provides some insight into the performance of research in the field of Marine Science.[25]

[25] The Centre for Technology and Social Change (TASC), *An Indicator-Based Profile of Australian Marine Research Activity, 1989.*

Figure 5.2 Summary of Publication Share — Earth and Space Science

Above world average share of output	Fast Relative Growth	Fast Absolute
Geology	Geology	Geology
—	Oceanography & Limnology	Oceanography & Limnology
—	Meteorology & Atmospheric	Meteorology & Atmospheric
—	Earth & Planetary Science	Earth & Planetary Science

In commenting on the strength of Marine Science, the report stated that:

> "Available data suggest that Australian [marine] research is of world class, is having an international impact, or generally represents a relative international advantage in these areas: tropical marine science in general, marine biology, ecology (particularly of the coral reef), marine geoscience, and physical oceanography. Other potential areas are marine microbiology, productivity and fluxes, fisheries management, environmental pollution and remote sensing."

ASTEC concluded that marine research in Australia receives approximately 6 per cent of the research budget, of which Commonwealth provides 96 per cent[26] of the funds. This is higher than in any other areas of science. The strength of the research resides mainly in CSIRO, AIMS, and BMR.

In absolute terms, Australian marine R&D is small compared with the UK, USA and Japan but still ranks among the top five in the OECD. An effective core capability has been established in a number of areas such as marine biology, marine ecology, tropical marine science, and remote sensing techniques, as well as areas of physical oceanography and marine geoscience.

[26] Australian Marine Sciences Association submission to ASTEC.

CHAPTER 6

COMMENTARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This Review addresses those aspects of the terms of reference for the Study of Environmental Research in Australia which required ASTEC to:

> " . . . review the organisation of, and effort expended in, environmental research in Australia ..." and ". . . assess the status of environmental research (including research training) in Australia . . ."

Essentially, the Review has been a data collecting exercise which has aimed to describe the area of environmental research. It does not attempt to address the more qualitative issues raised by the terms of reference. These will be the subject of the second stage of the Study, the results of which will be presented to the Prime Minister at the end of 1990 in a report entitled *Environmental Research in Australia — The Issues.*

6.2 COMMENTARY ON THE REVIEW PROCESS

This Review has attempted to extract data at a analytically useful level of resolution in a poorly defined research area. Easily accessible data at this level were available from ABS only for the financial years 1984–85 and 1986–87. Data before 1984 could not be retrieved to the new ABS computer system. The 1988–89 data were not available before the conclusion of this report. Therefore, interpretation of the available ABS data must be constrained by the possibility that the most recent information, when it becomes available, may not support trends discernable from the earlier years. Also, the impact of the additional funds foreshadowed in the Government's 1989 Statement on the Environment cannot be assessed at this stage.

It is important to note that the figures contained in this Review are a minimum data set. They only reflect easily identified environmental research and do not include environmental research undertaken in pursuit of other socioeconomic objectives (SEOs).

In consultation with ABS, ASTEC selected a set of socioeconomic objectives which were considered to best reflect ASTEC's definition of environmental research. These are described in detail in Chapter 4. This SEO set is not exhaustive, does not always accord with reality, and did not reflect ASTEC's analytical requirements as a user of the data. SEOs could be improved in several ways to describe environmental research more accurately and to better meet the analytical needs of users.

ABS, in consultation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and other interested agencies (including ASTEC itself), is currently undertaking a review of its statistical classification used within the R&D survey to present a more precise picture of, amongst other things, environmental research. The revised classification provides for data collection at a fourth level of resolution not possible previously. An explanation of the various levels at which ABS data has been collected to date is at Section 2.2.

Even with the development of revised SEO classification agreed to by all user groups, there will remain questions:

- whether the demand for R&D data at the fourth level is sufficient for ABS to commit the necessary resources to collection; and
- whether respondents such as institutions of higher education which already have difficulty finding the resources to meet the data collection demands of the Commonwealth government are willing to cooperate.

Data reflecting the contribution of private enterprise to the environmental research effort is unsatisfactory. Because ABS private enterprise R&D statistics are not collected by socioeconomic objective they are not amenable to extraction of information on private enterprise environmental research activity. Furthermore, it is difficult for private enterprise to differentiate between research and experimental development, and product development in a way which would allow useful comparisons with public sector data. Another constraint on collection of truly representative statistics is the commercial-in-confidence nature of much private enterprise R&D.

It is unfortunate that the contribution of private enterprise to Australia's environmental research effort cannot be estimated. Given the private sector's generally positive response to the increasing community concern about environmental responsibility, a substantial measure of research performance is excluded because private enterprise R&D is not classified by socioeconomic objectives.

Attempts to assess the status of Australian environmental research are plagued by the subjectivity of practitioners and the shortcomings of more objective means of measurement. In this Review, ASTEC considered bibliometrics as a instrument for such measurement. The limitations of bibliometrics include the dated view it can give, the very small numbers on which percentages are often based and the inherent problems in basing statistical analysis on who authors choose to cite in publications. These limitations are compounded by the fact that environmental research tends to be multidisciplinary, drawing on the traditional sciences across a range of disciplines for particular applications.

6.3 COMMENTARY ON THE ENVIRONMENTAL RESEARCH DATA

Despite the difficulties outlined above, the available quantitative and qualitative information about environmental research in Australia makes it is possible to draw a number of conclusions about its organisation and funding.

In 1986–87, the Commonwealth Government funded 84.1 per cent of all environmental research in Australia of which it performed 56 per cent. Most of the research activity took place in major Commonwealth research organisations such as CSIRO and ANSTO and institutions of higher education. This is of interest when considered in the light of the Commonwealth's limited constitutional powers in regard to the environment. State and local governments funded 13.6 per cent of environmental research while performing 14 per cent.

Also, it is clear that the Commonwealth is the major supporter of environmental research conducted in institutions of higher education. These institutions supplement Commonwealth funds with those from private enterprise and overseas sources.

State Governments perform surprisingly little research of their own given their more immediate responsibilities in regard to environment protection. It is particularly disturbing that State government investment in environmental pollution research and soil science appears to be decreasing. The higher performance level in the Commonwealth sector probably reflects the Commonwealth tendency to take responsibility for research in areas of national significance such as atmospheric and marine research, or areas which require larger scale or expensive equipment such as Antarctic research or research relating to uranium mining in the Alligator Rivers Region.

The pattern of performance by research type indicates the primary concerns of each performance sector. State Governments, for example, with primary responsibility for environmental monitoring and control, direct the majority of their environmental research funds into applied research. The Commonwealth, on the other hand, has been increasing its expenditure on pure basic environmental research, in contrast to the national trend.

The low relative expenditure on environmental experimental development indicated by the data is a reflection of the nature of the science in question, which is as likely to lead to improved management processes as to the development of new or improved technologies.

Australia performs more research in areas dealing with the natural environment than it does in those dealing with environment protection and pollution control. It should not be surprising that a nation which relies as heavily as Australia does on its natural resources should invest a relatively high percentage of its research effort in the natural sciences.

The view, frequently voiced by the conservation movement and academic researchers, that funding of environmental research is declining is not supported by

the data which suggest that in real terms funding for environmental research remained steady between 1984–85 and 1986–87. The view appears to be a reflection of two factors:

- Awareness of environmental problems has increased considerably in the past decade and there is a perceived need for more research across a broader spectrum of issues. In consequence, the environmental research dollar is being spread more thinly than in previous years.
- Pressure for instant answers to an array of high profile problems such as nomination of the Queensland Wet Tropics to the World Heritage list, and the Franklin Dam dispute, has drawn research scientists and funds away from fundamental, long-term research in taxonomy, entomology and soil science (see Chapter 5).

6.4 CONCLUSIONS AND RECOMMENDATIONS

6.4 1 Adequacy of Data Sources

Although the recommendations in this report arise from the difficulties encountered in the identification, organisation and management of environmental research data in Australia, the suggested remedies to the specific problems have implications for the broader area of scientific research data management.

6.4.1.1. Research In Progress Databases

The public sector allocates substantial funding to environmental research in Australia and it would be reasonable to assume that the information about that research would be easily accessible to the sponsors.

The decision to survey the research in progress databases, outlined in Chapter 2, and to develop a database of Environmental Research in Progress was based on this assumption. Contrary to expectations, the resulting Compendium of Environmental Research in Progress was of minimal assistance to ASTEC in meeting its Terms of Reference.

There are several issues which arise out of ASTEC's experience in its use of research-in-progress databases to compile *Environmental Research in Australia — A Compendium*.

Firstly, the purpose and function of research-in-progress databases must be addressed. The data held are limited. For example, although each database describes the research being performed, where it is being conducted and by whom, other significant information is not collected.

Without some estimate of research effort and expenditure it is difficult to judge the size and significance of a project. Also, it would be useful to know the sources of funding for individual projects. Such information would have allowed a better estimate of private sector contribution to environmental research than has been possible in this Review. It would also have permitted a more meaningful comparison between categories of environmental research than was possible using simple numerical counts of projects.

Secondly, the existing research in progress databases use software with restricted capabilities. To locate information in the current environment users must be experienced, know which database they need to access and have a clear idea of what they are looking for before they attempt to use the system. The existing databases do not allow analysis of such key issues as research effort, even if the data were available for each item.

The current maintenance of several entirely separate databases of research in progress, not all of which are mutually exclusive, must be questioned. There does not appear to be any justification for a proliferation of research in progress databases when a single integrated database would fulfil the function more efficiently.

Thirdly, the relevance of the research in progress databases should be more closely considered. While there is no doubt that the databases contain useful research information, usage reports indicate that these databases are used very infrequently on-line by public administrators, and hardly at all by the tertiary and private sectors. Obviously this is an issue which needs to be examined; if the problem is difficulty of access, preference for hard copy information or inaccuracy, it needs to be redressed; if the problem is lack of relevance to decision makers and researchers the nature of the databases must be questioned.

The most critical issues are discussed below.

(i) Inclusion of research projects in the CSIRO research-in-progress databases is random. A number of the major industry research corporations now require that applicants for grants search relevant databases before submitting applications to reduce the risk of duplication of research funding. Newly funded projects are automatically included in the appropriate database. Some of the major public sector research bodies, such as the Australian Institute of Marine Science, automatically incorporate research projects into the relevant database. However, there is no way of knowing what has not been included, particularly when completion of the registration form is often the responsibility of the project manager, not the funding body itself.

(ii) The research in progress databases are not integrated with national statistical collections. The Australian Bureau of Statistics publishes figures for R&D funding in Australia by socioeconomic objective. However, registers of funded research do not indicate socioeconomic objectives or fields of science — a relatively simple exercise which would make them compatible with the ABS statistical collection.

CSIRO has recently moved to a more sophisticated method of recording its research program and the resources devoted to it. Each CSIRO project is classified according to field of science and socioeconomic objective. The system is flexible enough to allow for a percentage allocation between classifications which gives a more accurate indication of corporate research activity. It also means that when CSIRO indicates a dollar allocation to environmental research it includes research undertaken across a range of its Institutes and for a number of purposes. Since the fields of science and socioeconomic objectives are aligned with those used by ABS, any CSIRO statistical analysis can be compared to national data.

(iii) Responsible decision making about resources is dependent on availability, among other things, of the results of high quality research. Several attempts are being made at the national level to develop systems that are able to integrate a range of data sets, including research activity, into a useful information base for decision makers. Both the National Resource Information Centre (NRIC) in DPIE and the Environmental Resources Information Network (ERIN) in DASETT have identified geographic information systems (GIS) as the most appropriate way to achieve this. It is essential that any scientific research database be compatible with such systems. A first step would be to ensure geocoding (that is, a geographic focus or location) of research where this is appropriate.

ASTEC recommends that:

(a) All scientific research funded by the Commonwealth Government be included in a national research-in-progress database as a condition of grant.

(b) Information collected on research-in-progress include research effort, expenditure and source of funds as well as an indication of the socioeconomic objective and field of science of the research to enable cross referencing with ABS statistics and, where appropriate, an indication of its geographic location or focus to enable integration with geographic information systems (GIS) as they are developed.

(c) Consideration be given to making the existing research-in-progress systems more user friendly and relevant to the decision making needs of the sectors which support them.

6.4.1.2. *Australian Bureau of Statistics Socioeconomic Objectives*

ASTEC found the existing Australian Bureau of Statistics socioeconomic objectives (SEOs) used to classify environmental research extremely difficult to use. By far the largest single category was one called *Other Environment: Natural*. There is no further breakdown of this category. It is not possible to determine whether the majority, or any, of this research is carried out into vegetation patterns, extinction of native mammals or the life forms in our inland waterways.

In addition, soil research, which is not unnaturally grouped under Agriculture is described as *Agriculture: Soils (conservation, science etc)*. It is impossible to tell from this category how much Australia is investing in describing soil characteristics, soil mapping, erosion control or salinity research.

While it is clear that private enterprise performs a percentage of environmental research relevant to its corporate goals, there is no acknowledgement of this in the data classifications. The environmental research associated with the extraction of energy minerals is quantified, but that undertaken in other mineral areas or in the manufacturing industry is not.

As part of a general review of its statistical classification systems the Australian Bureau of Statistics is reviewing its socioeconomic objectives (SEOs). This review should ensure that the needs of the user agencies such as DPIE, DASETT and DITAC are taken into account. Attention should also be given to how data collected through the ABS can be made most useful to those mechanisms established to improve the integration of environmental information into the decision making process ie. ERIN, NRIC and the Resource Assessment Commission.

The ABS socioeconomic objective classification is essentially a three level hierarchy. Data are collected at the third level but usually published at the more aggregated first and second levels. An exception is the Energy SEOs for which data are collected to a fourth level. Given the importance of the debate on the environment at the moment, and the paucity of data available , it would be appropriate for ABS to undertake a similar fourth level data collection exercise for environmental research. Research-in-progress databases would then reflect the statistical information collected by the ABS, thus providing a useful tool for those developing researching funding policy.

Astec Recommends that:

(d) The Australian Bureau of Statistics recognise the usefulness of fourth level collection of R&D data to guiding policy and decision making on the nation's investment in research generally and environmental research in particular and construct its R&D survey accordingly.

(e) If collection of R&D data at the fourth level is not possible ABS should ensure that the third level classification of R&D socioeconomic objectives is specific enough to identify clearly environmental research, including that which takes place as an adjunct to other types of research.

(f) Notwithstanding the difficulties private enterprise might have in completing such a survey, that sector be asked by ABS to identify the environmental research it undertakes, either directly or as an adjunct to its other activities.

6.5 ORGANISATION OF RESEARCH INFORMATION

Recent public debate about natural resource use decision making processes points to concerns about mechanisms for integrating scientific research into the political process.

One of the identified problems is the disaggregated nature of environmental science. There are very good reasons for environmental research to be carried on by, or for, the agency or organisation with immediate concerns to be addressed. However, there is presently no simple, established mechanism for accessing data about environmental research-in-progress or drawing conclusions about its nature, or the effort expended.

Further consideration must be given to increasing investment in information systems such as the National Resources Information Centre and the Environmental Resources Information Network, which although time consuming and expensive to establish, have the potential to make long-term improvements in the quality of advice available to government decision makers.

It is essential that key Commonwealth Departments such as Primary Industries and Energy (DPIE), the Arts, Sport, the Environment, Tourism and Territories (DASETT) and Industry, Technology and Commerce (DITAC) together with major agencies such as the CSIRO, ANSTO, AIMS, the Resource Assessment Commission (RAC), the Australian Bureau of Statistics (ABS) and the Australian Land Information Group (AUSLIG), coordinate their information gathering activites in a consistent manner. This coordination should reduce costs by avoiding duplication. Any such system should be compatible with ABS and CSIRO data. ASTEC views with concern the proposal by RAC to establish its own database when there is already such a proliferation of unconnected and incompatible data sets.

ASTEC recommends that:

(g) representatives of the major Commonwealth departments and agencies (such as DPIE, DASETT, DITAC, SCIRO, ANSTO, AIMS, RAC, ABS AND AUSLIG) cooperatively analyze the problems of providing databases relevant to the needs of decision makers and develop a policy and procedure to ensure compatibility among databases, improve access to data for decision makers and reduce the proliferation of existing databases.

CHAPTER 7

THE ROLE OF ENVIRONMENTAL RESEARCH IN PLANNING AND DECISION MAKING

This Review has attempted to describe the performance and funding of environmental research in Australia. It has not addressed the larger issues raised in the Terms of Reference relating to the integration of such research into the policy development and decision making process.

The Review is a starting point for the consideration of these issues and others related to improving education, training and information exchange in the area.

The second stage of the Study, *Environmental Research in Australia — The Issues,* will address the remainder of the Terms of Reference.

The issues listed below have been developed by the ASTEC Working Party members in an attempt to refine the significant questions. The issues listed are neither prescriptive nor exhaustive and should be seen as a starting point for discussion.

The potential for environmental research to contribute to the resolution of major environmental issues

How necessary is environmental research to the process of government decision making? It could be argued that it is necessary but not sufficient to the resolution of environmental issues. It is frequently difficult to quantify the significance of environmental research (as opposed to socioeconomic aspects and political considerations) to the final decision. Often, the contribution of environmental research to the resolution of major environmental issues is through the demonstration that certain options are incompatible with the sustainable function and use of natural resources.

The effectiveness of environmental research in contributing to Government decisionmaking

Some underlying concerns about utilising environmental research for effective decision making include:

a) Deficiencies in environmental research

- Australia's large size and dispersed population complicates the formation of a single, complete environmental research database.
- Existing predictive environmental models may not provide adequate information or cover the range of environmental types.

- Environmental research may be reactive rather than proactive.
- The separation between the biological/physical components, and the social/economic components of the environment may be a major problem for decision makers.
- Australia has no organisation with an integrated biological, physical, social and economic approach to the environment which also examines outcomes. The lack of an adequate interdisciplinary research and development base may be a deficiency in Australian environmental research.
- Is the research being done cost effective?

b) *Regulatory aspects of environmental research*

The need to comply with State environment legislation and regulations generates much of private industry environmental research. Does such legislation ensure high quality research?

An important category of environmental legislation is environmental impact assessment (EIA). Issues to be considered in this type of research are: fluctuations in the quality of the research; lack of data access; and the lack of monitoring programs (which test compliance with commitments).

c) *Communication of research results to governments*

Research may not be adequate for decision making purposes. Research available may be adequate but not focused. Techniques for integrating environmental research with economic issues in the process of decion making may not be adequate.

The manner in which research results are conveyed to decision makers can enhance or diminish the benefits of the research effort. Do existing administrative arrangements and government decisionmaking processes encourage effective use of environmental research?

Another consideration is the ability of governments — given environmentally sound advice — to mobilise the necessary resources to implement environmental research results.

d) *Global environmental issues — Australia's role*

Many of the solutions to environmental problems require global action. Research in areas such as cross border pollution and climate change require an international perspective. Can Australia benefit by being a key player in the global environmental research community?

Australia's training needs in environmental research

Is there a need for excellent generalists in the field of environmental research? Should scientists be expected to acquire general environmental qualifications? Are graduates with the right mix of skills, particularly practical skills, being produced in sufficient numbers? The problems of poor recruitment of scientists and the rapidly ageing structure is very important in the environmental sciences.

Many Australian universities are not adequately structured to stimulate or facilitate essential interdisciplinary studies. The traditional university departmental structure may not be the best for developing either the teaching or research strengths.

The appropriateness of environmental research and the most effective means of enhancing relevance to decision makers

Are there major gaps in Australia's coverage of environmental research? Preliminary observation suggests that Australia is weak in ecological theory, process understanding and systems research. It also suggests that Australia lacks strength in research into the environmental impact of pollutants on the land, waters and air.

Is a measure of the quality of environmental research required? Establishment of criteria for assessing quality is difficult. On the basis of international peer comparisons Australia does have world leadership in some aspects of environmental research, particularly in CSIRO and the Bureau of Meteorology, and, to an extent, in the Australian Institute of Marine Science, the Universities and the Museums.

One way to assess quality is through feedback from government decision makers as to the usefulness to them of the research and researchers.

Is the most effective means of enhancing quality to stimulate the best people to enter the research and teaching fields? This has funding implications. How can this be done? Adequate funding will also ensure interaction with world peer groups. Overseas peer group participation has been reduced over the past few years due to financial restrictions. What does this mean?

The overall level of government funding and the means by which environmental research is best funded

Many environmental research programs require long-term commitment, monitoring and measurement. The capacity of institutions to undertake 10 to 20 year research programs is declining because research funding is largely short-term.

A problem with environmental research funding is the lack of continuity of funding. Once baseline data becomes available for a particular area, funding is likely to cease and be directed to other areas where such data is absent.

One model for environmental research funding is a small group of scientists established in a government department disbursing 'seed' money to scientists for research projects through a tightly directed, competitive, peer-assessed program.

There is a view that federal funding mechanisms support research which is predominantly 'production oriented'. If this is so it perpetuates an imbalance amongst production, development and conservation research which needs to be considered in total, rather than separately.

Setting our environmental research priorities

Australia's environmental research priorities are being determined by a number of factors including political ones.

The relevance of research is an important consideration. Are resources being used in areas which address the major problems and opportunities?

It would seem imperative that a national approach is taken to meet research priorities. A national approach would, inter alia, need to take account of priority determination processes within and between Federal Government and State Governments and industry, and mechanisms for coordination.

The extent of industry's role in undertaking environmental research

Industry is likely to take a greater role in undertaking environmental research in the future in order to be proactive rather than reactive. The variable quality of Environmental Impact Statements and monitoring programs is presently a handicap to industry pursuing development in an environmentally sensitive manner.

The organisation of and access to private sector databases could be dramatically improved (despite restrictions because of commercial confidentiality).

The dearth of environmental data necessitates a greater industry role in environmental research, particularly as an integral element of development planning from the earliest possible stage (a lesson arising from the Wesley Vale pulp mill).

The lessons Australia can learn from overseas experience of integrating environmental research findings into government decisions

Possibly the most effective system in the world for collecting environmental data and integrating it into the decision making processes of government is in Canada. The Canadians have solved their primary data collection problems by geocoding the primary data, permitting a range of environmentally sensible analyses for all possible users. The systems which facilitate such data organisation have been in place for over a decade. Canada is in a position to apply fundamental research to natural resource issues. Are there other countries providing useful models for Australia?

The importance of research on such matters as value systems, lifestyles, resource economics and equity in resolving environmental conflicts

The lack of a clear understanding of the relationship between the biological and physical components as well as the social and economic components of the environment is a major impediment to resolving environmental conflicts. The social and economic components may turn out to be the most important.

Case Studies

In the second stage of the ASTEC study of environmental research in Australia, the Working Party is adopting, in part, a case study approach as a means of exploring the issues to their fullest extent. The case studies being investigated are likely to include:

- Wesley Vale pulp mill;
- Wet Tropics;
- Murray-Darling Basin;
- La Trobe Valley Air Shed Study;
- Great Barrier Reef Marine Park;
- Southern Blue-Fin Tuna;
- Coastal zone management; and
- Bauxite Mining in the Darling Ranges.

It would seem imperative that a national approach is taken to meet research priorities. A national approach would, inter alia, need to take account of priority determination processes within and between Federal Government and State Governments and industry, and mechanisms for coordination.

APPENDIX I.A

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APPENDIX I.B

MEMBERSHIP OF THE ENVIRONMENTAL RESEARCH IN AUSTRALIA WORKING PARTY

In accordance with ASTEC's usual procedures, this Review was prepared by a working party. Drafts of the Review were considered by the full Council prior to final approval. The working party consisted of three members of ASTEC and four coopted members:

Mr Michael Davidson, OBE (Convenor)
Grazier

Dr Joe Baker OBE FTS
Director
Australian Institute of Marine Science

Professor Bob Gregory, FASSA
Department of Economics
Australian National University

Professor Henry Nix, FAIAS
Director
Centre for Resource and Environmental Studies
Australian National University

Dr Joe Landsberg
Deputy Chief
Division of Wildlife and Ecology
CSIRO

Mr Peter Laver
Corporate General Manager
Technology and Development
BHP Transport Limited

Dr Brian Robinson
Chairman
Environment Protection Authority of Victoria

The working party met eight times between June 1989 and May 1990. There were several secretaries to the working party during that period: Gordon Drake (April 1989 – August 1989), Andrew McCredie (August 1989 – November 1989) and Christine Lawrence (from November 1989) who were supported at various stages by Deane Larkman and Patricia Berman from the Office of ASTEC, Fred Howe from the Department of the Arts, Sport, the Environment, Tourism and Territories and Bill Curnow.

APPENDIX II.A

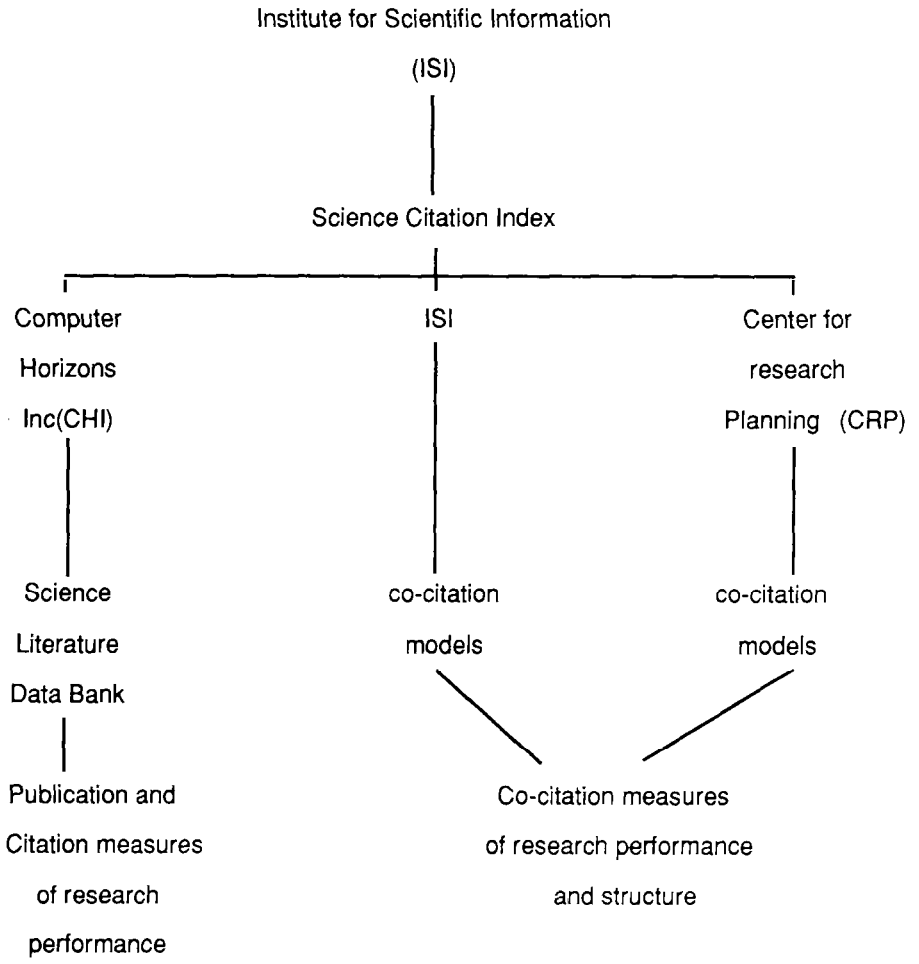
CONSULTATIONS

Mr Simon Balderstone	Environment Consultant, Graham Richardson (then Minister for the Environment)
Dr Michele Barson	Bureau of Rural Resources
Mr Kevin Bryant	DITAC
Prof Ralf Buckley	Centre for Environmental Management Bond University
Dr Gordon Burch	BRR
Ms Chris Burnup	Business Council of Australia
Ms Inara Bush	Australian Institute of Marine Science
Mr Warwick Conn	Tertiary Statistics Section, DEET
Ms JoAnne DiSano	Natural Environment Division, DASETT
Mr Philip Eliason	National Farmers Federation
Mr Tony Ermers	CSIRO, Information Services Unit
Mr Andrew Garran	Coal and Minerals Division, DOPIE
Mr Trevor Germyn	Australian Bureau of Statistics
Dr Roy Green	CSIRO Institute of Natural Resources and Environment
Ms Sue Harvey	CSIRO, Information Services Unit
Dr Ted Henzell	CSIRO Institute of Plant Production and Processing
Dr Paul Herbert	Environment Assessment, DASETT
Ms Joanna Hewitt	Land Resources Division, DPIE
Mr Ric Humphries	Australian Conservation Foundation
Dr David Johnson	NRIC
Dr Jones	Bureau of Rural Resources
Mr Graeme Kelleher	Great Barrier Reef Marine Park Authority
Mr Peter Kennedy	DASETT
Dr Guy Kretschmer	Climate Change, DASETT
Mr Ian Lamb	Environment Assessment, DASETT
Mr David McCarthy	Australian Research Council
Mr Terry O'Brian	Environment Assessment, DASETT
Mr Tony Ockwell	Australian Bureau of Agricultural and Resource Economics, DOPIE
Mr Dennis O'Neill	Australian Mining Industry Council
Ms Annette Quinn	Corporate Policy Division, DOPIE
Mr Nelson Quinn	Conservation Division, DASETT
Dr Barry Richardson	Australian Biological Resources Study, DASETT
Dr Roy Rickson	School of Environmental Studies Griffith University
Mr Terry Roberts	Water Branch, DOPIE
Mr Malcolm Robertson	CSIRO
Mr Wayne Slater	ERIN
Dr David Smiles	CSIRO Division of Soils
Mr David Tait	Environment Assessment, DASETT
Ms Judith Campbell	BRR

Mr John Tilley	Corporate Policy Division, DOPIE
Mr David Townsend	National Fishing Industry Council
Mr Ian Walker	Energy Programs Division, DOPIE
Mr David White	BRR
Mr David Whitrow	Australian Mining Industry Council
Dr Meryl Williams	Bureau of Rural Resources
Ms Janet Willis	Private Secretary, Senator Graham Richardson (then Minister for the Environment)
Dr Charles Willoughby	Land Resources Division, DPIE
Dr George Wilson	Bureau of Rural Resources

APPENDIX II.B

DIAGRAMMATIC EXPLANATION OF INSTITUTE OF SCIENTIFIC INFORMATION SCIENCE CITATION INDEX



The Institute of Scientific Information (ISI) is a private organisation based in Philadelphia. It is one of the world's largest commercial producers of information services covering the professional literature. Citation indexing measures the relationship between published articles. ISI published the first Science Citation Index (SCI) in 1960. The SCI has an annual coverage of 621 000 items from 3100 leading science journals.

APPENDIX II.C

RESEARCH IN PROGRESS DATABASES MAINTAINED ON CSIRO AUSTRALIS

ROAD & R2D2

INROADS: Australian Road Research Board. This database looks at topics such as the monetary valuation of road traffic's environmental hazards and road construction including the aesthetics of roadside landscaping. The problem of traffic noise is addressed. Renewable energy and the effects it has on the environment are covered as are the effects of the coastal environment on concrete highway bridges and the relationship that exists between highways, roads etc and wildlife.

For further information: Mrs Judy Tickner Tel (03) 881 1555. Commonwealth Department of Transport and Communications, 500 Burwood Highway, Vermont South VIC 3133.

RRIP

Rural Research in Progress includes research reports dealing with environmental geology — floods and drought patterns on a 10–100 years scale range. It also looks at alternative land tenure arrangements, herbicides in soils in areas like the Australian Wheat Belt, and the genotype environmental interactions of sheep, goats and crops.

For further information: Judith Campbell, Bureau of Rural Resources Tel (06) 2725636. Department of Primary Industries & Energy, GPO Box 858, Canberra ACT 2601.

ERIP

Enerlinks: Australian Energy Research, Development and Demonstration Projects covers information on the environmental and biological impacts of uranium mining, oil shale offshore operations, coal mining and usage as well as the impact of power stations on fisheries, estuarine ecology and seagrasses. Nuclear fuel cycles, and environmental effects of resource developments are also covered.

For further information: Tel (06) 2723933. Department of Primary Industries & Energy, GPO Box 858, Canberra ACT 2601.

AMRIP

Australian Marine Research in Progress covers material relating primarily to marine and aquatic environments. It includes factors that influence water humidity, mangrove microfauna, coral communities, environmental impact studies of pulp and paper mill effluents, port installations such as that at Jervis Bay, and estuarine wetlands surveys. It also looks at the use of remote sensing devices such as that of LANDSAT imagery which monitors environmental changes.

AMRIP is produced by a partnership of the Australian Institute of Marine Science, CSIRO Database Production Group, Great Barrier Reef Marine Park Authority and the Victorian Institute of Marine Sciences.

For further information: Tony Ermers, Manager, CSIRO Database Production Group, 314 Albert St, East Melbourne VIC 3002. Tel (03) 418 7333.

WATR **STREAMLINE: Australian Water Research** contains both bibliographic and research in progress information in environmental areas. However, marine and aquatic information is of primary importance covering such topics as environmental management studies, policy and legislation affecting places such as the Dandenong Valley in Victoria, the Alligators River Region in the NT and the Murray Basin. Also included is the role of water in environmental degradation.

For further information: Tel (06) 2723933, Department of Primary Industries & Energy, GPO Box 858, Canberra ACT 2601.

APPENDIX II.D

ORGANISATIONS SURVEYED BY THE BRR FOR CONTRIBUTIONS TO ENVIRONMENTAL RESEARCH IN AUSTRALIA — A COMPENDIUM

Australian Conservation Foundation
Association for the Protection of Rural Australia
Australian Waterbird Association
Australian National Parks and Wildlife Service
Australian Fisheries Service, Department of Primary Industries and Energy
Australian Bureau of Agricultural and Resource Economics
Department of Primary Industries and Energy
Australian National Botanic Gardens, Department of the Arts, Sport, The Environment, Tourism and Territories
Australian Government Analytical Laboratory, Department of Administrative Services
Australian Centre for International Agricultural Research
Australian Plague Locust Commission, Department of Primary Industries and Energy
Australian Nuclear Science and Technology Organisation
Australian National University
Antarctic Division, Department of the Arts, Sport, The Environment, Tourism and Territories
Bureau of Mineral Resources, Geology and Geophysics, Department of Primary Industries and Energy
Bureau of Flora and Fauna/Australian Biological Resources Study
Department of the Arts, Sport, The Environment, Tourism and Territories
Bureau of Meteorology, Department of Administrative Services
Conservation and Environment and Assessment Division, Department of the Arts, Sport, The Environment, Tourism & Territories
Conservation Commission of the Northern Territory
Catchment Areas Protection Board (NSW)
Coal and Nuclear Division, Department of Primary Industries and Energy
Crops Division, Department of Primary Industry and Energy
Darling Downs Institute of Advanced Education
Department of Industry, Technology and Commerce
Department of Environment and Planning (SA)
Department of Environment (Tas)
Department of Administrative Services
Department of Conservation Forests and Lands (Vic)
Department of Water Resources (NSW)
Department of Water Resources (Vic)

Department of Agriculture and Fisheries (NSW)
Department of Agriculture and Rural Affairs
Department of Primary Industries (Tas)
Department of Primary Industry and Fisheries
Department of Agriculture and Rural Affairs (Vic)
Department of Administrative Services
Department of Conservation Forests and Lands (Vic)
Department of Conservation and Land Management
Deakin University
Environment Protection Council (SA)
Engineering Development Establishment, Department of Defence
Environment Protection Authority (Vic)
Environmental Protection Authority (WA)
Forest Production Council (WA)
Flinders University
Griffith University
Great Barrier Reef Marine Park Authority
James Cook University
Land Conservation Council of NSW
Livestock and Pastoral Division, Department of Primary Industries and Energy
La Trobe University
Muresk Agricultural College
Murdoch University
Monash University
Murray Valley League
Murray-Darling Basin Commission
Ministry for Planning and Environment (NSW)
Mineral Commodities Division, Department of Primary Industries and Energy
Macquarie University
Nature Conservation Council of NSW
Natural Resources Conservation League of Victoria
National Parks and Wildlife Service (NSW)
National Parks and Wildlife Service (SA)
National Parks and Wildlife Service (Tas)
Natural Resource Management Division, Department of Primary Industries and Energy
National Parks and Wildlife Service (Qld)
National Parks and Nature Conservation Authority (WA)
Orange Agricultural College
Planning and Environment (Vic)
Plant Diversity Protection Committee
Pastures Protection Boards' Association of New South Wales
Petroleum Division, Department of Primary Industries and Energy
Queensland Agriculture College
River Murray Commission
Riverina College of Advanced Education/Charles Sturt University

Rural Lands Protection Board (Qld)
Rural Water Commission of Victoria
Roseworthy Agriculture College
Royal Melbourne Institute of Technology
Soil Conservation Service (NSW)
Soil Conservation Association of Victoria
Snowy Mountains Engineering Corporation
Space and Scientific Assessments, Defence Science and Technology Organisation
State Pollution Control Commission (NSW)
Telecom Research Laboratories
University of Queensland
University of New England
University of Sydney
University of New South Wales
University of Newcastle
University of Melbourne
University of Adelaide
University of Western Australia
University of Tasmania
University of Wollongong
University of Western Sydney, Hawkesbury
Western Lands Commission (NSW)
WA Institute of Technology

APPENDIX II.E

SUMMARY OF PROJECTS CONTAINED IN ENVIRONMENTAL RESEARCH IN AUSTRALIA — A COMPENDIUM

Summary of Projects contained in the Compendium by Subject Category and Organisation

	Commonwealth	*State*	*Tertiary*	*Industry*	*Private*	*Total*	*Percentage*
Open Ocean	47	4	46	5	1	**103**	4.76%
Marine Coastal	45	66	80	10	0	**201**	9.29%
Land Coastal Region	4	10	7	0	0	**21**	0.97%
Forests and Woodlands	17	34	36	0	0	**87**	4.02%
Inland Waters	64	141	136	11	2	**354**	16.37%
Land in general	58	126	79	11	0	**274**	12.67%
Flora and Fauna	179	275	290	5	6	**755**	34.91%
Atmosphere	40	11	24	2	0	**77**	3.56%
Antarctica	37	8	46	4	2	**97**	4.48%
Miscellaneous	53	24	105	11	1	**194**	8.97%
Totals	**544**	**699**	**849**	**59**	**12**	**2163**	100.00%

Source of Compendium Project Contributions

	AARP	*ANPWS*	*ERIP*	*MRIP*	*ROAD*	*RRIP*	*WATR*	*Other*	*Total*
Projects	80	55	112	723	8	515	524	146	2163
Percentage	3.70%	2.54%	5.18%	33.43%	0.37%	23.81%	24.23%	6.75%	100.00%

AARP — Australian Antarctic Research in Progress
ANPWS — Australian National Parks and Wildlife Service
ERIP — Energy Research in Progress
MRIP — Marine Research in Progress
ROAD — INROADS: Australian Road Research Board
RRIP — Rural Research in Progress
WATR — STREAMLINE: Australian Water Research

APPENDIX II.F

LEVELS AT WHICH AUSTRALIAN BUREAU OF STATISTICS COLLECTS R&D DATA

level 1	level 2	level 3	level 4
Current environment categories			
Advancement of knowledge	earth, ocean, atmosphere not elsewhere classified	earth	
		ocean	
		atmosphere	
		remote sensing	
		soils	
Proposed environment categories			
National Welfare	Environment	climate	climate change
			climate variability
			weather
			other climate
		atmosphere	atmospheric components
			atmospheric processes
			other atmosphere
		oceans	continental shelf
			deep water
		land use	high country
			forest
			farmland
			ecumene
			sparseland
			coastal zone
			mineral enclave

Data source: ABS

APPENDIX II.G

ORGANISATIONS CONTACTED IN INDUSTRY SURVEY

Alcan Australia Limited
Allan Pettigrew Consultants Pty Ltd
Allunga Exposure Laboratory
Amcor Ltd Technical Division
AMDEL
Analchem Cosultants Pty Ltd
Apace Research Ltd C/- Hawkesbury Agricultural College
Apgor Industries Limited
Ashland Croda Pty Ltd Research and Development Division
Associated Pulp and Paper Mills Group Research Unit
Associated Surveys Group
Esri Australia Pty Ltd
Aussat Pty Ltd
Austgen Biojet International Pty Limited
Australian Coal Industry Research Laboratories Ltd
Australian Conservation Foundation
Australian Mineral Industries Research Association Limited
Australian Newsprint Mills Limited
Australian Road Research Board
Binnie and Partners Pty Ltd
Biopolymers Limited
Biotech Ltd
Boral Limited Boral Research
Bruch (Australia) Limited
Bunge Meat Industries
Bunge (Industrial) Pty Ltd
Camp Scott Furphy
Capricorn Coal Mgt Pty Ltd, Development Department
CIBA-CEIGY Australia Limited, CIBA-CEIGY Research Centre
Containers Packaging, Research Department
CSR Limited, Sugar Division/Central Laboratory
Dames and Moore
D G Lampard and Associates
Dow Chemical (Australia) Limited
Dowell Australia Limited, Dowell Technology Group
Electrolytic Zinc Company of Australasia Limited
Elliott Scientific Equipment
Fluidization Technology Pty Ltd
Food Laboratories (Australia) Pty Ltd
Gene Link Australia Limited
Genesearch Pty Ltd

Geoff Williames (Aust) Pty Ltd
Holden's Motor Company, Technical Centre
Hunter Valley Research Foundation
I Wallis and Associates, Marine and Freshwater Research Centre
ICI Australia Operations Pty Ltd, Research Department
Industrial Design Research Pty Ltd
Industrial Ecologists Pty Ltd, T D Meagher & Associates
Intec Pty Ltd
Interox Chemicals Pty Ltd
J Gadsden Australia Limited, Corporate Technical Services and Can Division Engineering and Technical Services
John Connell Group (Consulting Engineers)
Kraft Foods Limited, Research and Development Department
K W and P Lawrence, Consulting Engineers
L Sulligoi and Associates, Dissolved Air Co
Laser Dynamics Ltd, Laser applications laboratory
Lincolne Scott Australia Pty Ltd
Marine Research Group of Victoria
Marine Science & Ecology Environmental Consultants
M E McKay and Associates Pty Ltd
Microchem Associates
Mount Isa Mines Limited
Neville Jones and Associates
Pak-Poy and Kneebone Pty Ltd
Penfolds Wines Pty Ltd
Polychem Products Pty Ltd
Simmonds & Bristow Pty Ltd
Steedman Limited
Sulphide Corporation Pty Limited
Tioxide Australia Pty Ltd
Victorian Innovation Centre Limited
Vipac Group, Vipac Laboratories Pty Ltd
Water Research Foundation of Australia
Water Science Laboratories Pty Ltd
Wilkinson-Murray Consulting Pty Ltd
William Boby and Co (Australia) Pty Ltd
WLPU Consultants (Australia) Pty Ltd
World Life Research Institute, Australian Division
Z C Mines

APPENDIX II.H

SUBMISSIONS TO THE REVIEW

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Dr C D Garland
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Acting Premier of Victoria

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Vice-President
Ecology Society of Australia

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The Wilderness Society

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The Nature Conservation Society of South Australia Inc

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for the Conservation Committee of The Australian Entomological Society

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Dean
Faculty of Biological & Behavioural Sciences
University of New South Wales

Mr Don Wignall
President
Western Australian Wildflower Society (Inc)

Mr Greg Wilkins
United Scientists for Environmental Responsibility and Protection (USERP)

Dr P R Wilkinson
National President
The Royal Australian Chemical Institute

Professor Martin Williams
Department of Geography & Environmental Science
Monash University

Mr Wolfgang Zeidler
Curator of Marine Invertebrates
South Australian Museum

Dr J W Zillman
Director of Meteorology
Bureau of Meteorology

APPENDIX III.A

Environmental Research by Socioeconomic Objective by Source of Funds — 1984–85 ($'000)

	Commonwealth	State	Business Enterprises	Other: Higher Education	Other: Private Non-profit	Other: Overseas Overseas	Total	% of Total
ENVIRONMENT PROTECTION								
air pollution	1965	170	55	—	65	12	2267	1.22%
water pollution	8532	1330	167	41	147	9	10226	5.48%
other pollution	492	—	—	—	10	—	502	0.27%
other environment: natural	19159	9096	155	1	138	221	28770	15.43%
other environment: human	35	128	—	—	2	—	165	0.09%
other environment	6035	211	268	—	84	30	6628	3.55%
Total	**36218**	**10935**	**645**	**42**	**446**	**272**	**48558**	**26.04%**
ADVANCEMENT OF KNOWLEDGE								
earth	36388	2980	552	—	330	207	40457	21.69%
ocean	23602	210	140	—	47	53	24052	12.90%
atmosphere	20328	23	49	—	26	19	20445	10.96%
remote sensing	1803	80	22	—	10	14	1929	1.03%
soils	14362	12302	537	—	166	7	27374	14.68%
Total	**96483**	**15595**	**1300**	**—**	**579**	**300**	**114257**	**61.26%**

MINING AND ENERGY								
Production & utilisation of energy								
Environment protection								
oil & gas	817	4	7	—	3	—	831	0.45%
oil shale & tar sands	984	4	2	—	3	—	993	0.53%
coal	2549	49	44	—	18	—	2660	1.43%
Total	**4350**	**57**	**53**	**—**	**24**	**—**	**4484**	**2.40%**
Conservation of energy								
industry	5625	43	58	—	47	1	5774	3.10%
residential & commercial	986	1143	59	—	20	—	2208	1.18%
transportation	2150	22	123	—	9	9	2313	1.24%
other (eg waste recycling)	163	47	7	—	4	1	222	0.12%
Total	**8924**	**1255**	**247**	**—**	**80**	**11**	**10517**	**5.64%**
Mining of energy minerals								
Environment protection								
uranium	8040	2	5	—	2	—	8049	4.32%
coal	429	20	152	—	4	1	606	0.32%
oil & gas	26	—	1	—	4	—	31	0.02%
oil shale & tar sands	—	—	—	—	—	—	—	0.00%
Total	**8495**	**22**	**158**	**—**	**10**	**1**	**8686**	**4.66%**
Total	**21769**	**1334**	**458**	**—**	**114**	**12**	**23687**	**12.70%**
TOTAL	**154470**	**27864**	**2403**	**42**	**1139**	**584**	**186502**	**100.00%**

APPENDIX III.B

NERD&D Program Funding for Environmental Research — 1980–1989 (1989 dollars)

	Commonwealth	*Higher Education*	*State*	*Industry*	*Total Environmental Research*	*Total NERD&D program funding*	*% of*
1980	1352575	465320	184015	937346	2939257	13.18%	
1981	479738	877893	42201	1743372	3143204	11.78%	
1982	601005	7366	159677	612052	1380100	4.83%	
1983	159770	837799	686283	466406	2150259	9.12%	
1984	715911	267791	181523	170055	1335280	6.16%	
1985	475591	1601596	656681	0	2733867	10.13%	
1986	124412	371746	116542	226604	839305	4.48%	
1987	570703	339007	60553	816866	1787129	5.57%	
1988	187177	505073	0	1533651	2225900	5.98%	
1989	1101964	479381	133000	367634	2081979	7.23%	

APPENDIX IV.A

DEFINITIONS OF RESEARCH TYPES USED BY THE AUSTRALIAN BUREAU OF STATISTICS

Basic research is experimental and theoretical work undertaken primarily to acquire new knowledge without a specific application in view. It consists of pure basic research and strategic basic research. Pure basic research is carried out without looking for long-term benefits other than the advancement of knowledge. *Strategic* basic research is directed into specified broad areas in the expectation of useful discoveries. It provides the broad base of knowledge necessary for the solution of recognised practical problems.

Applied research is original work undertaken in order to acquire new knowledge with a specific practical application in view. It is undertaken to determine possible uses for the findings of basic research or to determine new methods of achieving some specific and pre-determined objectives.

Experimental development is systematic work, using existing knowledge gained from research and/or practical experience, for the purpose of creating new or improved products/processes.

Source: Australian Bureau of Statistics, *1986–87 Research and Experimental Development: General Government and Private Non-Profit Organisations Australia*, Cat. No. 8109.0, 1988.

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research Activity for 1984–85 ($'000)

	Commonwealth					
	Pure basic research	*Strategic basic research*	*Applied research*	*Experimental development*	*Total $1984–85*	*Total $1986–87*
ENVIRONMENT PROTECTION						
air pollution	—	—	213	—	213	243
water pollution	—	592	3366	704	4662	5322
other pollution	—	195	210	87	492	562
other environment: natural	1244	8806	5296	3680	19026	21719
other environment: human	—	—	—	—	—	—
other environment	na	na	na	na	na	na
Total	**1244**	**9593**	**9085**	**4471**	**24393**	**27846**
ADVANCEMENT OF KNOWLEDGE						
earth	9166	1439	4796	701	16102	18381
ocean	8976	5428	2979	1923	19306	22039
atmosphere	6319	5085	4221	1151	16776	19151
remote sensing	—	—	526	221	747	853
soils	1158	4971	2570	1044	9743	11122
Total	**25619**	**16923**	**15092**	**5040**	**62674**	**71546**

MINING AND ENERGY						
Production & utilisation of energy						
Environment protection						
oil & gas	—	—	538	—	538	614
oil shale & tar sands	—	—	776	—	776	886
coal	7	118	1498	34	1657	1892
Total	**7**	**118**	**2812**	**34**	**2971**	**3392**
Conservation of energy						
industry	—	1116	1731	872	3719	4245
residential & commercial	—	—	—	371	371	424
transportation	—	125	838	371	1334	1523
other(eg waste recycling)	—	—	—	—	—	—
Total	**—**	**1241**	**2569**	**1614**	**5424**	**6192**
Mining of energy minerals						
Environment protection						
uranium	—	—	7570	299	7869	8983
coal	—	—	—	—	—	—
oil & gas	—	—	—	—	—	—
oil shale & tar sands	—	—	—	—	—	—
Total	**—**	**—**	**7570**	**299**	**7869**	**8983**
Total	7	1359	12951	1947	16264	18566
TOTAL	**26870**	**27875**	**37128**	**11458**	**103331**	**117958**
TOTAL (1986–87 dollars)	**30674**	**31821**	**42384**	**13080**		

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research Activity for 1984–85 ($'000) — continued

	State					
	Pure basic research	*Strategic basic research*	*Applied research*	*Experimental development*	*Total $1984–85*	*Total $1986–87*
ENVIRONMENT PROTECTION						
air pollution	–	202	41	–	243	275
water pollution	–	61	1347	10	1418	1606
other pollution	–	–	10	–	10	11
other environment: natural	141	751	8128	721	9741	11032
other environment: human	17	73	76	–	166	188
other environment	na	na	na	na	na	na
Total	**158**	**1087**	**9602**	**731**	**11578**	**13112**
ADVANCEMENT OF KNOWLEDGE						
earth	1483	43	1129	310	2965	3358
ocean	175	154	–	–	329	373
atmosphere	–	–	–	–	–	–
remote sensing	27	26	–	–	53	60
soils	–	137	11293	1681	13111	14848
Total	**1685**	**360**	**12422**	**1991**	**16458**	**18639**

MINING AND ENERGY						
Production & utilisation of energy						
Environment protection						
oil & gas	—	—	—	—	—	—
oil shale & tar sands	—	—	—	—	—	—
coal	—	42	—	—	42	48
Total	—	**42**	—	—	**42**	**48**
Conservation of energy						
industry	—	—	5	—	5	6
residential & commercial	—	—	1154	—	1154	1307
transportation	—	—	—	—	—	—
other (eg waste recycling)	—	—	—	—	—	—
Total	—	—	**1159**	—	**1159**	**1313**
Mining of energy minerals						
Environment protection						
uranium	—	—	—	—	—	—
coal	—	—	7	—	7	8
oil & gas	—	—	—	—	—	—
oil shale & tar sands	—	—	—	—	—	—
Total	—	—	7	—	7	8
Total	—	**42**	**1166**	—	**1208**	**1368**
TOTAL	**1843**	**1489**	**23190**	**2722**	**29244**	**33119**
TOTAL (1986–87 dollars)	**2087**	**1686**	**26263**	**3083**		

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research Activity for 1984–85 ($'000) — continued

	Higher Education					
	Pure basic research	*Strategic basic research*	*Applied research*	*Experimental development*	*Total $1984–85*	*Total $1986–87*
ENVIRONMENT PROTECTION						
air pollution	372	297	1017	125	1811	2096
water pollution	473	1774	1654	246	4147	4800
other pollution	na	na	na	na	na	na
other environment: natural	na	na	na	na	na	na
other environment: human	na	na	na	na	na	na
other environment	1220	1778	3063	566	6627	7670
Total	**2065**	**3849**	**5734**	**937**	**12585**	**14566**
ADVANCEMENT OF KNOWLEDGE						
earth	14067	3668	2896	761	21392	24759
ocean	2437	1411	450	71	4369	5057
atmosphere	1977	728	741	222	3668	4245
remote sensing	188	95	626	221	1130	1308
soils	504	1467	2239	311	4521	5233
Total	**19173**	**7369**	**6952**	**1586**	**35080**	**40602**

MINING AND ENERGY						
Production & utilisation of energy						
Environment protection						
oil & gas	12	126	142	12	292	338
oil shale & tar sands	108	46	63	—	217	251
coal	208	393	278	82	961	1112
Total	**328**	**565**	**483**	**94**	**1470**	**1701**
Conservation of energy						
industry	749	241	896	165	2051	2374
residential & commercial	19	47	512	105	683	791
transportation	38	122	509	311	980	1134
other (eg waste recycling)	11	12	116	83	222	257
Total	**817**	**422**	**2033**	**664**	**3936**	**4556**
Mining of energy minerals						
Environment protection						
uranium	4	77	94	7	182	211
coal	4	68	516	11	599	693
oil & gas	—	12	18	—	30	35
oil shale & tar sands	—	—	—	—	—	—
Total	**8**	**157**	**628**	**18**	**811**	**939**
Total	**1153**	**1144**	**3144**	**776**	**6217**	**7196**
TOTAL	**22391**	**12362**	**15830**	**3299**	**53882**	**62363**
TOTAL (1986–87 dollars)	**25916**	**14308**	**18322**	**3818**		

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research Activity for 1984–85 ($'000) — continued

	Private Non-Profit					
	Pure basic research	*Strategic basic research*	*Applied research*	*Experimental development*	*Total $1984–85*	*Total $1986–87*
ENVIRONMENT PROTECTION						
air pollution	—	—	—	—	—	—
water pollution	—	—	—	—	—	—
other pollution	—	—	—	—	—	—
other environment: natural	—	—	4	—	4	4
other environment: human	—	—	—	—	—	—
other environment	na	na	na	na	na	na
Total	**—**	**—**	**4**	**—**	**4**	**4**
ADVANCEMENT OF KNOWLEDGE						
earth	—	—	—	—	—	—
ocean	45	—	—	—	45	49
atmosphere	—	—	—	—	—	—
remote sensing	—	—	—	—	—	—
soils	—	—	—	—	—	—
Total	**45**	**—**	**—**	**—**	**45**	**49**

MINING AND ENERGY						
Production & utilisation of energy						
Environment protection						
oil & gas	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
oil shale & tar sands	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
coal	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
Total	**n.p.**	**n.p.**	**n.p.**	**n.p.**	**n.p.**	**n.p.**
Conservation of energy						
industry	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
residential & commercial	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
transportation	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
other (eg waste recycling)	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
Total	**n.p.**	**n.p.**	**n.p.**	**n.p.**	**n.p.**	**n.p.**
Mining of energy minerals						
Environment protection						
uranium	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
coal	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
oil & gas	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
oil shale & tar sands	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
Total	**n.p.**	**n.p.**	**n.p.**	**n.p.**	**n.p.**	**n.p.**
Total	**n.p.**	**n.p.**	**n.p.**	**n.p.**	**n.p.**	**n.p.**
TOTAL	**45**	**—**	**4**	**—**	**49**	**53**
TOTAL (1986–87 dollars)	**49**	**—**	**4**	**—**		

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research for 1984–85. ($'000) — continued

Summary of 1984–85 data.

	Total Pure basic research	*Total Strategic basic research*	*Total Applied research*	*Total Experimental development*	*Grand Total*	*% of Total*
ENVIRONMENT PROTECTION						
air pollution	431	573	1467	145	2614	1.22%
water pollution	547	2798	7282	1100	11728	5.49%
other pollution	—	223	251	99	573	0.27%
other environment: natural	1580	10903	15255	5017	32755	15.34%
other environment: human	19	83	86	—	188	0.09%
other environment	1412	2058	3545	655	7670	3.59%
Total	**3989**	**16637**	**27886**	**7016**	**55528**	**26.01%**
ADVANCEMENT OF KNOWLEDGE						
earth	28424	5937	10105	2032	46498	21.78%
ocean	13314	8004	3922	2277	27517	12.89%
atmosphere	9502	6647	5676	1571	23396	10.96%
remote sensing	248	139	1325	508	2221	1.04%
soils	1905	7528	18315	3455	31203	14.62%
Total	**53393**	**28255**	**39343**	**9844**	**130835**	**61.28%**

MINING AND ENERGY						
Production & utilisation of energy						
Environment protection						
oil & gas	14	146	779	14	952	0.45%
oil shale & tar sands	125	53	959	—	1137	0.53%
coal	249	637	2032	134	3051	1.43%
Total	**388**	**836**	**3769**	**148**	**5141**	**2.41%**
Conservation of energy						
industry	867	1553	3019	1186	6625	3.10%
residential & commercial	22	54	1900	545	2521	1.18%
transportation	44	284	1546	783	2657	1.24%
other (eg waste recycling)	13	14	134	96	257	0.12%
Total	**946**	**1905**	**6598**	**2611**	**12060**	**5.65%**
Mining of energy minerals						
Environment protection						
uranium	5	89	8750	349	9194	4.31%
coal	5	79	605	13	701	0.33%
oil & gas	—	14	21	—	35	0.02%
oil shale & tar sands	—	—	—	—	—	0.00%
Total	**9**	**182**	**9376**	**362**	**9929**	**4.65%**
Total	**1342**	**2923**	**19744**	**3121**	**27130**	**12.71%**
TOTAL	**58725**	**47815**	**86972**	**19981**	**213493**	**100.00%**

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research Activity for 1986–87 ($'000)

	Commonwealth				
	Pure basic research	*Strategic basic research*	*Applied research*	*Experimental development*	*Total*
ENVIRONMENT PROTECTION					
air pollution	—	—	333	142	475
water pollution	94	523	4548	1269	6434
other pollution	—	—	3095	1477	4572
other environment: natural	4355	10905	4201	638	20099
other environment: human	—	—	—	—	—
other environment	na	na	na	na	na
Total	**4449**	**11428**	**12177**	**3526**	**31580**
ADVANCEMENT OF KNOWLEDGE					
earth	10513	5466	6172	3100	25251
ocean	15662	5265	2671	1798	25396
atmosphere	5722	3251	3684	1743	14400
remote sensing	35	546	828	352	1761
soils	2955	2112	2163	1118	8348
Total	**34887**	**16640**	**15518**	**8111**	**75156**

MINING AND ENERGY					
Production & utilisation of energy					
Environment protection					
oil & gas	—	10	998	—	1008
oil shale & tar sands	—	6	614	—	620
coal	—	31	3070	—	3101
Total	—	**47**	**4682**	—	**4729**
Conservation of energy					
industry	580	1740	2320	194	4834
residential & commercial	—	—	—	—	—
transportation	—	—	50	—	50
other (eg waste recycling)	—	—	—	—	—
Total	**580**	**1740**	**2370**	**194**	**4884**
Mining of energy minerals					
Environment protection					
uranium	—	—	6973	819	7792
coal	—	—	—	—	—
oil & gas	—	—	—	—	—
oil shale & tar sands	—	—	—	—	—
Total	—	—	**6973**	**819**	**7792**
Total	**580**	**1787**	**14025**	**1013**	**17405**
TOTAL	**39916**	**29855**	**41720**	**12650**	**124141**

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research Activity for 1986–87 ($'000) — continued

	State				
	Pure basic research	*Strategic basic research*	*Applied research*	*Experimental development*	*Total*
ENVIRONMENT PROTECTION					
air pollution	—	—	89	43	132
water pollution	—	205	2406	250	2861
other pollution	—	—	37	8	45
other environment: natural	102	412	7191	95	7800
other environment: human	36	37	124	0	197
other environment	na	na	na	na	na
Total	**138**	**654**	**9847**	**396**	**11035**
ADVANCEMENT OF KNOWLEDGE					
earth	571	312	211	20	1114
ocean	390	198	41	0	629
atmosphere	—	—	—	—	—
remote sensing	246	4	196	36	482
soils	12	76	12553	4114	16755
Total	**1219**	**590**	**13001**	**4170**	**18980**

MINING AND ENERGY					
Production & utilisation of energy					
Environment protection					
oil & gas	—	—	—	—	—
oil shale & tar sands	—	—	—	—	—
coal	5	—	232	—	237
Total	**5**	**—**	**232**	**—**	**237**
Conservation of energy					
industry	—	—	69	0	69
residential & commercial	—	—	271	0	271
transportation	—	—	—	176	176
other (eg waste recycling)	—	—	47	—	47
Total	**—**	**—**	**387**	**176**	**563**
Mining of energy minerals					
Environment protection					
uranium	—	—	—	—	—
coal	—	294	—	—	294
oil & gas	—	—	—	—	—
oil shale & tar sands	—	—	—	—	—
Total	**—**	**294**	**—**	**—**	**294**
Total	**5**	**294**	**619**	**176**	**1094**
TOTAL	**1362**	**1538**	**23467**	**4742**	**31109**

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research Activity for 1986–87 ($'000) — continued

	Higher Education				
	Pure basic research	*Strategic basic research*	*Applied research*	*Experimental development*	*Total*
ENVIRONMENT PROTECTION					
air pollution	92	365	828	261	1546
water pollution	459	1633	2642	306	5040
other pollution	na	na	na	na	na
other environment: natural	na	na	na	na	na
other environment: human	na	na	na	na	na
other environment	1514	3488	4706	895	10603
Total	**2065**	**5486**	**8176**	**1462**	**17189**
ADVANCEMENT OF KNOWLEDGE					
earth	15520	5170	3701	637	25028
ocean	2380	1585	1263	379	5607
atmosphere	1771	943	1302	259	4275
remote sensing	436	435	843	378	2092
soils	682	1431	3673	319	6105
Total	**20789**	**9564**	**10782**	**1972**	**43107**

MINING AND ENERGY					
Production & utilisation of energy					
Environment protection					
oil & gas	36	166	293	61	556
oil shale & tar sands	—	36	54	—	90
coal	136	116	467	240	959
Total	**172**	**318**	**814**	**301**	**1605**
Conservation of energy					
industry	188	477	691	218	1574
residential & commercial	58	164	438	175	835
transportation	41	111	559	279	990
other (eg waste recycling)	—	—	130	39	169
Total	**287**	**752**	**1818**	**711**	**3568**
Mining of energy minerals					
Environment protection					
uranium	—	9	91	6	106
coal	—	43	435	35	513
oil & gas	3	65	224	60	352
oil shale & tar sands	—	33	62	29	124
Total	**3**	**150**	**812**	**130**	**1095**
Total	**462**	**1220**	**3444**	**1142**	**6268**
TOTAL	**23316**	**16270**	**22402**	**4576**	**66564**

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research Activity for 1986–87 ($'000) — continued

	Private non-profit				
	Pure basic research	*Strategic basic research*	*Applied research*	*Experimental development*	*Total*
ENVIRONMENT PROTECTION					
air pollution	—	—	—	—	—
water pollution	—	—	—	—	—
other pollution	—	—	—	—	—
other environment: natural	—	—	564	—	564
other environment: human	—	—	—	—	—
other environment	na	na	na	na	na
Total	—	—	**564**	—	**564**
ADVANCEMENT OF KNOWLEDGE					
earth	—	—	—	—	—
ocean	48	—	—	—	48
atmosphere	—	—	—	—	—
remote sensing	—	—	—	—	—
soils	—	—	—	—	—
Total	**48**	—	—	—	**48**

MINING AND ENERGY					
Production & utilisation of energy					
Environment protection					
oil & gas	—	—	—	—	—
oil shale & tar sands	—	—	—	—	—
coal	—	—	—	—	—
Total	—	—	—	—	—
Conservation of energy					
industry	—	—	—	—	—
residential & commercial	—	—	13	248	261
transportation	—	—	16	25	41
other (eg waste recycling)	—	—	—	—	—
Total	—	—	**29**	**273**	**302**
Mining of energy minerals					
Environment protection					
uranium	—	—	—	—	—
coal	—	—	—	—	—
oil & gas	—	—	—	—	—
oil shale & tar sands	—	—	—	—	—
Total	—	—	—	—	—
Total	—	—	**29**	**273**	**302**
TOTAL	**48**	—	**593**	**273**	**914**

APPENDIX IV.B

Environmental Research by Socioeconomic Objective by Type of Research for 1986–87. ($'000) — continued

Summary of 1986–87 data.

	Total Pure basic research	*Total Strategic basic research*	*Total Applied research*	*Total Experimental development*	*Grand Total*	*% of Total*
ENVIRONMENT PROTECTION						
air pollution	92	365	1250	446	2153	0.97%
water pollution	553	2361	9596	1825	14335	6.44%
other pollution	—	—	3132	1485	4617	2.07%
other environment: natural	4457	11317	11956	733	28463	12.78%
other environment: human	36	37	124	—	197	0.09%
other environment	1514	3488	4706	895	10603	4.76%
Total	**6652**	**17568**	**30764**	**5384**	**60368**	**27.10%**
ADVANCEMENT OF KNOWLEDGE						
earth	26604	10948	10084	3757	51393	23.07%
ocean	18480	7048	3975	2177	31680	14.22%
atmosphere	7493	4194	4986	2002	18675	8.38%
remote sensing	717	985	1867	766	4335	1.95%
soils	3649	3619	18389	5551	31208	14.01%
Total	**56943**	**26794**	**39301**	**14253**	**137291**	**61.64%**

MINING AND ENERGY						
Production & utilisation of energy						
Environment protection						
oil & gas	36	176	1291	61	1564	0.70%
oil shale & tar sands	—	42	668	—	710	0.32%
coal	141	147	3769	240	4297	1.93%
Total	**177**	**365**	**5728**	**301**	**6571**	**2.95%**
Conservation of energy						
industry	768	2217	3080	412	6477	2.91%
residential & commercial	58	164	722	423	1367	0.61%
transportation	41	111	625	480	1257	0.56%
other (eg waste recycling)	—	—	177	39	216	0.10%
Total	**867**	**2492**	**4604**	**1354**	**9317**	**4.18%**
Mining of energy minerals						
Environment protection						
uranium	—	9	7064	825	7898	3.55%
coal	—	337	435	35	807	0.36%
oil & gas	3	65	224	60	352	0.16%
oil shale & tar sands	-	33	62	29	124	0.06%
Total	**3**	**444**	**7785**	**949**	**9181**	**4.12%**
Total	**1047**	**3301**	**18117**	**2604**	**25069**	**11.26%**
TOTAL	**64642**	**47663**	**88182**	**22241**	**222728**	**100.00%**

APPENDIX IV.C

ORGANISATION OF COMMONWEALTH ENVIRONMENTAL RESEARCH

The Department of Administrative Services

The *Australian Surveying and Land Information Group* (AUSLIG) has primary responsibility for the coordination of Commonwealth land information. AUSLIG is responsible for general policy and procedures relating to accessing, storage and dissemination of land related data needed to assist government decision making. In addition, AUSLIG provides surveying, mapping and land information services and advice to government and other client groups.

AUSLIG's national land information coordination activities include membership of the Australian Land Information Council (ALIC), the Australian Advisory Committee on Land Information (AACLI) and the Intergovernmental Advisory Committee on Surveying and Mapping (IGACSM). AUSLIG also provides the chair and secretariat for the Commonwealth Land Information Forum (CLIF) established in 1989 to:

- increase coordination of Commonwealth activities in the collection, storage and dissemination of land information;
- support the national coordination of land information; and
- act as a consultative mechanism for Commonwealth agencies with land information responsibilities.

AUSLIG has two programs – a public interest program fully funded by the Commonwealth Government and a user pays client service program:

Public Interest Services in *1988–89*

- 1:100 000 National Topographic Map Series of Australia in 3064 maps;
- 1:250 000 Series of Australia in 554 maps;
- Volume 5 of the National Atlas: Geology and Minerals;
- Volume 6 of the National Atlas: Vegetation;
- 1:2.5m Geographic Information System based general reference map of Australia incorporating roads, railways, ocean depths, coastline, streams, lakes, reservoirs, nature conservation reserves and current vegetation.[1]

Department of Administrative Services, *Annual Report 1988–89*, AGPS, Canberra, 1989.

The *Bureau of Meteorology* observes Australian weather and climate and provides meteorological, hydrological and oceanographic information, forecast, warning and advisory services in support of Australia's national needs and international obligations. Research includes work on the El Nino phenomenon, tropical cyclone motion, new methods of data acquisition and improved forecasting. The Bureau also operates the national ozone monitoring network. There is significant research and development required for quality control and data interpretation. The Baseline Air Pollution Station at Cape Grim provides a focus for Australia's participation in the World Meteorological Organisation's Background Air Pollution Monitoring Network (BAPMON). The station's scientific program is supervised jointly by the Bureau and CSIRO with a monitoring program undertaken on behalf of scientists drawn from those organisations, ANSTO and universities. The station's research programs fall into three categories, namely climatology, radiation and atmospheric constituents.[2]

The Department of the Arts, Sport, the Environment, Tourism and Territories

The *Antarctic Division* of DASETT seeks to advance Australia's scientific, environmental, political, strategic and economic (other than mining and oil drilling) interests in the Antarctic and sub-Antarctic regions through research, a presence in the Antarctic and an involvement in international Antarctic organisations.

This Antarctic Division does not have a specific environment research program but it has Land Based, Marine Biology and Glaciology programs which in 1987–88 cost $2.4m. The Division conducts research in glaciology, terrestrial and marine biology, upper atmosphere physics, cosmic ray physics and medicine. It also administers the Antarctic Science Advisory Committee research grants scheme, which provides for research in all the above disciplines as well as a number of others.[3]

The Australian Heritage Commission (AHC) conducts research in:

- methodologies and typologies related to the assessment of places for the Register of the National Estate;
- identification of natural places of National Estate significance; and
- documentation of places of National Estate and international significance.

The AHC carries out research relevant to the natural environment through in-house research; the Australian Heritage Research Program (AHRP) through which the AHC selects and engages suitable consultants and funds through its own budget, and the National Estate Grants Program (NEGP) which is a Commonwealth/State funded program which allows funds to be given directly to heritage committees in the States and Territories for programs related to the identification or protection of the National Estate.

2 DAS, *Annual Report* 1988–89.

3 Department of the Arts, Sport, the Environment, Tourism and Territories, *Annual Report 1988–89*, AGPS, Canberra, 1989.

Antarctic Division, DASETT, *1989–90 Australian Antarctic Research Program: Antarctic Treaty Exchange Information*, AGPS, Canberra, 1989.

Funding for natural environment research through the NEGP in 1987–88 was $980.23 (28.5 per cent of the total NEGP budget). Funding through the AHRP in 1987–88 was $212.00 (59 per cent of the total AHRP budget).[4] The AHC is also overseeing the completion of the *National Wilderness Inventory*.

The Australian Biological Resources Study (ABRS), in collaboration with Commonwealth, State and Territory agencies, coordinates studies on the description, classification and distribution of Australian plants and animals, as a record of the natural heritage and to provide a scientific basis for conservation and resource management. The Bureau of Flora and Fauna has a scientific staff of 12 and distributes between 50 and 60 research grants each year. Funding of $1 million for the calendar year 1989, an increase of 27 per cent on 1988, included $150 000 of special support for rainforest projects. The ABRS publishes *Flora of Australia, Fauna of Australia and Zoological Catalogue of Australia.*[5]

The *Australian National Botanic Gardens* (ANBG) conducts research into the systematic botany and plant biology of Australia and related floras. Activities of the botanical research group include revisionary and nomenclatural studies, phylogenetics, biogeography and flora treatments. It has also focused on the study of the propagation, breeding systems and pollination biology of rare and endangered plant taxa.[6]

The *Australian National Parks and Wildlife Service* (ANPWS) carries out and commissions research that is relevant to the establishment and management of national parks and nature reserves, and the protection, conservation and management of wildlife. It also conducts surveys of animals and plants and collects statistics. The ANPWS 'in-house' environmental research relates to the following programs:

- Uluru and Kakadu National Parks: bushfire monitoring and management to minimise the impacts of wildfires; survey and control of feral animals;
- Kakadu National Park: survey and control of exotic weeds; monitoring to assess the recovery of the saltwater crocodile;
- Christmas Island: study of Abbots Booby;
- Surveys of kangaroos.

The ANPWS also funds and manages research under the Research and survey program, the States cooperative assistance program and the Endangered species research and management program.

The *Great Barrier Reef Marine Park Authority* (GBRMPA) was established in 1975 to provide for the protection, wise use, understanding and enjoyment of the great Barrier Reef in perpetuity through the care and development of the Great Barrier Reef Marine Park. GBRMPA manages and co ordinates research projects relevant to planning and management of the Marine Park. Most research is contracted externally to agencies including universities, government bodies and private consultants.

4 Department of the Arts, Sport, the Environment Tourism and Territories, Submission to the ASTEC Review of Environmental Research.

5 DASETT, *Annual Report 1988–89.*

6 *DASETT, Annual Report 1988–89.*

The Authority's research program covers a range of disciplines including marine biology, physical, chemical and social sciences. Many projects are multi-disciplinary to provide a broad appreciation of particular sites or issues.

Nine priority areas were identified for the 1988–89 financial year: Crown-of-Thorns starfish, effects of trawling, effects of demersal Reef fishing, Reef benthos monitoring, water quality assessment, human use monitoring, social impact assessment, management studies and oceanography.

The total cost of GBRMPA's Research Program of 107 new and 51 continuing projects in 1988–89 was $1.04 m.[7]

The *Alligator Rivers Region Research Institute* conducts, coordinates and integrates research to provide a scientific basis for developing standards and measures for the protection and restoration of the environment and for assessing the actual and potential effects of mining operations in the Alligator Rivers Region. The Institute is managed by the Supervising Scientist for the Alligator Rivers Region. A particular responsibility is the Conservation Zone, a small part of the Region set aside for a program of mineral exploration and resource assessment. The research is divided into aquatic biology, plant ecology, geomorphology, environmental modelling, radio-activity and chemistry.

The internal research capacity of the Institute is supplemented by consultancies and collaborative research projects with organisations such as CSIRO, ANSTO and tertiary institutions. The cost of the Research Program in 1988–1989 was $4.03m.[8]

The Department of Industry, Technology and Commerce

The *Australian Nuclear Science and Technology Organisation* (ANSTO) has a total of 80 staff and an annual budget of $3.9m committed to its Environmental Science Program. This program investigates the processes controlling the release, and the water and air-borne dispersion, of mining and industrial pollutants, and assesses their biological impact on the environment. The program assists in minimising the environmental impact of industry through development of more efficient methods for processing uranium and other ores and for the management and rehabilitation of wastes. Recently, effort has diversified to more generic problems including elucidation of more fundamental processes occurring in the atmosphere and in surface, marine and ground waters.[9]

The *Australian Institute of Marine Science* (AIMS) conducts strategic and applied research in the marine sciences in response to national needs and priorities, generally within the waters of the continental shelf, and, in particular, in the tropics.

7 Great Barrier Reef Marine Park Authority, *Annual Report 1988–89*, AGPS, Canberra, 1989.

8 Office of the Supervising Scientist for the Alligator Rivers Region, *Annual Report 1988–89*, AGPS, Canberra, 1989.

9 Australian Nuclear Science and Technology Organisation, Submission to the Review of Environmental Research in Australia.

It also does sufficient basic research to maintain a sound scientific foundation for its other activities. All four of the Institute's research programs into:

- coastal processes and resources,
- reef studies,
- environmental studies and biotechnology; and
- marine system analysis and oceanography;

include the aim of developing an integrated understanding of the marine environment, or particular systems or components of it, to contribute to the advancement of scientific knowledge and to assist in future conservation, development and management. More than 83 per cent of the Institute's efforts and expenditure are devoted to environmental research, amounting to $10 million in 1988–89, and an estimated $12.2 million in 1989–90.[10]

The Department of Defence

The Department of Defence conducts environmental research to fulfil its obligations under the *Environment Protection (Impact of Proposals) Act,* 1974 in regard to the impact of defence activities such as military manoeuvres in training areas, management of defence lands and development of new installations. Major activities have recently been the development of baseline data for Environmental Impact Statements such as those related to the proposed removal of the Navy from Sydney to Jervis Bay and the establishment of a new airfield in Cape York. Other research in the environmental area is directed at the provision of baseline data to support environmental management plans. The Department of Defence also undertakes several research projects carried out by CSIRO and aimed at improving existing management techniques in training areas. The research is for the development of decision support systems and impact prediction models. The research was valued at $3m in 1988–89.

The Department of Primary Industries and Energy

The *Bureau of Rural Resources* promotes the development of sustainable and efficient fisheries, forestry and agricultural industries in Australia by providing appropriate scientific and technological advice for policy formulation and planning and the effective and efficient management of a number of operational programs that have a significant scientific and technical content, including several significant inventories.[11]

The *Murray–Darling Basin Commission* (MDBC) was established in 1988 to provide advice to the Murray–Darling Basin Ministerial Council on the planning and management of the Basin's water, land and environmental resources. In conjunction with the governments of New South Wales, Victoria, and South Australia the Commission is developing strategies to deal with those problems which cross, or have effects which cross, State boundaries.

10 Australian Institute of Marine Science, *Annual Report.*

11 Department of Primary Industries and Energy, *Annual Report 1989–90,* AGPS, Canberra, 1989.

Priority is being given to development of strategies directed toward the sustainable use of the Basin's resources, deal with salinity and drainage problems and protect the Basin's natural resources.[12]

The Murray–Darling Basin (MDB) Natural Resource Management Studies (NRMS) program was allocated $5.05m in 1989–90. The MDBC also has an significant water quality monitoring program.

The *Australian Bureau of Agricultural and Resource Economics* (ABARE) was formed in 1987 through the merger of the Bureau of Agricultural Economics and the Bureau of Resource Economics. ABARE's role is to enhance the economic performance of Australia's agricultural, pastoral, mineral, energy, forestry and fishing industries and hence the Australian economy by providing independent and objective analyses of the economic and policy issues facing these industries. A major research effort on natural resource management and resource use conflict resolution with applications to soil, water, fisheries, forests, and minerals and energy was commenced in 1988–89.[13]

The *Bureau of Mineral Resources, Geology and Geophysics* (BMR) conducts research concentrated upon the mineral components of the environment, including groundwater. The research includes studies of the regional structure of the earth, sedimentary basins, mineral provinces, and the ground covering them and understanding the availability and replenishment of groundwater.

Under its new charter, announced in June 1989, BMR is required to provide knowledge required for the consideration of environmental issues. In response, BMR proposes to introduce three new research programs, as follows:

- land/environmental degradation: to improve understanding of the geological controls on soil erosion and salination;
- compilation of high-resolution records for the Australian Quaternary: to discover how the Australian continent has responded to climatic changes in the past, and to test models of global circulation;
- the coastal zone: to provide knowledge of the Australian coastal zone including geology, minerals and recent history of sea levels.[14]

The growing demand that environmental science be integrated into the economic management structure has led to attempts to establish mechanisms to simplify acquisition and analysis of environmental information to support decision making which impact on natural resource management and environmental protection.

12 Murray–Darling Basin Commission, *Annual Report 1988.*

13 DPIE, *Annual Report 1989–90.*

14 DPIE, *Annual Report 1989–90.*

APPENDIX IV.D

DESCRIPTION OF COMMONWEALTH BIOLOGICAL COLLECTIONS

Australian National Wildlife Collection

This collection is held by the CSIRO Division of Wildlife and Ecology in Canberra and contains 65 000 specimens of mammals, birds and amphibians. It also includes a 'national tissue bank'. The collection is funded from program research funds from projects using the collections. The present budget is $10 000. Staff consists of one scientist and two technicians who are responsible for research programs as well as collection and curation.

Australian National Insect Collection

This collection is held by the CSIRO Division of Entomology in Canberra and contains 8 000 000 specimens of insects, spiders and related groups. The collection is funded out of program research funds from those projects based on the collections. The present budget is approximately $40 000. Staff consists of 11 scientists and 7 technicians who are responsible primarily for research and will undertake collection curation only as a secondary task.

Australian National Herbarium

This collection is held in Canberra by the CSIRO Division of Plant Industry. A subsidiary collection of primarily rainforest plants is at Atherton, Queensland. The collection contains 500 000 specimens. The collection is funded out of program research funds from those projects based on the collections. The present budget is $90 000. Staff consists of 9 scientists and 8 technicians who are responsible primarily for research with collection curation only a secondary task.

Australian National Fish Collection

This collection is held by CSIRO Division of Fisheries in Hobart and contains 100 000 specimens of fishes. The maintenance of the collection is an independent item in the Division's budget. The present budget is approximately $20 000. The staff is responsible for research programs as well as collection curation.

Australian National Botanic Gardens Herbarium

This collection is held by the Botanic Gardens in Canberra, which is part of the Department of the Arts, the Environment, Tourism and Territories (DASETT). The collection contains 205 000 specimens of plants including algae and fungi and is used as a research collection and is closely linked to the living plant collections. The present operational budget is approximately $120 000. Staff consists of 2 scientists and 4.5 technicians.

Antarctic Division Collections

These collections are held by the DASETT Antarctic Division in Hobart and contains 14 000 moss or lichen specimens and several thousand animal specimens. The maintenance of the collections has no independent budget and there are presently no curatorial staff. Several scientists use the collection for research. Arrangements have been made to transfer sections of the plant collection to the Tasmanian Museum at suitable times. It is planned to transfer other collections in due course, though no formal arrangements have been made.

National Museum of Australia

This collection is held by the Museum in Canberra and contains approximately 2 000 specimens of mammals and molluscs. The Museum does not presently plan to build a major biological collection. However, the material held is of historic significance and includes the specimens from the old Department of Health collection in the Institute of Anatomy. The present budget is several hundred dollars and there are presently no staff positions attached exclusively to the biological collection.

APPENDIX IV.E

ORGANISATION OF ENVIRONMENTAL RESEARCH IN THE STATES AND TERRITORIES

All information contained within this appendix has been derived directly from State submissions provided to ASTEC.

Environmental Research in New South Wales

The **Electricity Commission of New South Wales** conducts:

- Power station related research into air quality, surface and ground water quality, chemistry, environmental acoustics, aquaculture, biology, archaeology and heritage;
- Tree planting research;
- Transmission line research to monitor the effect of the proposed transmission line, if any, on the birdlife and to develop solutions should significant problems arise.

The **Department of Minerals and Energy** undertakes regional geological mapping, data compilation and resource assessment, floristic studies, topsoil handling and comparison of the patterns of plant succession in pre and post mining environments. The Department is also responsible for the Hunter Valley/Central Coast Regional Air Study.

Under its charter, the **Department of Water Resources** is responsible for maximising the long term benefits of the State's water resources. As part of its role in operating storages and water delivery systems it engages in catchment management to protect and enhance the aquatic and related environment; to contribute to the integrated management of the natural resources within catchment areas; and to manage the quality of the State's water resources to meet agreed needs for water uses and the aquatic environment.

The **Ministry for the Environment** conducts a number of programs requiring environmental research through a range of authorities.

Waste Management Authority

- Waste minimisation
- Recycling
- Landfill gas

Hunter Water Board

- Water Source Conservation, Quality and Treatment
- Wastewater

Water Board

State Pollution Control Commission

Zoological Parks Board

Research and conservation studies are currently conducted at the zoo's two properties Taronga and Western Plains Zoo aimed at:

- improvement in the care of breeding or management of the collection;
- making use of opportunities presented by a diverse collection to conduct comparative studies in behaviour or other aspects of biology;
- application of skills gained through captive animal management to wider wildlife conservation issues.

Bicentennial Park Trust

Royal Botanic Gardens undertakes:

- systematic research into Australian plants with information on their distribution and, for rare or endangered species, their conservation status;
- ecological surveys of plant communities and their distribution and processes affecting their survival;
- research into the propagation of rare and endangered species at both the Sydney Gardens and the Mount Annan Botanic Gardens near Campbelltown.

The National Herbarium of NSW pursues botanical, horticulture and other appropriate research programs of quality with emphasis on Australian flora.

Environmental Research in Victoria

Victoria conducts environmental research on land, inland waters, flora and fauna, forests and woodlands and atmosphere. This reflects the areas over which the States have primary responsibility and accounts for 85 per cent of the State's environmental research budget.

The majority of the research tends to be applied and experimental rather than basic research, which again reflects the Government's priorities and perceived role in research.

Environmental Research in Queensland

In Queensland environmental research is carried out by the State Government in the following departments and agencies:

The **Queensland Department of Mines** includes three Programs and each contains a number of subprograms:

- Geological Survey Program
  - Marine and Coastal Investigations Sub-program
  - Geological Mapping Sub-program Environmental Management Sub-program
  - Occupational Hygiene and Laboratory Services Sub-program
- Land Conservation Program
  - The Land Resource Assessment Sub-program
  - Soil Conservation Sub-program
  - Soil Fertility and Product Quality Sub-program
- Fisheries and Wetlands Management Program
  - The Marine and Freshwater Habitats Sub-program
- Plant Industries Program
  - Plant Protection

The **Queensland Department of Lands** also carries out environmental research.

The **Water Resources Commission** is involved in environmental research through the following projects:

- Burdekin Project Ecological Study (1981).
- Barratta Wetlands Study.
- Salt and Water Movement and Hillslope Soil Toposequences in the Burdekin River Irrigation Area.
- Limnological Monitoring Program on Burdekin Falls Dam.
- Tinaroo Water Quality Study.
- Environmental Study of the Bjelke-Petersen Dam.
- Fish Ladder Development.
- Environmental Assessment of the Murphy's Creek Dam Site.
- Data collection on Groundwater Levels, Water Quality, Surface Runoff and Climatic Data in the Callide Valley System and Three Moon Creek System.
- Physical Environment and Sustainable Use of our Natural Resources for the Burdekin River Irrigation Project.

Environmental Research in South Australia

In the **Department of Agriculture**, three functional areas have been identified as having major input into environmental research:

- Soil and Water Conservation
- Animal and Plant Control (eg pest plants and animals)
- Agricultural Chemicals

The Department of Agriculture identifies the Protection and Management of Natural Resources as one of its major corporate directions. Under this program the Department encourages the efficient use of the State's natural resources relevant to agriculture, including soil, water, plant and animal resources, for the benefit of the entire community.

Soil Conservation policy is provided to the Minister by the Advisory Committee on Soil Conservation which is established under the *Soil Conservation Act 1939–84*. This function will be replaced by the Soil Conservation Council which will be established under the Soil Conservation and Land Care Bill currently before Parliament.

Similar policy for animal and plant control is determined by the **Animal & Plant Control Commission** which carries out research on pest animals for the protection of agriculture, the environment and public safety with advice from regional officers and local government. Agricultural Chemical policy direction is provided by an Advisory Committee established to provide technical review and advice to the Minister.

The **Woods and Forests Department** carries out research related to the management of the State's forest resources.

The **Department of Lands** conducts research into:

- Land System Mapping
- Land Unit Mapping
- Grazing exclosures
- Revegetation
- Recreation Impact on Aquatic Vegetation

Current environmental research undertaken by the **Department of Environment and Planning** includes:

- Identification and mapping of samphire swamps.
- Biological Survey of South Australia.
- Assembling data bases using Geographical Information System.
- Monitoring of population and biological studies.
- Long-term effect of fire on reptile fauna and vegetation.
- Modelling the response of vegetation to fire using

Environmental Research in Western Australia

The Research Division of the **Department of Conservation and Land Management** (CALM) aims to develop a scientific basis for conservation and land management in Western Australia by conducting research and providing expert scientific advice. The Division is structured into twelve research programs: Biogeography, Entomology, Fauna Conservation, Fire, Flora Conservation, Herbarium, Marine Conservation, Plant Diseases, Rehabilitation, Silviculture, Wetlands and Waterbirds and Wood Utilization.

Each of these programs has been designed to provide specialised information which will support conservation of flora and fauna, land and resource management planning in discrete areas of the CALM estate.

The **Department of the Environment** has environmental research activities as part of its Investigations division of the Environment Protection Agency (EPA). These include the Estuarine Impacts Branch and the Marine Impacts Branch. The EPA also requires as conditions of approval of projects that certain investigations be done eg WAWA is commissioning a three year study of marine community response to nutrients as a condition of approval for Beenyup Outfall.

The **Water Authority** of Western Australia (WAWA) contributes funding or directly participates in research related to a range of environmental issues including impacts of a development on wetlands, salinity studies, stream habitats and catchment management.

The **Department of Agriculture** includes environmental research in its activities. In the Division of Resource Management the following three branches have research programs:

- Salinity and Hydrology research
- Soil Conservation
- Rangeland Management

The **Department of Health** funds research in the ecology of mosquitoes and the viruses they transmit under the Ross River Virus and Mosquito-Borne Disease Control budgets.

The **Fisheries Department** conducts research to provide sound biological information on Western Australian wild fish stocks; and on aquatic species suitable for aquaculture in Western Australia; and to provide sound scientific information relevant to the conservation of the Western Australian aquatic environment and biological resources.

Environmental Research in Tasmania

All of the major programs undertaken by the former **Department of the Environment** can be divided into two categories, namely atmosphere and marine coastal region

Department of Primary Industry research, development, advisory and regulatory programs are initiated in response to Government policies, industry needs and market opportunities for agriculture (pastoral, horticulture, intensive livestock and field crops) and sea fisheries (all forms of seawater life either in wild fisheries or marine farms).

- Division of Agriculture

  Land and water conservation.

  Integrated pest and disease control (cultural, biological and chemical).

  Utilisation of waste products.

  Monitoring/minimising chemical use.

  Management of Wildlife.

  Knowledge of Flora and Fauna.

  Monitoring climate and its effect on production.

- Division of Sea Fisheries

  Wild fisheries.

  Marine farm fishing.

The **Inland Fisheries Commission** conducts research for the acquisition of knowledge about the freshwater environment, the impact of other activities and the management of the inland fisheries resource.

The **Tasmanian Forestry Commission** has an environmental research program:

- to formulate recommendations for appropriate reservation of major forest types including rainforest, wet eucalypt and dry eucalypt forest;
- to obtain data which allows recommendations on conservation of other forest values including archaeology, hydrology, zoology and geomorphology to be formulated; and
- to obtain data on pests, diseases and weeds which threaten conservation values in forests.

The information contained in these is used to modify forest management to improve practices and to cater for conservation values.

Within the Forestry Commission the Division of Silvicultural Research and Development is designed to have research and development programs targeted to improving operational performance while ensuring the regeneration of all State forests harvested using appropriate methods and achieving the maximum economic sustainable supply of wood products. The Commission also assists in the establishment and retention of trees on rural lands for their values other than timber and direct commercial production.

Environmental Research in the Northern Territory

The prime agency is the Conservation Commission of the Northern Territory. The Commission undertakes research, monitoring and environmental assessment activities with respect to:
National Parks and Reserves

- Flora and Fauna — Protection and Utilisation
- Rangeland, forest and coastal environments
- Endangered species
- Problem Species
- Soil Conservation and Erosion studies
- Land Use Surveys and Land Utilisation strategies
- Land planning and development
- Pollution monitoring
- Ecological mapping and environmental geographic information systems

The **Department of Primary Industry and Fisheries** is conducting research into:

- Effective utilisation of Territory fish stocks
- Coastal Management
- Croplands Erosion — in conjunction with the Commission
- Noxious Weeds Control — both terrestrial and aquatic
- Rangeland Management
- Domestic Animal Production (Extensive and Intensive)
- Improved Pastures Development
- Horticultural Development
- Broadacre cropping

The **Department of Mines and Energy** does not undertake fundamental research, but is involved, within the Alligator River Region, with:

- Hydrology and water quality monitoring
- Dust monitoring
- Monitoring the levels of radon and radon daughter products

The Department is also responsible for extensive geological and geophysical mapping studies of the Northern Territory.

The **Power and Water Authority** undertakes applied environmental research with respect to the development of power stations and transmission lines, limnological studies in water supply dams, harbours and recreation lakes, water resource inventory studies with specific reference to ground water reserves and is responsible for a range of environmental assessments associated with power and water distribution developments.

Substantial quantities of data are collected by the **Department of Health and Community Services** but little relates directly to understanding of the environment. Medical entomologists do however collect information on mosquito populations with reference to existing and proposed land use.

The **Tourist Commission** has also undertaken a number of planning studies which have addressed land usage and identified resources.

Environmental Research in the Australian Capital Territory

The **Conservation and Land Management Branch** is responsible for managing ACT lands and living resources to achieve sustainable usage and long-term survival of plant and animal wildlife species. This encompasses a wide range of habitat conditions from highly natural to severely modified. The Branch aims for improvement of habitat conditions, restoration of more natural diversity patterns and amelioration of land degradation in both the short and long term.

The Branch has compiled scientific and general data on land, soil, water quality, meteorology and biological organisms and collects new information to extend the range of environments covered and to review/monitor those already under examination from time to time.

The **Interim Territory Planning Authority** (ITPA) is responsible for environmental and social planning in the ACT. The ITPA has collected substantial data in respect to terrain analysis, soils mapping, vegetation, and habitat–fauna resources of the ACT, as the basis for assessment of land-use planning and development proposals.

APPENDIX IV.F

Competitive Grants for Environmental Research in Higher Education Institutions ($'000, 1989 dollars)

Category	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*
Plant & Animal Biology	3710	4136	3787	3334	4053	4302	4178	4612	4861	8964
Environment & Analytical Chemistry	124	109	50	104	66	108	127	165	na	353
Earth Sciences	2504	2457	1977	2178	2042	2066	2297	2400	2699	4756
Soil & Rock Mechanics	193	151	125	108	78	56	43	126	na	322
Environmental Engineering	42	40	52	42	39	91	9	—	na	—
Surveying & Earth Resources	195	155	107	113	128	117	87	45	na	154
Physics of Ocean Atmosphere, Ionosphere & Magnetosphere	384	438	175	178	333	415	392	423	na	484
Physical Oceanography	—	—	—	—	—	—	—	—	—	1596
Marine Sciences & Technologies Grants Scheme	2515	3677	3261	3099	3679	4978	4460	3380	3386	—
TOTAL	**9668**	**11162**	**9536**	**9156**	**10418**	**12133**	**11594**	**11152**	**11666***	**16629**
% OF TOTAL GRANTS	**32.5**	**33.0**	**29.4**	**28.9**	**30.7**	**33.7**	**31.7**	**28.4**	**31.3**	**31.9**

Source of data: Australian Research Council, Australian Research Grants Scheme and Marine Sciences and Technologies Grants Scheme Annual Reports.

na: not available.

* this total was calculated using the available data and working out proportionate values for the categories for which data was not available based on patterns in previous years.

APPENDIX IV.G

Students Enrolled in Courses Leading to Environment Qualifications by Institution, 1987–89

University/ Institution	*Qualifications*	*Full-Time*			*Part-Time*			*External*		
	Undergraduate	*1987*	*1988*	*1989*	*1987*	*1988*	*1989*	*1987*	*1988*	*1989*
Victoria College	B.App. Sci. Env. Assessment	106	108	na	30	40	na	—	—	—
University of Wollongong	B.Environmental Science	89	65	60	24	16	21	—	—	—
	B.Environmental Science (Hons)	—	2	—	—	—	1	—	—	—
Roseworthy Agricultural College	B.App. Science (Natural Resources)	116	122	175	32	30	16	—	—	1
Riverina-Murray Institute of Higher Education	B.App. Science (Park Management)	—	25	42	—	1	1	64	106	130
	Assoc. Diploma (Park Management)	6	2	—	1	7	—	155	160	141
	B.App. Science (Environmental Analysis)	—	—	13	—	—	1	—	—	24
Orange Agricultural College	Ass.Dip. Env. Control	—	31	—	—	—	—	—	—	—
	Ass.Dip. Land Management	—	—	—	—	—	—	—	73	90
Northern Rivers CAE	B.App. Sc. (Coastal Management)	72	140	219	4	5	8	—	—	—
University of New England	B.Sci/Dip Nat. Res	1	—	—	—	—	—	—	—	—
	B.Natural Resources	113	114	114	1	3	5	2	2	1
	B.Nat. Res/B.E.	9	18	20	—	—	—	—	1	—

University/ Institution	*Qualifications*	*Full-Time*			*Part-Time*			*External*		
	Undergraduate	*1987*	*1988*	*1989*	*1987*	*1988*	*1989*	*1987*	*1988*	*1989*
Murdoch University	B.Sc Environmental Science	51	46	87	12	17	8	56	48	61
	B.Sc. (Hons) Env. Science	6	8	5	2	2	6	1	–	3
	B.Env. Science	2	9	12	–	2	1	–	–	2
Griffith University	B.Sc. (Aust.Env. Studies)	454	498	542	79	82	77	–	–	–
	B.Sc.(AES) (Hons)	9	4	6	5	9	13	–	–	–
	B.Sc. (AES)/Japanese language	7	11	12	1	–	–	–	–	–
Canberra College of Adv. Ed/ University of Canberra	B.Env. Science (Nat Res)	4	2	–	1	–	–	–	–	–
	B.Env. Science (Ecology)	6	1	–	3	3	1	–	–	–
	B.Env. Science (Ecol/Nat Res)	72	84	90	17	26	31	–	–	–
Macquarie University	B.Env. Studies	–	–	5	–	–	2	–	–	2
	B.Sc. Env. Studies	–	–	16	–	–	10	–	–	9
	B.Sc. (Hons) Env. Studies	–	–	–	–	–	1	–	–	–
TOTAL		**1123**	**1290**	**1418**	**212**	**243**	**203**	**278**	**390**	**464**

University/ Institution	*Qualifications*	*Full-Time*			*Part-Time*			*External*		
	Graduate	*1987*	*1988*	*1989*	*1987*	*1988*	*1989*	*1987*	*1988*	*1989*
W.A. Institute of Technology/Curtain Uni of Technology	M.App. Sc. (Natural Resources)	7	3	2	7	8	6	—	—	1
	Post Grad. Dip. (Natural Resources)	4	5	4	7	13	6	3	2	0
University of WA	$M.Sc_1$ (Natural Resource Management)	3	—	—	10	10	—	1	1	—
University of Tasmania	M.Environmental Studies	2	6	8	5	3	9	3	1	4
	PhD (Env. Science)	4	9	4	4	—	4	3	—	1
	Grad. Dip. Env. Studies	—	—	5	—	—	2	—	—	1
Roseworthy Agriculture College	Graduate Diploma (Natural Resources)	3	—	5	3	—	3	—	10	11
Northern Rivers CAE	Dip App.Sci (Coastal Management)	42	25	1	4	4	5	—	—	—
University of NSW	Land + Geographic Information Systems	—	—	—	1	2	—	—	—	1
	Arid Lands Management	3	1	2	2	1	1	—	—	—
	Environmental Studies	2	5	4	14	19	12	—	—	—
	Water Management	1	—	2	2	4	1	5	4	7
University of New England	PhD (Ecosystem Management)	6	6	5	1	—	4	2	2	3
	PhD (Resource Management)	2	3	—	1	2	—	5	6	—
	M.Natural Resources	5	5	5	4	4	2	14	11	10
	Diploma in Natural Resources	6	5	4	—	3	3	58	50	51
	PhD (Resources Engineering)	—	—	1	—	—	3	—	—	5

University/ Institution	Qualifications Graduate	Full-Time 1987	1988	1989	Part-Time 1987	1988	1989	External 1987	1988	1989
Murdoch University	Dip.Env. Science	4	2	4	3	4	5	28	27	26
	M.Phil.Env & Life Science	—	9	—	—	4	—	—	2	—
	PhD Env & Life Science	—	26	—	—	12	—	—	—	—
	Dip. Env. Impact Assessment	—	6	5	—	12	6	—	8	20
	PhD Environment Science	—	—	11	—	—	4	—	—	—
	M.Phil.Environmental Science	—	—	6	—	—	6	—	—	—
Macquarie University	M.Science Env. Studies	—	1	—	3	4	—	—	—	—
	M.Science (Hons) Env. Studies	—	—	—	2	—	—	—	—	—
	PhD Environmental Studies	—	2	2	4	1	1	—	—	—
	M. Environmental Studies	3	2	1	15	19	15	—	—	—
	Postgraduate qual in Env. Studies	—	—	—	1	1	—	—	—	—
	Dip Env. Studies	3	4	3	40	32	35	—	—	—
Monash University	M.Env. Science	14	14	15	90	64	53	—	—	—
	Dip. Env. Studies	7	7	8	15	23	30	—	—	—
Griffith University	M.Phil (Aust.Env. Science)	2	5	10	16	20	16	—	—	—
	PhD (AES)	35	29	26	16	15	12	—	—	—
	M. Science (AES)	0	0	0	17	12	10	—	—	—

Canberra CAE/ Canberra University	Higher degree – Resource Management	11	17	8	3	5	17	–	–	–
	Postgraduate degree – Resource Management	8	8	2	14	17	15	–	–	–
University of Adelaide	M. Env. Studies	4	9	12	21	18	23	–	–	1
	M. Env. Studies – Env. Studies	1	1	–	4	9	–	2	4	–
	Dip. Env. Studies	–	8	20	–	9	15	–	–	–
TOTAL		**182**	**223**	**185**	**330**	**354**	**324**	**124**	**128**	**140**

Source: DEET Higher Education Statistics.

APPENDIX IV.H

Numbers and Employment conditions of Environmental Research Staff in Institutions of Higher Education

Institution/ University	Subject Area	Research 1988 L	T	O	Research 1989 L	T	O	Research + Training 1988 L	T	O	Research + Training 1989 L	T	O
University of Adelaide	Environmental Studies	.	.		1	.		.	2		.	3	
	Botany	6	.		4	.		3	7		3	7	
	Geology & Geophysics	5	2		8	2		7	14		7	14	
	Zoology	8	1		6	1		1	11		1	11	
	Entomology	9	1		11	.		.	6		.	6	
	Soil Science	2	1		6	.		.	5		.	5	
		30	5		36	3		11	45		11	46	
	Total Staff	314	35		326	37		133	503		139	493	
Australian National University	Plant Environmental Biology	10	10		10	9		.	.		.	.	
	Ecosystems Research Groups	3	4		7	5		.	.		.	.	
	Environmental Geochemistry	1	6		1	6		.	.		.	.	
	Centre for Resource & Env Studies	14	18		16	19		.	.		.	.	
	Zoology	5	1		9	1		5	20		5	20	
		133	39		43	40		5	20		5	20	
	Total Staff	678	1172		589	1044		136	572		122	563	

Flinders University	Biological Sciences	14	.		12	.		2	19	2	4	19	2
	Earth Sciences	6	.		8	.		.	11	1	.	12	1
		20	0		20	0		2	30	3	4	31	3
	Total Staff	150	1		154	1		53	262	8	72	260	8
Griffith University	Australian Env. Studies	18	1		15	.		11	31		10	32	1
	Total Staff	48	1		47	.		58	196		57	200	12
UWS Hawkesbury	Food & Env. Sciences	.	.		.	.		.	1		.	1	
	Total Staff		1	1		—	—		2	3		2	3
Macquarie University	Biological Sciences	9	—		7	.		8	28		8	27	
	Sch of Earth Science — Env.	—	—		.	.		—	—		2	7	
	Centre for Env. Studies	1	—		.	.		2	3		2	2	
		10	0	7	0		10	31		12	36		
	Total Staff	96	0		79	2		143	400		168	389	
University of Melbourne	Geology	4	2		2	2		.	11		.	9	
	Zoology	3	1	4	3	1	4	.	13		.	12	
		7	3	4	5	3	4	0	24		0	21	
	Total Staff	320	58	63	319	63	76	140	849	—	171	104	4

Institution/ University	Subject Area	Research 1988 L	T	O	Research 1989 L	T	O	Research + Training 1988 L	T	O	Research + Training 1989 L	T	O
Monash University	Geography & Env. Science	—	—		5	.		—	—		7	12	
	Botany and Zoology	—	—		9	1		—	—		6	16	
	Environmental Sciences	.	.		—	—		4	1		—	—	
	Botany	4	1		—	—		5	4		—	—	
	Earth Sciences	6	.		11	.		2	7		1	8	
		10	1		25	1		11	12		14	36	
	Total Staff	378	20		370	26		330	619		327	623	
Murdoch University	Inst. Env. Science	1	.		—	—		.	.		—	—	
	Biology	28	.	—	30	.	—	6	17	15	5	13	18
	Env. Sci.	6	.	—	13	.	—	3	9	10	4	9	10
		35	0		43	0		9	26	25	9	22	28
	Total Staff	89	2		101	2		86	172	165	95	185	180
University of Newcastle	Dept of Geology	—	—		—	—		.	8		.	7	
	Dept of Biological Sc.	—	—		—	—		.	9		.	9	
								0	17		0	15	
	Total Staff	—	—		—	—		26	287		27	270	
University of New England	Ecosystem Management	3	—		3	—		1	7		2	7	
	Resource Engineering	4	—		.	—		2	5		2	3	
	Agronomy & Soil Sc.	5	—		5	—		3	10		3	10	
	Botany	7	—		3	—		3	8		4	8	
	Geology & Geophysics	2	—		3	—		1	7		1	6	
	Zoology	2	—		1	—		1	9		1	9	
		23			15			11	46		13	43	
	Total Staff	61	—		45	—		99	323		96	322	

Institution/ University	Subject Area	Research 1988 L	T	O	Research 1989 L	T	O	Research + Training 1988 L	T	O	Research + Training 1989 L	T	O
University of NSW	Ctr for Groundwater Mgmt	2	.		2	1		2	1		.	.	
	School of Biological Sciences	16	.		15	.		.	25		1	22	
	Ctr for Marine Science	.	.		2	.		.	.		.	.	
	Ctr for Remote Sensing	4	.		3	.		.	.		.	.	
		20	0		20	0		0	25		1	22	
	Total Staff	365	13		344	37		212	932		313	831	
University of Queensland	Botany	.	.	8	.	.	4	5	10		3	10	
	Entomology	.	.	5	.	.	3	5	4		7	4	
	Zoology	1	.	7	.	.	6	21	13		22	14	1
		1	0	20	0	0	13	31	27	0	32	28	1
	Total Staff	15	6	468	6	5	452	603	254	6	594	766	4
University of Sydney	Biological Sciences	27	19		27	4		18	25		19	42	
	Marine Studies Ctr	—	—		.	1		—	—		.	.	
	Geology & Geophysics	11	9		4	8		1	16		2	13	
		38	28		31	13		19	41		21	55	
	Total Staff	559	394	—	544	279	—	413	954	—	411	1016	—
University of Tasmania	Botany	7	.		3	.		1	7		.	7	
	Geology	9	.		8	.		1	9		2	8	
	Zoology	5	.		8	.		.	10		1	9	
		21	0	0	19	0	0	2	26		3	24	
	Total Staff	99	0	2	72	0	1	72	310		87	288	
University of Wollongong	Biology	10	.		10	1		3	7	2	1	7	1
	Geology	1	.		1	.		1	7		2	7	
		11	0		11	1		4	14	2	3	14	1
	Total	57	1		59	2		90	273	22	86	276	26

Institution/ University	Subject Area	Research 1988 L	Research 1988 T	Research 1988 O	Research 1989 L	Research 1989 T	Research 1989 O	Research + Training 1988 L	Research + Training 1988 T	Research + Training 1988 O	Research + Training 1989 L	Research + Training 1989 T	Research + Training 1989 O
Victoria College	Heritage & Resource Mgt	.	1	.	—	—		3	6	.	3	6	.
		0	1	0				3	6	0	3	6	0
	Total Staff	10	1	10	—	—	—	79	151	1	147	303	7
University of WA	Botany	13	.		10	—		1	6		1	6	
	Geology	7	.		5	—		2	9		4	5	
	Ctr for Env. & Fluid Dynamics	3	.		5	—		.	1		.	.	
	Ctr for Water Research	15	1		14	—		3	1		.	.	
		38	1		34				6	17		5	11
	Total Staff	377	3		345	—		193	452	—	109	419	

Appendix V.A

CHI CLASSIFICATION OF FIELDS OF SCIENCE

Physical Sciences

Mathematics	General Maths Applied Maths Probability and Statistics Miscellaneous Maths
Physics	Chemical Physics
	Solid State Physics
	Solid State Physics Acoustics Optics
	Fluids and Plasmas Miscellaneous Physics Nuclear and Particle Physics General Physics
Chemistry	Physical Chemistry Inorganic and Nuclear Chemistry Organic Chemistry
	Polymers
	Analytical Chemistry General Chemistry Applied Chemistry

Biological Sciences

Biological Research	Biophysics
	Biochemistry and Molecular Biology Genetics and Heredity
	Biochemistry Virology

	Physiology
	Anatomy and Morphology
	Embryology
	Miscellaneous Biology
	Cell Biology, Cytology, Histology
	Parasitology
	General Zoology
	Marine Biology and Hydrobiology
	Biomedical Engineering
	Agricultural and Food Science
	Misc. Biomedical Research
	Dairy Animal Science
	Botany
	Physiology
	Microbiology
	Ecology – part
	Miscellaneous Biology
	General Biology
Earth Sciences	Geology
	Earth and Planetary Science
	Oceanography and Hydrology
	Meteorology and Atmospheric Sciences
	Astronomy – Astrophysics
Engineering Technology	Computers
	Computers/Electrical Eng and Electronics
	Metals and Metallurgy/Geology
	Aerospace Technology
	Civil Engineering
	Chemical Engineering
	Electrical Engineering and Electronics
	Mechanical Engineering
	Materials Science
	Metals and Metallurgy
	Industrial Engineering
	General Engineering

Animal Medicine	Veterinary Medicine
	Veterinary Medicine Neurobiology
	Endocrinology Immunology Pathology Pharmacology/Pharmacy Pharmacology Misc. Biomedical Research General Biomedical Research
	Allergy Anaesthetics Dentistry Hygiene and Public Health Fertility
	Geriatrics
	General and Internal – part Cardiovascular System Gastroenterology Haematology Arthritis and Rheumatism Respiratory System Urology Nephrology
	Neurology and Neurosurgery Nutrition and Dietetics Obstetrics and Gynaecology Cancer Opthalmology Orthopaedics Otorhinolaryngology Paediatrics General and Internal Med – part Psychiatry Radiology and Nuclear Med Misc Clinical Medicine Surgery
	Misc. Clinical Medicine Dermatology and Venereal Disease Tropical Medicine Addictive Diseases
	Hygiene and Public Health Misc. Biomedical Research

Appendix V.B

SUMMARY TABLES OF BIBLIOMETRIC DATA FROM PROFILE OF AUSTRALIAN SCIENCE

Biology — Publication Data — 1984

JOURNAL ARTICLES

FIELD	NUMBER OF PAPERS
Botany	299
Ecology	45
Entomology	49
General Biology	54
General Zoology	16
Marine Biology and Hydrobiology	100
Miscellaneous Biology	9
Percentage of World Publications	**%**
Botany	4.17
Ecology	3.06
Entomology	2.70
General Biology	4.26
General Zoology	1.40
Marine Biology and Hydrobiology	5.46
Miscellaneous Biology	2.16
Above average influence	
Percentage of World citations	**%**
Botany	5.24
Ecology	2.65
Entomology	2.22
General Biology	3.71
General Zoology	1.79
Marine Biology and Hydrobiology	4.64
Miscellaneous Zoology	2.61

Earth and Space Science — Publication Data — 1984

JOURNAL ARTICLES

FIELD	NUMBER OF PAPERS
Earth and Planetary Science	137
Geology	94
Meteorology and Atmospheric science	40
Oceanography and Hydrobiology	21
Percentage of world publications	**%**
Earth and Planetary science	2.79
Geology	5.24
Meteorology and Atmospheric science	3.45
Oceanography and Hydrobiology	1.85
Above average influence	
Percentage of world citations	**%**
Meteorology and Atmospheric science	4.34
Geology	5.76

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